FINAL REPORT

OF THE

NEW HORIZONS II

REVIEW PANEL

March 31, 2005
Revised May 5, 2005

EXECUTIVE SUMMARY

The FY 2005 Omnibus Appropriations Conference Report for NASA included the following:

New Horizons II Feasibility Study

NASA is directed to undertake a detailed study of the feasibility for a New Horizons II mission, to be launched within the near-term, if the study results can justify the scientific return for such a follow-on mission, at a price considerably less than the original New Horizons mission. Such a study should have its results submitted to the Committees on Appropriations by April 15, 2005.

The NASA Science Mission Directorate (SMD) therefore chartered the ***New Horizons II Review Panel*** (hereafter referred to as the Panel) to perform this feasibility study. The Panel was to consider the feasibility of such a mission. Within the guidelines of the committee language, the Panel was to consider as possible missions one or more of the following:

a) a further survey of the Pluto-Charon system,
b) a further survey of Kuiper Belt Objects,
c) a survey of objects believed to be captured Kuiper Belt Objects (for example, Neptune's moon, Triton).

The SMD specifically tasked the Panel with answering the following questions:

1) Considering that the New Horizons mission was competed, determine whether New Horizons II should also be competed.
2) Determine whether such a mission can be developed and launched "within the near term."
3) Determine whether the potential science return can be justified for such a mission.
4) Determine whether such a mission can be developed and launched at a cost "considerably less" than that of New Horizons.

In answering these questions, the Panel was given latitude as to how to define "near-term" and "considerably less than." A general guideline of 2-3 years following the launch of New Horizons was given for the definition of "near-term."

The Panel worked over a roughly seven week period beginning in early February. The Panel held multiple telecons, and held meetings in Rosslyn, VA on March 16-17 and March 23-24, 2005. The Panel summary report was submitted to NASA's Science Mission Directorate on March 31, 2005.

In performing its work, the Panel considered a range of potential spacecraft and missions. These included an exact copy of the New Horizons spacecraft and launch vehicle, variations on this spacecraft and launch vehicle, other existing spacecraft which could potentially be adapted for this mission, and a more general spacecraft which would represent a complete development program. Cost and schedule estimates were provided for each candidate case.

In performing its review, the Panel quickly identified the availability of a radioisotope thermoelectric generator (RTG) as the limiting factor in launching a New Horizons II mission. A RTG would provide electricity and heat for the spacecraft, and is fueled with plutonium-238. A RTG is not presently available for this mission. Delivery of a suitable New Horizons class RTG will either require refurbishment and refueling of an existing RTG, or the production of a new unit. In either case, the availability of plutonium-238 heat sources would limit delivery of this unit to not earlier than mid-2010. Consequently, no missions can be launched prior to this date, and, in the opinion of the Panel, providing reasonable schedule margins prevents launches prior to 2011.

CHARTER QUESTIONS AND PANEL RESPONSES

Q: *Considering that the New Horizons mission was competed, determine whether New Horizons II should also be competed.*

In light of the long time to earliest launch, the Panel recommends that if a New Horizons II mission is selected, it should be competed. While the Panel concluded that a mission based on an exact copy of New Horizons was likely to result in the lowest cost, the additional time for a competitive award process does not appear likely to impact the final launch date. Competing the mission will allow other possible designs to be forwarded which may decrease the mission cost, or increase its scientific return.

Q: *Determine whether such a mission can be developed and launched "within the near term." The definition of "near-term" shall be up to the Committee to determine, with a general guideline of 2-3 years after the launch of New Horizons.*

The Panel concludes that a New Horizons II mission can be launched no earlier than 2011, and therefore concludes that it is not possible to launch such a mission in the "near-term."

Q: *Determine whether the potential science return can be justified for such a mission.*

The Panel concludes that the most likely scenario for a New Horizons II mission in the 2011 time frame or later will involve a further exploration of the Kuiper Belt. The Panel evaluated possible Kuiper Belt Objects (KBOs) which could be visited by missions in this time period, and concludes that the science return from such a mission would be similar to that from the New Horizons mission, but is less likely to be paradigm shifting. Furthermore, the Panel recommends that the possibility of a New Horizons II mission should be reviewed by the National Research Council's Committee on Planetary and Lunar Exploration (COMPLEX).

Q: *Determine whether such a mission can be developed and launched at a cost "considerably less" than that of New Horizons. Here, "considerably less" will be in the opinion of the Committee. Risks to mission success shall be considered when considering cost.*

The Panel evaluated several possible scenarios. The estimated costs ranged from a low of approximately $623M for a copy of the New Horizons spacecraft, launched without use of a third stage, to a high of $912M or greater for a new design spacecraft. This compares to a latest estimated cost for New Horizons of $723M. The Panel therefore concludes that a mission is possible at lower cost. The consensus opinion of the Panel was that savings had to be at least 20% of the New Horizons cost (savings of approximately $145M) to be considered "considerably less". The Panel, therefore, concluded that, while the mission could be accomplished at lower cost, the savings were not sufficient to be considered "considerably less."

CAVEATS AND CONCLUDING REMARKS

In order to complete our study within the allotted time, the Panel worked under a key set of assumptions.

The Panel attempted to identify the lowest cost approach to achieving the mission. Although other alternatives were considered, if these did not present obvious cost or schedule savings, they were not further evaluated. For example, the lowest cost approach appeared to be an Atlas or Delta IV with no third stage. Although other launch vehicles could also support the mission, these would typically involve higher costs (for example, a Delta IV Heavy), or additional mission risks with no significant cost improvement (for example, an Atlas 521 instead of an Atlas 551). The Panel therefore notes that other potential mission implementations do exist which may yield benefits, but do not appear to provide as low-cost a mission.

Similarly, the Panel has focused on a New Horizons II mission to the Kuiper Belt, rather than to Pluto or Neptune. The Kuiper Belt mission both represents a new science investigation, and can be accomplished in the shortest mission time due to the availability of Jupiter-gravity assists. Missions to Pluto or Neptune are also possible, but would involve much longer mission durations, and do not appear to provide a greater science return than that of a Kuiper Belt mission.

In assessing the scientific return and mission risk, the Panel also notes that launching a New Horizons II mission in the assumed time frame (2011 and beyond) will require developing the mission before any science return from New Horizons has been received. This introduces mission and science risks which cannot be evaluated. The Panel notes that this is a lien on selection of such a mission.

In developing the schedules, the Panel assumed that funds for the mission development effort are available in early FY2006. The RTG procurement is assumed to begin in early FY2006. The Panel assumed a sole source contract could be placed by January 2006, and also assumed a competitive contract could be awarded by July 2006. The Panel recognized that these are aggressive schedules and would require initiating the procurement development (preparation of the specification and other documents, preparation of the Announcement of Opportunity, etc.) in FY2005. Also, the Panel notes the sole source procurement would be very large (greater than $600M). This is much larger than any previous NASA sole source procurement of which the Panel was aware, Also, the competitive schedule assumed that award would be made based on initial proposal, and did not include time for a two-phase down selection. A two-phase selection process is estimated to add three months to the schedule timeline. The Panel therefore considers these to be best case development schedules.

In summary, the Panel concludes that a New Horizons II mission is technically feasible, could potentially be completed for lower cost than New Horizons, but cannot be completed in any near-term time frame. Furthermore, the Panel suggests that the potential science return from such a mission be reviewed by COMPLEX. In light of this, the Panel further recommends that any future New Horizons mission should be competed.

INTRODUCTION

Background

The New Horizons mission is presently under development. This mission has as its primary objective the first spaceborne investigation of Pluto and its moon Charon, and is also planning to make measurements of one or more Kuiper Belt Objects (KBOs). The mission is presently planned for launch in January, 2006.

The FY 2005 Omnibus Appropriations Conference Report for NASA included the following language:

New Horizons II Feasibility Study

NASA is directed to undertake a detailed study of the feasibility for a New Horizons II mission, to be launched within the near-term, if the study results can justify the scientific return for such a follow-on mission, at a price considerably less than the original New Horizons mission. Such a study should have its results submitted to the Committees on Appropriations by April 15, 2005.

As part of the response to this direction, NASA's Science Mission Directorate chartered the New Horizons II Review Panel to perform the requested feasibility study.

Panel Charter

As chartered by the Science Mission Directorate, the New Horizons II Review Panel was assigned responsibility for evaluating the feasibility of such a mission, and, in particular, addressing the following questions:

1) Considering that the New Horizons mission was competed, determine whether New Horizons II should also be competed.
2) Determine whether such a mission can be developed and launched "within the near term."
3) Determine whether the potential science return can be justified for such a mission.
4) Determine whether such a mission can be developed and launched at a cost "considerably less" than that of New Horizons.

In responding to these questions, the Panel was given considerable flexibility. The definition of "near-term" was left up to the Panel, with a general guideline of 2-3 years following the launch of New Horizons. The definition of "considerably less" was also left to the discretion of the Panel. Finally, the science mission requirements were left to the Panel, with the exception that the mission was to consist of one or more of the following:

a) a further survey of the Pluto-Charon system,
b) a further survey of Kuiper Belt Objects,

c) a survey of objects believed to be captured Kuiper Belt Objects (for example, Neptune's moon, Triton).

Process

Panel membership (see Appendix A) was set over a period of a week. The first telecon was held on February 5. At that time, the particular need for specific skills was identified. Additional Panel members were added over the next few weeks, with the final member joining the Panel on February 10. The Panel was asked to conclude its deliberations and provide a report and presentation to NASA's Science Mission Directorate by March 31, 2005. In order to meet this schedule, the Panel operated in accordance with the following schedule:

- February 5, 2005: Panel kickoff teleconference
- February 9, 2005: Second teleconference
- February 10, 2005: Third teleconference
- March 1, 2005: Fourth teleconference
- March 3, 2005: Fifth teleconference
- March 10, 2005: Final teleconference
- March 16-17, 2005: First meeting held at Aerospace Corp facility in Rosslyn, VA
- March 23-24, 2005: Second meeting held in Rosslyn, VA, draft report and charts prepared
- March 25-30, 2005: Final report completed
- March 31, 2005: Final report submitted to SMD
- April 1, 2005: Presentation to SMD

Because of the schedule constraints, several issues were worked in parallel. A candidate minimum set of instruments was developed, based on those presently on New Horizons. Similarly, a set of spacecraft and launch vehicle candidates were identified and cost models developed. The Department of Energy representative evaluated the Radioisotope Thermoelectric Generator (RTG) availability, and separately evaluated the cost and schedule options associated with providing a New Horizons class RTG to NASA. In parallel, a timeline for the launch approval process was developed. This required assumptions regarding candidate launch vehicles and mission flight profiles. Orbit profiles were developed for various potential missions and launch dates.

The Panel met on March 16-17, 2005 to review the data collected to date. At that meeting, the proposed cost and schedule methodologies were reviewed and agreed upon. It was apparent that availability of the RTG would limit the launch date to no earlier than mid-2010. Using a standard reference of maintaining approximately one month of schedule slack for each year from launch implied a launch date of January 2011 or later. A significant cost savings could be achieved if no third stage were required on the launch vehicle. A set of missions meeting these constraints were identified for further analysis.

The Panel met again on March 23-24, 2005. At that time, the final cost and schedule estimates were provided and agreed upon, and an initial report and presentation package was assembled. The final Panel findings and conclusions were also agreed upon. Some costs were identified as preliminary, and required updating.

The Panel reviewed and revised the final report and presentation package over the period from March 25-30, 2005. Updated costs were included. The final report was submitted to NASA SMD on March 31, 2005, and the Panel results were presented to SMD on April 1, 2005. At that meeting, additional questions were raised which SMD requested the Panel evaluate. The Panel addressed these additional questions, and submitted a revised report to SMD on May 5, 2005..

NEW HORIZONS II MISSION ASSESSMENT

Trade Studies

The Panel considered several candidate spacecraft and launch vehicle combinations which could meet the mission requirements. In the absence of specific New Horizons II requirements, the Panel considered the New Horizons mission, and developed a subset of the New Horizons instruments as the minimum set of instruments which would be able to address issues regarding Kuiper Belt Objects. This minimum set of instruments consisted of the Long Range Reconnaissance Imager (LORRI) and Ralph instruments. Using the mass, power and data rate requirements of these two instruments, the minimum spacecraft capability was therefore determined.

The initial assessment consisted of the following cases:

a) An exact copy of New Horizons, launched on the same launch vehicle;
b) An exact copy of New Horizons, launched on an alternate launch vehicle;
c) A modified New Horizons spacecraft;
d) Modified Heritage spacecraft, which might be adapted for the New Horizons II mission. These included spacecraft such as MESSENGER, CONTOUR, Odyssey, Dawn, Genesis, and Triana;
e) A completely new design spacecraft.

Cost and schedule profiles for each scenario were prepared using comparisons with actual New Horizons or heritage spacecraft experience.

In subsequent discussions, it was determined that certain missions could be accomplished using either an Atlas V or Delta IV without a third stage. Because eliminating the third stage would, in turn, result in significantly lower cost, these studies were adjusted to include this launch vehicle option as well.

Cost and schedule estimates were developed for each case. These estimates were computed using the following assumptions:

a) For the exact copy of New Horizons, the actual cost and schedule from Critical Design Review (CDR) to launch was used as the basis for the New Horizons II cost and schedule;
b) For a modified version of New Horizons, the actual cost and schedule from Preliminary Design Review (PDR) to launch was used as the basis for the New Horizons II cost and schedule;
c) For the Modified Heritage spacecraft, the actual cost and schedule from PDR to launch was used as the initial basis. This schedule was then increased by three to six months and the cost adjusted accordingly in order to account for likely modification efforts;
d) For the new design spacecraft, the actual cost and schedule of New Horizons from PDR to launch was used as the basis for the New Horizons II mission.

To these costs were added the estimated costs for the launch vehicle and for operations. For costing the launch vehicle, the latest cost estimates per the POP 05-1 were used. As noted below, per the POP 05-1, the cost for an Atlas 551 in the launch time of interest is estimated at $223M for a June, 2010 launch to $229M for a July 2011 launch. These estimates include the costs associated with the vehicle modifications for the nuclear payload. The lower estimate ($223M) was used for the trade studies. This is comparable to the actual launch vehicle cost for New Horizons ($213M). For post-launch costs, the cost was estimated as the approximate post-launch estimated cost for New Horizons, less the post-launch DOE and KSC costs (which are not associated with mission operations).

As noted below, the cost estimated General Purpose Heat Source (GPHS) RTG costs range from $65M-$90M, depending on the exact delivery option. For these studies, the cost of the GPHS RTG was taken as $65M. This cost is therefore considered at the lower end of the likely RTG costs. For the Multi-Mission RTG (MMRTG) designs, the costs were based on estimated costs presented at the New Frontiers Pre-Proposal Conference of 13 November 2003.

For the launch vehicle, discussions indicated that the likely lowest cost approach would be to use an Atlas V or Delta IV with no third stage. Eliminating the third stage saves substantially on costs (approximately $20M), but requires that a Jupiter gravity assist opportunity be available in order to accomplish the mission in less than a 20 year duration. As discussed below, this is feasible for Kuiper Belt missions in the timeframe of interest.

For the Modified Heritage spacecraft cases, the candidate spacecraft were reviewed for mission suitability. Based on this review, none of the spacecraft appeared to be viable candidates for this mission. Each of the candidates studied would require significant modifications to accomplish the New Horizons II mission. The Panel concluded that this case would effectively be subsumed by the New Design case. Accordingly, these spacecraft were not considered for cost and scheduling purposes.

For schedule purposes, it was assumed that a sole source procurement could be authorized at the start of FY2006, with actual build beginning as early as January, 2006. For a competitive procurement, it was assumed that an Announcement of Opportunity (AO) could be available for release in early FY2006, with award in July 2006. This schedule (from AO release to award) is consistent with the guideline schedule in the latest Discovery AO; however, it also assumes that selection would occur based on the initial AO response. It does not allow for a later competitive downselection among multiple initial study winners. Allowing for a later downselection would add at least three months to this timeline.

These initial schedule assessments were adjusted based on the availability of the RTG power system. As discussed below, the RTG is not estimated to be available prior to mid-2010. Accordingly, the schedules were adjusted to ensure that the spacecraft development and build schedule was consistent with a RTG availability in mid-2010. In some cases, this required assuming that the spacecraft was assembled and then stored awaiting RTG availability.

This baseline schedule would include zero-slack. The Panel therefore added schedule margin of 3-6 months to this baseline (approximately one month of slack per year of development), and concluded that January 2011 would represent the earliest realistic launch date for a New Horizons II mission. As mentioned above, the mission would require a Jupiter gravity assist due to the absence of the third stage. As discussed below, Jupiter gravity assists are available every thirteen months in this time period for a Kuiper Belt mission, with the first such post-January 2011 opportunity occurring in July, 2011.

Costs were computed in both constant year (FY05) and real-year dollars. For the real year dollars, the launch vehicle and RTG costs were taken as fixed, and the remaining costs were inflation-adjusted based on assumed build and flight schedules. The spacecraft and instrument builds were assumed to begin immediately following contract start. In several cases, this resulted in the spacecraft completion well in advance of the RTG availability. As noted above, in these cases, the spacecraft was then assumed to be placed in storage until RTG availability. No storage costs were included. These assumptions were considered to provide the lowest estimated cost.

The Panel recognized that some cost contingency would need to be included in any mission scenario. Accordingly, contingency was added as follows:

For designs which had been through CDR, a 16% reserve was included on system development costs. For designs which had been through PDR, but not CDR, a 20% reserve was included for system development costs. For systems which represented a new design, a 35% reserve was included on system development costs.

In all cases, an $11M reserve was included for the existing GPHS RTG. For the Multi-Mission RTG (MMRTG), a reserve of 32% against the baseline was included to reflect uncertainties. No reserve was included on the launch vehicle or mission operations cost.

The cost and schedule estimates developed in accordance with these scenarios provided the envelope for the Panel's estimate of the likely cost and schedule requirements for a New Horizons II mission.

The results for each case are:

a) Case 1: Exact copy of New Horizons

For this case, an exact copy of New Horizons, including all instruments, was assumed. The mission was assumed to be launched on an Atlas 551, as for New Horizons. A sole source procurement was assumed.

The cost was assumed to be equal to the actual New Horizons costs from CDR through launch. The Panel assumed a sole source contract could be in place by January 2006, thus allowing the same New Horizons team to build the New Horizons II. This was considered to minimize build risk by using the same personnel for the follow-on mission. The Panel did not assume a learning efficiency improvement. The Panel also recognized that these costs include some costs which may not need to be repeated (such as for Ground Support Equipment); however, the exact value of these additional reductions could not be estimated from the cost data the Panel had available.

The schedule assumed that the spacecraft build would begin in January 2006, with completion in April 2008. The spacecraft would then be placed in storage until availability of the RTG in mid-2010. The Panel did not include any storage costs for this effort, although some costs would be expected. In addition, as noted above, the Panel assumed the New Horizons cost for the RTG of $65M, while the latest estimates for a RTG are $65M-$90M.

Using standard reserve estimating tools, the Panel included a reserve of 16% on the system development, and $11M on the RTG.

The Panel concluded that the mission could be accomplished using a standard Atlas 551 launch vehicle with no third stage. Accordingly, the New Horizons costs were reduced by $20M to account for deletion of the Star 48 third stage.

The results of this case study were:

Case	Concept	Cost (Real Year $) w/o Contingency	Cost (Real Year $) with Contingency	Schedule Duration	Estimated Completion Date (w/o reserve)	Comments
1	Exact Copy of New Horizons	$590M	$623M	54 months (not including schedule reserve)	June 2010	Assumes no third stage

b) Case 2: Copy of New Horizons on Atlas 521

For case 2, the launch vehicle was reconsidered. Based on review of launch capabilities and requirements, the Atlas 521 appeared to be a viable alternative vehicle. Based on data from KSC, the Atlas 521 would be approximately $33M less than the Atlas 551 in the time frame of interest, and thus use of this launch vehicle could reduce overall costs. However, because of the different launch loads, spacecraft reanalysis would be required. In addition, some additional redesign risk would be incurred due to the change in launch vehicle. The Panel estimated that the added analysis costs would likely be approximately half the launch vehicle savings (approximately $15M). Finally, it appears that an Atlas 521 would require use of a Star 48 third stage (estimated cost of $20M). Thus, in the opinion of the Panel, there would be little or no net savings, and somewhat higher risk.

As with Case 1, a sole source procurement was assumed, and spacecraft build was assumed to begin in January 2006.

The results of this case study are nearly identical to those for case 1. A slightly higher reserve was recommended due to the additional risk.

Case	Concept	Cost (Real Year $) w/o Contingency	Cost (Real Year $) with Contingency	Schedule Duration	Estimated Completion Date (w/o reserve)	Comments
2	Copy of New Horizons on Atlas 521	$593M	$632M	54 months (not including schedule reserve)	June 2010	Slightly higher development risk than Case 1

c) Case 3: Modified New Horizons Spacecraft

For case 3, the present GPHS RTG was assumed to be replaced by Multi-Mission RTGs (MMRTGs). The MMRTG is presently under development, and has significantly different size and power capabilities than the GPHS RTG. Thus significant redesign would be required. It was estimated that three MMRTGs would be required for the New Horizons II mission.

The costs were therefore computed based on the New Horizons cost from PDR through launch, with the additional estimated costs of three MMRTGs in place of the cost of a single GPHS RTG. A 32% reserve was applied against the MMRTG cost. The launch vehicle was assumed to not require a third stage.

A sole source procurement was also assumed. The spacecraft build was again assumed to begin in January 2006.

The results for this case were:

Case	Concept	Cost (Real Year $) w/o Contingency	Cost (Real Year $) with Contingency	Schedule Duration	Estimated Completion Date (w/o reserve)	Comments
3	Modified New Horizons spacecraft using MMRTGs	$744M	$827M	65 months (not including schedule reserve). Assumes January 2006 start	May 2011	Schedule for MMRTG is controlling path

d) Case 4: Heritage Designs

For case 4, multiple alternate spacecraft were considered as potential candidates. The Dawn, Deep Impact, MESSENGER, CONTOUR, Genesis, Odyssey and Triana spacecraft were evaluated for New Horizons II. Review of these spacecraft indicated that all would require significant modification to accomplish the New Horizons II mission. Cases 3 (Modified New Horizons Spacecraft) and 5 (New Design Spacecraft) were considered to envelope the cost and schedule trade space for such modified designs, and thus no further investigation of these alternative spacecraft was required.

e) Case 5: New Design Spacecraft

For Case 5, a new design spacecraft was assumed. A competitive award was assumed, with contract start in July 2006. The minimum payload was set as the Ralph and LORRI instruments. Both a single GPHS RTG and two MMRTGs were considered as power sources. The costs and schedule were based on the New Horizons costs and schedule from contract start through launch. Mass and power estimates were developed for such a spacecraft.

The results of Case 5 were:

Case	Concept	Cost (Real Year $) w/o Contingency	Cost (Real Year $) with Contingency	Schedule Duration	Estimated Completion Date (w/o reserve)	Comments
5a	New Design Spacecraft Using GPHS RTG	$774M	$898M	48 months (not including schedule reserve). Assumes July 2006 start	June 2010	RTG availability, launch approval process, and spacecraft development all estimated to finish in June 2010. Thus high schedule risk
5b	New Design Spacecraft Using 2 MMRTGs	$777M	$912M	59 months (not including schedule reserve). Assumes July 2006 start	May 2011	MMRTG availability is controlling path

The cost and development schedules for the mission cases studied are summarized in the table below:

Scenario Number	Spacecraft Concept	Cost ($M) w/o Contingency	Cost ($M) with Contingency	Schedule Duration/Completion Date	Comments
1	Exact Copy New Horizons	$590M	$623M	54 months/June 2010	
2	Copy New Horizons, Atlas 521 LV	$593M	$632M	54 months/June 2010	
3	Modified New Horizons	$744M	$827M	65 months/May 2011	MMRTG limits schedule
4	Modified Heritage Design	N/A	N/A	N/A	N/A
5a	New Design GPHS RTG	$774M	$898M	48 months/June 2010	RTG procurement must begin in early FY2006
5b	New Design MMRRTG	$777M	$912M	59 months/May 2011	MMRTG limits schedule

Regarding the confidence in these cost and schedule estimates, the Panel notes that the estimates are heavily based on actual New Horizons cost and schedule performance. The Panel considered this most directly applicable. The cost and schedule information provided to the Panel showed the costs on a fiscal year basis, and was broken down to the center level (Johns Hopkins Applied Physics Lab, JPL, Kennedy Space Center, Southwest Research, etc.) This level of detail was sufficient for estimating overall costs and schedule at a summary level. However, there are some costs which could conceivably be further reduced, but could not be estimated from the cost data provided. For example, the cost data provided to the Panel includes items such as Ground Support Equipment and software development. For cases 1 and 2, these costs could be reduced or eliminated, if the work was again performed at the Applied Physics Lab. Similarly, the cost data provided to the Panel includes costs associated with modifications of the Star 48B third stage. These costs are therefore reflected in the cost estimates for cases 3, 5a and 5b. Finally, for cases 1 and 2, no learning efficiency improvement was assumed. Therefore, the estimates can be seen as somewhat conservative.

The Panel notes, however, that there were several assumptions which tend to offset these potential cost savings. The Panel estimated the cost of both the RTG ($65M) and launch vehicle ($223M) at the low end of the estimated cost. For the RTG, the estimated cost was $65M-$90M, while for the launch vehicle, the estimated cost was $223M-$229M. Similarly, the Panel did not include any storage costs associated with storing the completed spacecraft while awaiting the RTG delivery. Finally, the Panel assumed that contracts (either sole source or competitive) could be in place very quickly (by January 2006 for a sole source or by July 2006 for a competitive selection), which tended to minimize inflation adjustments.

In light of the above considerations, the Panel does not believe these costs can be significantly reduced. The Panel recognizes that some additional savings may be possible, but does not believe these savings would be significant, and that there are, in turn, significant liens against the Panel's estimated costs. For the schedule, the Panel concludes that it is a best case estimate, including a 3-6 month reserve.

The Panel was tasked with determining if the New Horizons II mission could be accomplished at a cost "considerably less" than that of New Horizons. The consensus opinion of the Panel was that savings had to be at least 20% of the estimated New Horizons cost to be considered "considerably less". The Panel noted that, while the New Horizons costs are accurately known, the costs estimated in this report possess inherently less reliability; accordingly, a cost threshold of this magnitude was considered appropriate as the definition of "considerably less." In the best case, the savings is estimated at approximately 14% of the New Horizons cost. The Panel did not, therefore, conclude that the New Horizons II mission could be accomplished at a cost "considerably less" than that of New Horizons.

In summary, the Panel concludes that a New Horizons II mission is technically feasible in the 2011 timeframe, and could be accomplished for a cost between $623M and $912M.

Radioisotope Thermoelectric Generator

Any mission to the Kuiper Belt will require a nuclear power system for instrument and spacecraft power. The present New Horizons uses a Cassini class RTG, which could generate up to 300 W of electrical power. This unit is referred to as a General Purpose Heat Source (GPHS) RTG.

At present, there is one remaining GPHS RTG. This unit is designated F5. It is presently being prepared for defueling, scheduled to begin in April 2005. The remaining plutonium fuel has been designated for other users. Consequently, at this time, there is no GPHS RTG available for a New Horizons II mission.

New design RTGs (designated Multi-Mission RTGs (MMRTGs) and Stirling Radioisotope Generators (SRGs)) are under development, but would not be available for a New Horizons II mission prior to 2010. Furthermore, these new units are substantially different in terms of size and power, and thus would require substantial spacecraft redesign to accommodate them. Consequently, it appears the most cost and schedule effective approach is to evaluate procuring a new Cassini/New Horizons I class RTG.

In developing an RTG, fuel processing time (converting the plutonium-238 into usable fuel pellets) is the time limiting factor. Present production capacity is fully utilized and committed, and consequently obtaining fuel for a new RTG will be the controlling schedule path. With present production loads, the earliest sufficient RTG fuel would be available is mid-2009. Following fuel delivery, an estimated one year is required to assemble the RTG, and deliver it to the launch site for spacecraft integration.

Two options exist for developing the converter for this fuel. Either the existing F5 RTG can be refurbished for flight, or a new converter can be produced. In either case, a converter can be ready prior to mid-2009, and thus be ready to accept the fuel once it becomes available. Either approach therefore would provide for an RTG available in mid-2010.

Regarding these options, refurbishing the present F5 unit appears to provide a unit at lower cost and earlier delivery date; however, the fully assembled RTG will still not be ready earlier than mid-2010 due to fuel availability. The estimated cost for refurbishment, refueling, and completing the required safety documentation of the F5 unit is $65M-75M, while a new converter is estimated at $80M-90M. Refurbishing the F5 unit involves some slightly greater risk, given the age of the unit (in excess of 20 years). If during the defueling and/or refurbishment process additional work was required to make the unit flight worthy, some additional schedule impact would be incurred, but would likely not impact the delivery date. This particular risk is eliminated by the production of a new converter, but at a higher cost and assumption of some smaller set of risks.

Launch Vehicle Considerations

The New Horizons mission is planned for launch on an Atlas 551, with Star 48 third stage. The Panel considered potential alternate launch vehicles for New Horizons II in an attempt to lower the mission cost without incurring additional risk. The NASA costing guidelines indicate that the Atlas class and Delta IV are equal in cost, so the Panel treated these two designs as one option. Since there were no apparent cost or availability issues between these two launch vehicles, the Atlas 551 was taken as the baseline.

Based on POP 05-1 guidelines, the estimated cost of an Atlas 551 for a June 2010 launch date is $223M (real year dollars), including the costs associated with the nuclear payload. The estimated cost for an Atlas 551 for a July 2011 launch date is $229M (real year dollars). The Panel used the lower estimated cost for its estimates ($223M).

As noted above, an Atlas 521 could potentially provide somewhat lower costs; however, some reanalysis is required and there is some risk of limited redesign. Furthermore, the lower launch capacity would provide additional mission constraints, as well as likely require use of a Star 48 third stage. Accordingly, the Panel concluded that no significant cost savings would occur from use of an Atlas 521, while some additional mission risks would be incurred.

A Delta IV Heavy could accomplish the mission and would allow the spacecraft to reach its destination in a shorter time; however, the Delta IV Heavy is significantly more expensive, and was therefore dropped from consideration.

A Delta II with third stage could potentially satisfy the mission requirements if a Venus assist were also available. This launch vehicle option is estimated to be significantly lower in cost than the baseline Atlas 551. The POP 05-1 guidelines indicate that the estimated cost of a Delta II with third stage in 2011 is $117M (real year dollars). However, the present New Horizons spacecraft cannot be accommodated within a Delta II. Therefore, this option would only be viable for the new design spacecraft (Cases 5a and 5b). Furthermore, there are costs and availability concerns regarding the Delta II in the post-2010 timeframe, as NASA is the only planned user of this launch vehicle in that timeframe. Therefore, the Delta II option was not considered for the mission scenarios.

In the interest of time, therefore, the Panel concentrated on the Atlas 551 as the likely lowest-cost, lowest-risk approach.

Nuclear Safety Launch Approval Processes

Launch approval processes are utilized by missions that use Radioisotope Power Systems (RPS), Radioisotope Heater Units (RHUs) or nuclear reactors. These processes include compliance with the National Environmental Policy Act (NEPA), Presidential Nuclear Safety Launch Approval, Launch Accident Contingency Planning, and Risk Communication. Only NEPA and Presidential Nuclear Safety Launch Approval are discussed in this report as they pertain to a potential New Horizons II mission since they are the only launch approval activities requiring substantial schedule.

National Environmental Policy Act (NEPA)

NEPA requires federal agencies to consider, before an action is taken, environmental values in the planning of activities that may have a significant impact on the quality of the human environment. NEPA accomplishes this by directing agencies to evaluate alternative courses of action that may mitigate the potential environmental impact of a planned activity, such as use of radioactive material on a space mission. NASA's implementing regulations for NEPA are established in 14 CFR 1216.1 and 1216.3. These regulations specify actions that can be expected to have a significant effect on the quality of the human environment, which include the development and operation of nuclear systems, require preparation of an Environmental Impact Statement (EIS).

Since New Horizons II would be baselined to use an RPS, NASA will be required to complete its own EIS. Development of an EIS commences as early as possible in the development of a mission, with a target for completion (i.e., a Record of Decision) by Critical Design Review (CDR) (i.e., usually at least 3 years before launch) or earlier. NASA Headquarters is responsible for preparing EISs that propose using RPS and have historically enlisted subcontractors to assist in developing the required documentation. Development of this type of EIS also requires development of a nuclear risk assessment by the Department of Energy (DOE), and participation by NASA Kennedy Space Center (KSC) and the Jet Propulsion Laboratory (JPL) for developing launch system data pertinent to the DOE risk assessment.

An EIS must explain the purpose and need for the mission, evaluate the environmental impacts associated with the proposed action, evaluate the environmental impacts associated with a range of reasonable alternatives to the planned action (including a No Action alternative), and allow for public and governmental agency review and comment. A representative schedule of associated activities for development of an EIS entailing a proposed action baselining the use of an RPS can be seen in Table 1.

Table 1
NEPA Schedule For Competed Mission Unknown Launch System Using RPS

Task Name	Duration	Start	Finish
Kick-Off NEPA Planning Meeting Window	**10d**	**7/3/06**	**7/14/06**
Publish Notice of Intent			**10/9/06**
EIS Databook Development	***165***	***10/17/05***	***6/5/06***
EIS Risk Assessment Development	***165***	***6/6/06***	***1/23/07***
Draft EIS Development	**148d**	**1/3/07**	**7/13/07**
EPA Notice of Availability: Draft EIS			**7/20/07**
Public Review Period – 45 Calendar Days	**31d**	**7/23/07**	**9/3/07**
Final EIS Development	**114d**	**8/14/07**	**1/4/08**
EPA Notice of Availability: Final EIS			**1/11/08**
Waiting Period – 30 Calendar Days	**22d**	**3/14/08**	**2/12/08**
Earliest Date to Render Record of Decision			**2/13/08**

Note: Items in italics assume task duration reductions from the standard planning durations. Durations are in work days.

All of the tasks in the EIS schedule are standard tasks that are required for any NASA EIS entailing the potential use of an RPS, and assume the standard planning durations (in work days) except where noted in italics. Historically, the biggest schedule drivers are initiating work on NEPA compliance, development of the EIS Databook, and development of the EIS Risk Assessment. It is worth noting that the standard task durations are representative of what KSC, DOE, and NASA assume for planning purposes across all future programs. Actual task durations for any specific mission could differ depending on factors such as competing and complimentary work for other missions. Assuming EIS Databook work started in October 2005, a Record of Decision could be rendered by February 2008, almost 3 years before the earliest launch period in January 2011 and more than 3 years before the earliest launch period with a gravity assist in July 2011.

Table 2 shows a NEPA schedule for a New Horizons II mission assuming the same spacecraft design as New Horizons, being launched on an Atlas 551 with a Star-48 third stage.

Table 2
NEPA Schedule For Clone Spacecraft on Atlas 551 with Star-48

Task Name	Duration	Start	Finish
Kick-Off NEPA Planning Meeting Window	**10d**	**1/2/06**	**1/13/06**
Publish Notice of Intent			**4/10/06**
EIS Databook Development	**135d**	**11/24/05**	**6/2/06**
EIS Risk Assessment Development	***135d***	***6/2/06***	***12/8/07***
Draft EIS Development	***148d***	***11/20/06***	***5/30/07***
EPA Notice of Availability: Draft EIS			**6/8/07**
Public Review Period – 45 Calendar Days	**31d**	**6/11/07**	**7/23/07**
Final EIS Development	**114d**	**7/3/07**	**11/23/07**
EPA Notice of Availability: Final EIS			**11/30/07**
Waiting Period – 30 Calendar Days	**22d**	**12/3/07**	**1/1/08**
Earliest Date to Render Record of Decision			**1/2/08**

Note: Items in italics assume task duration reductions from the standard planning durations. Durations are in work days.

In this instance it is reasonable to assume reductions in task durations to the risk driving tasks due to similarities to New Horizons existing information. Specifically, the EIS Databook work is assumed to begin November 2005, and this in combination with task driver duration reductions supports a Record of Decision in January 2008, three years in advance of the earliest launch period in January 2011, and more than three years in advance of the earliest launch period with a gravity assist in July 2011. Task duration reduction assumptions are detailed in Appendix 3.

Table 3 shows a NEPA schedule for a New Horizons II mission assuming the same spacecraft design as New Horizons, being launched on an Atlas 551 but without a Star-48 third stage.

Table 3
NEPA Schedule For Clone Spacecraft on Atlas 551 No Star-48

Task Name	Duration	Start	Finish
Kick-Off NEPA Planning Meeting Window	**10d**	**1/2/06**	**1/13/06**
Publish Notice of Intent			**4/10/06**
EIS Databook Development	***155d***	***10/17/05***	***5/22/06***
EIS Risk Assessment Development	***155d***	***5/23/06***	***12/26/06***
Draft EIS Development	**148d**	**12/6/06**	**6/15/07**
EPA Notice of Availability: Draft EIS			**6/22/07**
Public Review Period – 45 Calendar Days	**31d**	**6/25/07**	**8/6/07**
Final EIS Development	**114d**	**7/17/07**	**12/7/07**
EPA Notice of Availability: Final EIS			**12/14/07**
Waiting Period – 30 Calendar Days	**22d**	**12/17/07**	**1/15/08**
Earliest Date to Render Record of Decision			**1/16/08**

Note: Items in italics assume task duration reductions from the standard planning durations. Durations are in work days.

In this instance as well it is reasonable to assume some reductions in task durations to the risk driving tasks due to some similarities to New Horizons existing information. The reductions were offset some to account for hardware differences in the launch system and the sensitivities of radiological risk assessments to launch periods and launch times. The EIS Databook work is assumed to begin in October 2005, and this in combination with task driver duration reductions supports a Record of Decision in January 2008. This would be three years before the earliest launch period in January 2011 and more than three years before the earliest launch period with a gravity assist in July 2011. Task duration reduction assumptions are detailed in Appendix C.

Presidential Nuclear Safety Launch Approval Process

For any U.S. space mission involving use of nuclear energy for heating or electrical power, launch approval must be obtained from the Office of the President per Presidential Directive/National Security Council Memorandum #25 (PD/NSC-25) paragraph 9 as amended May 8, 1996. The approval decision is based on an established and proven review process that includes an independent evaluation by an ad hoc Interagency Nuclear Safety Review Panel (INSRP). The process begins with development of a launch vehicle Databook (i.e., a compendium of information describing the mission, launch system, and potential accident scenarios). DOE uses the Databook to prepare a Preliminary Safety Analysis Report (PSAR) for the space mission. In all, three safety analysis reports (SAR's) are typically produced and submitted to the INSRP – the PSAR, an updated SAR (USAR or Draft Final SAR) and a final SAR (FSAR). The DOE project office responsible for providing the nuclear power system develops these documents.

The ad hoc INSRP conducts its nuclear safety/risk evaluation and documents their results in a nuclear Safety Evaluation Report (SER). The SER contains an independent evaluation of the mission radiological risk. The DOE uses the SER as its basis for accepting the SAR. If the DOE Secretary formally accepts the SAR-SER package, it is forwarded to the NASA Administrator for use in the launch approval process.

NASA distributes the SAR and SER to other cognizant government agencies, such as Department of Defense (DOD), Environmental Protection Agency (EPA), and solicits their assessment of the documents. After receiving responses from these agencies, NASA conducts internal management reviews to address the SAR and SER and any other nuclear safety information pertinent to the launch. If the NASA Administrator recommends proceeding with the launch, then a request for nuclear safety launch approval is sent to the Director of the Office of Science and Technology Policy (OSTP) within the Office of the President.

NASA Headquarters is responsible for implementing this process for NASA missions. It has traditionally enlisted JPL to assist in this activity. DOE supports the process by analyzing the response of RPS hardware to the different accident scenarios identified in the Databook, and prepares a probabilistic risk assessment of the potential radiological consequences and risks to the public and the environment for the mission. NASA KSC is responsible for overseeing development of Databooks, and traditionally uses JPL to characterize accident environments. Both KSC and JPL subcontractors provide information relevant to launch vehicle accident probability analysis, and other contractors assist in performing impact assessments and analyses. The development team ultimately selected for any potential future New Horizons II mission would be responsible for providing payload descriptions, describing how the nuclear hardware integrates into the spacecraft, describing the mission, and supporting NASA KSC and JPL in their development of the EIS and SAR Databooks. The schedule of associated activities for a New Horizons II Presidential nuclear safety launch approval process can be seen in table 4.

Table 4
Presidential Nuclear Safety Launch Approval Schedule
For Competed Mission Unknown Launch System

Task Name	Duration	Start	Finish
Project Start			**7/3/06**
SAR Launch Vehicle Databook Development	**614**	**7/5/06**	**11/10/08**
Launch Vehicle Input Development	140d	7/5/06	1/16/07
Accident Environment Updates	190d	1/17/07	10/9/07
Draft Launch Vehicle Databook Development	160d	10/10/07	5/20/08
Draft Databook External Review	45d	5/21/08	7/22/08
Comment Resolution Meeting	4d	7/23/08	7/28/08
Final Launch Vehicle Databook Development	75d	7/29/08	11/10/08
SAR Development	**618**	**11/11/08**	**3/24/11**
PSAR Development	200d	11/11/08	8/17/09
PSAR External Review	29d	8/18/09	9/25/09
Draft FSAR Development	180d	9/28/09	6/4/10
Draft FSAR External Review	29d	6/11/10	7/15/10
FSAR Development	180d	7/16/10	3/24/11
Safety Evaluation Report (SER) Development	**260d**	**3/25/11**	**3/22/12**
NASA and Other Agency Review	**92d**	**3/23/12**	**7/30/12**
OSTP Consideration of Launch Approval Req.	**82d**	**8/1/12**	**11/21/12**

All of the tasks in the schedule are standard tasks and assumed the standard planning durations (in work days). Historically, the biggest schedule drivers are development of the SAR Databook, and SAR. It is worth noting that the standard task durations are representative of what KSC, DOE, and NASA assume for planning purposes across all future programs. Actual task durations for any specific mission could differ depending on factors such as competing and complimentary work for other missions. Assuming a work start in July 2006 concurrent with a Project award stemming from a competitive selection process, this bounds the Presidential nuclear safety approval compliance schedule. It shows that if the project had to rework completely the SAR Databook and SAR, and use the long planning durations outline above, it would result in an approval by late November 2012.

Table 5 shows a Presidential nuclear launch approval schedule for a New Horizons II mission assuming the same spacecraft design as New Horizons, being launched on an Atlas 551 with a Star-48 third stage.

Table 5
Presidential Nuclear Safety Launch Approval Schedule
For Clone Spacecraft on Atlas 551 with Star-48

Task Name	Duration	Start	Finish
Project Start			**1/2/06**
SAR Launch Vehicle Databook Development	**229d**	**7/18/07**	**6/2/08**
Launch Vehicle Input Development	*30d*	*7/18/07*	*8/28/07*
Accident Environment Updates	*60d*	*8/29/07*	*11/20/07*
Draft Launch Vehicle Databook Development	*60d*	*11/21/07*	*2/12/08*
Draft Databook External Review	*30d*	*2/13/08*	*3/25/08*
Comment Resolution Meeting	4d	3/26/08	3/31/08
Final Launch Vehicle Databook Development	*45d*	*4/1/08*	*6/2/08*
SAR Development	**309d**	**6/3/08**	**7/24/09**
PSAR Development	*0*		
PSAR External Review	*0*		
Draft FSAR Development	*135d*	*6/3/08*	*12/8/08*
Draft FSAR External Review	29d	12/9/08	1/16/09
FSAR Development	*135d*	*1/19/09*	*7/24/09*
Safety Evaluation Report (SER) Development	***200d***	***7/27/09***	***4/30/10***
NASA and Other Agency Review	**92d**	**5/3/10**	**9/7/10**
OSTP Consideration of Launch Approval Req.	**82d**	**9/8/10**	**12/30/10**

Note: Items in italics assume task duration reductions from the standard planning durations. Durations are in work days.

Historically, Presidential nuclear safety launch approval is granted near (i.e., a few days to a few weeks before) the opening of the mission launch period. Assuming a launch period for New Horizons II opening on January 2011 this schedule shows that nuclear safety launch approval could be granted at the end of December 2011 with a work start (i.e., for nuclear safety launch approval compliance) as late as July 2007. Specifically, the SAR Databook work is assumed to begin July 18, 2007, and this in combination with task driver duration reductions supports a January 2011 launch.

Table 6 shows a Presidential nuclear safety launch approval schedule for a New Horizons II mission assuming the same spacecraft design as New Horizons, being launched on an Atlas 551 but without a Star-48 third stage.

Table 6
Presidential Nuclear Safety Launch Approval Schedule
For Clone Spacecraft on Atlas 551 No Star-48

Task Name	Duration	Start	Finish
Project Start			**1/2/06**
SAR Launch Vehicle Databook Development	**229d**	**7/18/07**	**6/2/08**
Launch Vehicle Input Development	*70d*	*10/18/06*	*1/23/07*
Accident Environment Updates	*60d*	*1/24/07*	*4/17/07*
Draft Launch Vehicle Databook Development	*80d*	*4/18/07*	*8/7/07*
Draft Databook External Review	45d	8/8/07	10/9/07
Comment Resolution Meeting	4d	10/10/07	10/15/07
Final Launch Vehicle Databook Development	75d	10/16/07	1/28/08
SAR Development	**309d**	**6/3/08**	**7/24/09**
PSAR Development	*0*		
PSAR External Review	*0*		
Draft FSAR Development	180d	1/29/08	10/6/08
Draft FSAR External Review	29d	10/7/08	11/14/08
FSAR Development	180d	11/17/08	7/24/09
Safety Evaluation Report (SER) Development	***200d***	***7/27/09***	***4/30/10***
NASA and Other Agency Review	**92d**	**5/3/10**	**9/7/10**
OSTP Consideration of Launch Approval Req.	**82d**	**9/8/10**	**12/30/10**

Note: Items in italics assume task duration reductions from the standard planning durations. Durations are in work days.

Assuming a launch period for New Horizons II opening in January 2011 this schedule shows that nuclear safety launch approval could be granted in late December 2010 with a work start (i.e., for nuclear safety launch approval compliance) as late as October 2006. Specifically, the SAR Databook work is assumed to begin October 18, 2006, and this in combination with task driver duration reductions supports a Janauary 2011 launch. It would be necessary to begin work earlier than for the clone case with a Star-48 since changes would be needed to the launch vehicle databook to account for different hardware configuration and differences in the launch vehicle Flight Termination System (FTS). Still, given great similarities to and recent experience with New Horizons, task duration reductions should be possible.

Orbital Scenarios

Multiple orbital simulations were run to determine the potential mission scenarios. Simulations were run including both use of a third stage and no use of a third stage. As discussed above, it became apparent that eliminating the third stage could provide significant cost savings.

The analysis indicated that missions to the Kuiper Belt could be launched in the 2011 or later time frame. Without use of any gravitational orbit assists, a mission to any Kuiper Belt Object near the ecliptic out to 50 AU could be accomplished with an approximately

20 year flight duration with the same launch capability and third stage as required for New Horizons. Similarly, a fly-by of Neptune and Triton is possible after an 11+ year flight time, with the possibility of additional KBO encounters after a Neptune gravity assist. However, a direct mission to Pluto using the same launch capability would require additional on-board ΔV capability beyond New Horizons to reach Pluto in the time frame of interest due to its orbital inclination.

Flight time to the Kuiper Belt could be significantly reduced through use of a Jupiter gravity assist maneuver, while at the same time eliminating the need for a launch vehicle third stage. No Jupiter gravity assists are available for Pluto or Neptune in the time frame of interest; however, annual launch opportunities are available for Jupiter gravity assists to the Kuiper Belt. These launch opportunities occur in July 2011, August 2012, September 2013 and every 13 months thereafter. Use of a Jupiter gravity assist would reduce the estimated mission flight times to approximately 15 years, significantly reducing mission risk and the time to data return.

Accordingly, the Panel's baseline New Horizon II mission consisted of a mission to investigate Kuiper Belt Objects, to be launched in the post-2010 time period. This mission would not require use of a third stage, thus reducing launch vehicle costs. In addition, this mission would provide the fastest science data return.

Science Justification

The study team was asked to consider **"…whether the potential science return can be justified…"** for a New Horizons II mission**.**

Since the discovery of the first Kuiper belt object (KBO) in 1992, detection and characterization of these bodies has become one of the highest priorities in solar system exploration because of the fundamental role they are expected to play in understanding the origin and evolution of the solar system. The discovery of hundreds of KBOs since 1992 has unexpectedly revealed a rich diversity among their properties. Photometric studies of KBOs show that these objects are typically very dark but that the percentage of light they reflect varies by a factor of at least two and they have colors ranging from grey to very red. Some appear to be active, while others are not.

With the large sample of objects currently known, dynamical models can be used to understand the structure of the disk. There appears to be at least four dynamically distinct groups of objects and the models suggest that these groups originated in different regions of the proto-planetary disk. The different sub-groups appear to have different physical properties. By comparing objects in the different groups it may be possible to determine the conditions in the proto-planetary disk as a function of heliocentric distance.
Studies of different populations may also lead to an understanding of how planetary accretion works.

The importance of studying KBOs was underscored by the recent National Research Council decadal survey "New Frontiers in Solar System Exploration: An Integrated

Exploration Strategy" (2003; hereafter referred to as SSE Survey). The SSE Survey, which involved a broad cross section of the planetary science community, has established the consensus priorities for solar system exploration in the decade 2003-2013. Concerning a mission to the Kuiper Belt, the SSE Survey states:

> A mission to the Kuiper Belt, including Pluto-Charon, will provide the first exploration of this newly discovered domain in the solar system, provide important insights into the physical nature of these planetary building blocks, and allow us to survey the organic matter and volatiles that they contain. Collisions with objects such as these diverted into the inner solar system may have imported the basic volatile and molecular stock from which habitable environments were constructed in early planetary history. Little is known of the physical properties of Kuiper Belt objects (KBOs). However, what is known (several physically large objects with high rates of spin, several loosely bound binaries, and a wide range of color) indicates that they have diverse and unexpected properties. The value of this mission increases as it observes more KBOs and investigates the diversity of their properties. The SSE Survey anticipates that the information returned from this mission might lead to a new paradigm for the origin and evolution of these objects and their significance in the evolution of objects in other parts of the solar system.
>
> Comparison of the cratering records on Pluto, Charon, and several smaller objects at a range of heliocentric distances will provide our first data on the collisional history of this region. Comparison of the surface compositions of objects in the belt with Pluto and Charon and Triton may allow us to separate evolutionary surface processes from primordial surface properties in the outer solar system. The observations, if extended to small objects, may provide information on whether comets are collisional fragments from large KBOs or are themselves primordial bodies. The surface material on KBOs may not survive entry into the inner solar system. Investigation of the composition of this material, which is probably the most primitive in the solar system, will provide an important reference for comparison with the surface materials on related bodies, including the Centaurs, the nuclei of comets, and certain near-Earth asteroids. The technical readiness of this mission is judged high, owing to the ongoing development of a technically equivalent mission concept.

The SSE Survey gave a Pluto-Kuiper Belt mission the highest priority in the medium cost (New Frontiers) mission category. They also recognized, as stated above, that "The value of this mission increases as it observes more KBOs and investigates the diversity of their properties." The science justification for investigating more than the three objects currently targeted by the New Horizons mission is therefore very strong.

The Panel was asked to consider the feasibility of a mission "in the near term" that cost "considerably less" than the New Horizons mission. The trade studies described in this report showed that the most cost-effective approach to a New Horizons II mission is to fly a clone of the New Horizons spacecraft. The New Horizons instrument complement was well chosen for Pluto studies and at least some of these instruments would be suitable for any KBO mission. The Panel therefore considered only missions that contain: (1) a reduced instrument complement compared to New Horizons; and (2) an identical instrument complement to New Horizons.

In the study team charter, the potential science targets were set out as follows:

> …the mission of New Horizons II shall be limited to one or more of a) a further survey of the Pluto-Charon system, b) a further survey of Kuiper Belt Objects, c) a survey of objects believed to be captured Kuiper Belt Objects (for example, Neptune's moon, Triton).

Any KBO within 50 astronomical units can be targeted with a mission flight time of approximately 20 years even if no gravity assists are possible. A Jupiter gravity assist is possible approximately once every 13 months, allowing 15 year flight times to restricted regions of the Kuiper belt. A Jupiter gravity assist allows some of the targets to be reached by an Atlas launch vehicle without requiring a third stage.

As with any other KBO, it would be possible to travel to Pluto on a direct orbit if arrival in 20 years is acceptable. However, there is no gravity assist trajectory to Pluto in the near term, so shorter mission times are not possible. Therefore, it was the opinion of the Panel that, given the long flight time, further Pluto science should await the results of New Horizons so that a mission can be designed to target towards answering questions which arise from New Horizons.

The Congressional mandate was to study a follow-on to the New Horizons mission. The SMD charter widened the purview to include Triton on the grounds that it is possibly a captured KBO. Orbital studies show that a 2023 flyby of Triton at >10.5 km/sec (which would provide about one hour of highest quality data) is possible with a 2012 launch. This would allow observations of comparable quality to the Voyager 2 mission provided that the full New Horizons instrument suite was flown. A launch to Neptune would impart enough ΔV to continue to KBO 1999 RZ253 in 2029, assuming a 2012 initial launch date.

The potential science return from a KBO flyby mission includes determining the geology, morphology (crater numbers and shape, for example), and composition of the surface. This science can be done with an optical/infrared imager/spectrometer. A wide field camera, which provides sensitivity for early observations and for looking for any weak atmosphere, would be desirable. On the New Horizons mission, these instruments are Ralph and LORRI.

We would expect a very similar science return from a follow-on mission to that from the original mission, with the exception that only one KBO flyby will be accomplished by the New Horizons II mission (unless there is a fortuitous line-up that allows a flyby of another object). That object will be smaller than Pluto, maybe significantly so, and is therefore unlikely to have an atmosphere. If only the two primary instruments (Ralph and LORRI) are flown, the primary scientific objectives stated above would be met, but significant ancillary science would not be accomplished. In a quantitative sense, then, the science return will be less, unless New Horizons fails. It has been common in solar system exploration to fly two concurrent missions as a risk mitigation strategy (cf, Pioneers 10, 11; Vikings 1, 2; Voyagers 1, 2; Mars Exploration Rovers Spirit and Opportunity). A New Horizons II mission might therefore be considered in this vein. However, we note that both the SSE Survey and NASA declined to endorse this strategy for New Horizons.

In trying to judge whether a largely unquantifiable science return justifies a follow-on mission, we are forced to consider whether the incremental gain in adding data from another 1-2 KBOs to that obtained from the 2-3 KBOs being targeted in the first mission would be significant enough to justify a second mission. The Panel notes that New Horizons II, as with the original mission, is a fast flyby (10 km/sec). Thus, the mission profile is a 15 year cruise phase followed by less than one hour of the highest quality imaging.

The Panel's expectation, like that of the SSE Survey, is that data from the New Horizons mission has the potential to be paradigm altering. The Panel's expectation for a second mission is that although the additional data could prove to be very helpful in more fully understanding the Kuiper belt and its implications for solar system formation and evolution, it is much less likely than data from the first mission to be paradigm altering. It is therefore expected to be of lesser scientific utility than data acquired in the New Horizons mission.

The Panel further emphasizes that on scientific grounds, despite recognizing the value of investigating multiple KBOs, the SSE Survey did not recommend multiple missions to the Kuiper Belt; they recommended a single mission at high priority.

Furthermore, the SSE Survey endorsed competition for New Frontiers missions, and recognized that re-prioritization may be necessary over the course of a decade. Accordingly, they recommended a process for such re-prioritization to occur (our emphasis added):

> "Many discoveries occur in the planetary sciences over the course of a decade, and for a decadal strategy to maintain a course consistent with ongoing discoveries, the need to reconsider the priorities recommended by this Survey may arise. NASA should issue Announcements of Opportunity for New Frontiers missions that are consistent with the priorities given in this Survey. **Only in the case where a new discovery changes the Survey's fundamental understanding should these priorities be reconsidered**, in which case the SSE Survey recommends that the National Research Council's Committee on Planetary and Lunar Exploration conduct

> a review to confirm or modify decadal survey recommendations and priorities for the New Frontiers flight program."

The Panel would consider addition of a new, uncompeted mission to the New Frontiers flight program line, especially ahead of the competitively selected New Frontiers 2 mission, to be a major change in the priorities of the SSE Survey. It is the opinion of the Panel that there has not been a discovery significant enough to change the recommendations and priorities of the SSE Survey, and that the expected scientific return does not presently justify a follow-on mission. However, because this opinion is by its nature subjective, and only a small group has been convened to consider this option, the Panel strongly endorses the recommendation of the SSE Survey in recommending that COMPLEX be engaged to review the relative priority of a follow-on New Horizons mission before it is undertaken by NASA.

The Panel notes that this mission requires the use of a GPHS RTG and a stock of plutonium. The long lead-time and difficulty of obtaining these for a New Horizons II mission underlines that Pu 238 and RTGs are a valuable commodity for the science community. Therefore, their use should be reserved for science with the highest possible return. A decision to use these should be considered carefully by the science community and high-level independent advisory boards such as COMPLEX.

Compete versus Non-Compete

In performing its feasibility study, the Panel was necessarily limited in the range of trades which could be considered. The Panel focused on the New Horizons mission as a cost and schedule baseline, given that it represented an equivalent type of mission and was contemporaneous.

In performing its feasibility study, the Panel also attempted to make schedule assumptions which, while achievable, would represent best-case results. The Panel assumed that a sole source contract could be in place by January 2006 (either a definitized contract or at least a letter contract allowing work to proceed), while a competitive contract could be in place by July 2006. These schedules are achievable, but both represent very aggressive schedules, and do not allow for such things as award protests, etc. Furthermore, as noted above, the competitive schedule did not include time for a two phase down selection. Including this time would add approximately three months to the estimated schedule. Accordingly, the Panel concluded that a competitive process would add 6-9 months to the award timeline compared to a sole source selection.

In reviewing the various mission cases, the Panel attempted to provide an earliest possible launch date for each case. As noted above, even under these conditions, launches prior to mid-2010 are not feasible due to RTG availability, and launch dates prior to 2011 are not considered viable due to the lack of schedule reserve. In most cases, the spacecraft was available well before the RTG. Only for the new design spacecraft case using a GPHS RTG (case 5a) was the spacecraft equally schedule limiting. Accordingly, the Panel concluded that sufficient schedule time exists to allow any of these cases to be competed, with little or no impact to the 2011 launch date. The Panel also notes that, because Jupiter gravity assists are available at approximately 13 month intervals, even a somewhat later date would still allow a New Horizons II mission to be accomplished, although with a slightly later data return date.

In the absence of compelling schedule concerns, the Panel recommends that any New Horizons II mission should be competed. The Panel notes that under a competitive procurement, a copy of the New Horizons spacecraft could still be bid; a competitive procurement would simply allow additional designs to be proposed. The Panel notes that there is some additional cost risk due to slightly higher inflation adjustments (due to later contract start), possible increased launch vehicle costs, and possible loss of key New Horizons personnel to other assignments, but believes that the potential benefits of allowing more designs to be proposed and considered offsets these concerns. Furthermore, competitive awards have been standard for the New Frontiers and Discovery programs, as well as other NASA programs. Finally, given the long development timeframe, the Panel notes that competition would allow consideration of other technologies which may provide cost or performance benefits, but which could not be considered due to the time limits of the feasibility study.

In light of these considerations, the Panel recommends that if a New Horizons II mission is selected, it should be competed.

Additional Considerations

Following presentation of the Final Report to NASA's SMD on April 1, 2005, the Panel was requested to address the following questions:

Should NASA refurbish the E5 RTG to have it available for a mission to launch in 2011 or 2012, and what would be the cost for such a refurbishment?

Should NASA complete a copy of the New Horizons spacecraft (without instruments) in the near-term, and offer it to the science community in a time certain to support a competition of a future mission?

The Panel responses follow.

Should NASA refurbish the E5 RTG to have it available for a mission to launch in 2011 or 2012, and what would be the cost for such a refurbishment?

The Panel reviewed the costs and schedule for both refurbishment of the existing E5 unit, and the cost for developing a new F9 unit. Lockheed Martin Space Systems (LMMS) was contacted for an updated cost and schedule estimate for both these cases.

LMMS indicated that refurbishment of the existing E5 converter could be accomplished in approximately 12 months, at a cost of $8M (refurbishment cost only). Following refurbishment, this unit would then have to be stored until fuel is available. As noted earlier, fuel availability would limit availability of a complete RTG until the 2010 timeframe. The total cost of a refurbished RTG, including fuel costs, is estimated at \$65M-\$75M.

LMMS also indicated that the cost for developing a new E9 RTG would be approximately \$25M and would require approximately three-and-a-half years. As with the refurbished unit, fuel availability would limit this unit's availability for flight to the 2010 timeframe. The total cost of a new F9 RTG, including fuel costs, is estimated at \$80M-\$90M.

As noted, a new GPHS RTG would not be available for launches prior to mid-2010 due to fuel availability. The new MMRTGs are expected to be available well in advance of this date. The MMRTGs are different in power capability and size from the GPHS RTG. In order to make use of a refurbished GPHS RTG, therefore, a spacecraft would need to be designed specifically for this RTG, and not for the newer MMRTGs. The Panel therefore concluded that refurbishment of the E5 unit would not provide significant benefit unless a corresponding decision was made to call for a spacecraft design built around a GPHS RTG. The Panel did not find a compelling case for making such a decision, and therefore does not recommend refurbishment of the E5 unit.

Should NASA complete a copy of the New Horizons spacecraft (without instruments) in the near-term, and offer it to the science community in a time certain to support a competition of a future mission?

This question assumed that the copy of the New Horizons spacecraft would be authorized in the very near term, thus allowing the present New Horizons team to build the second copy. This would improve the build efficiency by allowing the team that built the original unit also build the second copy, thus minimizing costs. The unit would then be available as Government Furnished Equipment (GFE) for a future mission.

To answer this question, the Panel first reviewed the Decadal Survey to determine what priority science missions the New Horizons spacecraft could address. The Decadal Survey identifies 13 prioritized missions, and 14 additional deferred high-priority missions.

The requirements for these 27 missions were then compared to the existing New Horizons capability. The Panel assumed that no modifications would be made to the spacecraft. The New Horizons spacecraft is designed for a fly-by mission, and thus has limited delta-V capability (less than 400 m/s). Because of this limited capability, the New Horizons spacecraft is not capable of being used for orbital missions, except possibly for asteroids or Trojan/Centaur objects. Furthermore, many of the Decadal Survey missions require elements such as landers or probes, and the New Horizons spacecraft is not designed to carry such objects. Accordingly, the Panel review concluded that the New Horizons spacecraft would be applicable to only two of the twenty-seven priority missions in the Decadal Survey: further exploration of the Pluto-Kuiper Belt, and a Trojan/Centaur Reconnaissance Flyby.

The Panel reviewed the actual costs to date for the New Horizons spacecraft, and then derived an estimated cost for another build. Based on the costs to date, the Panel estimates that a copy of the New Horizons spacecraft could be built for between approximately $68.4M to $90.8M, depending on the assumed build efficiency, etc. Thus, in the Panel's estimate, building a copy of the New Horizons spacecraft immediately following completion of the New Horizons mission could save up to approximately $22M in spacecraft costs.

The Panel also reviewed the actual New Horizons build timeline, and estimated that a copy of the New Horizons spacecraft could be built in approximately 18 months. Thus, assuming a New Horizons launch in January 2006, a copy of the New Horizons spacecraft could be available in July-August 2007. This schedule assumes that the spacecraft would undergo functional testing, but not environmental testing (acoustics, EMI/EMC and thermal cycling, in particular). If environmental testing was desired prior to long-term storage, a few additional months would be required, depending on the extent of testing required.

The Panel notes, however, that the New Horizons spacecraft requires a GPHS RTG, and, as noted, no such RTG will be available for a mission prior to mid-2010. Thus, the copy of the New Horizons spacecraft would only be useful as GFE for missions launching in the post-June 2010 timeframe, and it would require a concurrent decision to refurbish the E5 unit or build a new GPHS RTG for this future mission. Furthermore, while building a copy of the spacecraft at this time would save significantly on spacecraft costs, it would also necessarily restrict any future instrument designs to the same electrical and mechanical interfaces as the present New Horizons instrument suite, thus potentially reducing the instrument selections which might be offered in response to the future AO. In addition, GFE the spacecraft for a mid-2010 mission would prevent incorporating potential new technologies into the spacecraft and/or instrument interface designs. Finally, as noted, the New Horizons spacecraft is only applicable for a limited set of high priority missions. One of these missions is a duplicate of New Horizons, which has already been discussed extensively above; the other is a Trojan/Centaur mission, which was deferred from active prioritization in the Decadal report.

In light of these considerations, the Panel does not recommend that a copy of the New Horizons spacecraft be built.

APPENDIX A

PANEL MEMBERSHIP

Panel Members:

Mr. Kenneth Anderson – Goddard Space Flight Center/Chair
Dr. David Bearden – The Aerospace Corporation
Mr. Robert Bitten – The Aerospace Corporation
Dr. Francesco Bordi – The Aerospace Corporation
Dr. Anita Cochran – University of Texas at Austin
Mr. Allan Cohen – The Aerospace Corporation
Dr. Frank Donivan – The Aerospace Corporation
Mr. Leonard Dudzinski – NASA HeadquartersC
Mr. Timothy Frazier – Department of Energy
Mr. Eric Mahr - The Aerospace Corporation
Dr. Melissa McGrath – Marshall Space Flight Center
Mr. Paul Van Damme – NASA Headquarters/JPL

Supporting:

Ms. Debra Emmons – The Aerospace Corporation

Appendix B

ACRONYMS LIST

AO	Announcement of Opportunity
AU	Astronomical Units
CDR	Critical Design Review
COMPLEX	Committee on Planetary and Lunar Exploration
DOD	Department of Defense
DOE	Department of Energy
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
FSAR	Final Safety Assessment Report
GFE	Government Furnished Equipment
GPHS RTG	General Purpose Heat Source Radioisotope Thermoelectric Generator
INSRP	Interagency Nuclear Safety Review Panel
JPL	Jet Propulsion Laboratory
KBO	Kuiper Belt Object
KSC	Kennedy Space Center
LMMS	Lockheed Martin Space Systems
LORRI	Long Range Reconnaissance Imager
MMRTG	Multi-Mission Radioisotope Thermoelectric Generator
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
OSTP	Office of Science and Technology Policy
PDR	Preliminary Design Review
PSAR	Preliminary Safety Assessment Report
RPS	Radioisotope Power System
RTG	Radioisotope Thermoelectric Generator
SAR	Safety Assessment Report
SER	Safety Evaluation Report
SMD	Science Mission Directorate
SRG	Stirling Radioisotope Generator
USAR	Updated Safety Assessment Report

Appendix C

Below are detailed task duration reduction assumptions made for the competed mission, and spacecraft clone cases with and without Star-48 for both NEPA and Presidential nuclear safety launch approval compliance.

NEPA Schedule For Competed Mission Using RPS

Task duration reduction assumptions for this schedule included allowing:

- 165 days for the KSC EIS Databook development. The Databook would need to start development in October 2005 to support the earliest possible Record of Decision.
- 165 days instead of the standard 270 days for development, review, and iteration of the DOE EIS Risk Assessment. Present activities suggest the potential Mars Science Laboratory (MSL) EIS Risk Assessment conceivably could take only about 70 days to develop. Therefore, an assumption of 165 days attempts to bound the uncertainty for this task duration.

NEPA Schedule For Clone Spacecraft on Atlas 551 with Star-48.

Task duration reduction assumptions for this schedule included allowing:

- 135 days instead of the standard 270 days for the KSC EIS draft Databook development, review, and iteration. It was assumed that 90 days were needed for updates to launch vehicle information, time for document preparation, and internal reviews. Additionally, an EIS is required to use the best available information so there could be information gleaned during the New Horizons Presidential Nuclear Safety Review Process that would need to be considered for in the New Horizons II EIS Databook.
- 135 days instead of the standard 270 days for development, review, and iteration of the DOE Risk Assessment. Though there is relevant information (e.g., models) from New Horizons experience, work would still be required to tailor the assessment to launch period and launch times for New Horizons II and any updates made to the EIS Databook. Additionally, an EIS is required to use the best available information so there could be information gleaned during the New Horizons Presidential Nuclear Safety Review Process that would need to be considered for in the New Horizons II EIS Risk Assessment. Also, time is needed to put the documentation together and conduct internal reviews to ensure completeness and accuracy.

NEPA Schedule For Clone Spacecraft on Atlas 551 without Star-48.

Task duration reduction assumptions for this schedule included allowing:

- 155 days instead of the standard 270 days for the KSC EIS Databook development, review, and iteration. It was assumed that 110 days (about one month more than if flying clone with Star-48) were needed for updates to launch vehicle information (e.g., elimination of Star-48 changes hardware on-board and FTS design), time for document preparation, and internal reviews.
- 155 days (about one month longer than clone with Star-48) instead of the standard 270 days for development, review, and iteration of the DOE Risk Assessment. Though there is relevant information (e.g., models) from New Horizons experience, work would still be required to tailor the assessment to launch period and launch times for New Horizons II and any updates made to the EIS Databook. Additionally, an EIS is required to use the best available information so there could be information gleaned during the New Horizons Presidential Nuclear Safety Review Process that would need to be considered for in the New Horizons II EIS Risk Assessment. Also, time is needed to put the documentation together and conduct internal reviews to ensure completeness and accuracy.

Presidential nuclear safety launch approval schedule for a spacecraft clone on an Atlas 551 with Star-48.

Task duration reduction assumptions for this schedule included allowing:

- 30 days instead of the standard 140 days for the acquisition and development of launch vehicle input. It was assumed that 30 days were needed for updates to launch vehicle information (e.g., relevant information from recent flights, consideration of New Horizons INSRP comments) that was documented for New Horizons, time for document preparation, and internal reviews.
- 60 days instead of the standard 180 days for accident environment updates. Given similarity to New Horizons time would only be needed for updates and consideration of significant new information (e.g., relevant New Horizons INSRP comments, new test data), document preparation and internal reviews.
- 60 days instead of the standard 160 days for development of the KSC draft Launch Vehicle Databook. The Databook should essentially be the same as that produced for New Horizons except for any needed updates due to changes in the launch vehicle input and accident environment updates. Additionally, changes due to relevant New Horizons INSRP comments would need to be considered.
- 30 days instead of the standard 45 days for draft Launch Vehicle Databook external review since there would be familiarity with large portions of the information given recent experience with New Horizons.
- 45 days instead of the standard 75 days for final Launch Vehicle Databook development due to recent experience with New Horizons databook development. Still time is needed for addressing external comments on updated information and for document preparation and final internal reviews.
- 0 days instead of the standard 229 days for Preliminary SAR development and INSRP review since there is no need for such a document given New Horizons II is a spacecraft clone of New Horizons and is being launched on the same launch

vehicle system. It is reasonable for DOE to only produce a draft Final SAR and a Final SAR.

- 135 days instead of the standard 180 days for draft Final SAR development. Though a lot of information from New Horizons would be applicable, changes due to SAR Databook updates, differences in launch periods and launch times, consideration of any relevant New Horizons INSRP comments, documentation preparation and internal reviews to ensure quality would result in a need for about six months of work.
- 135 days instead of the standard 180 for Final SAR development. Given familiarity with New Horizons 1 experience some reduction should be possible but given the great quantity of information contained in a SAR and a need to allow for time to give full consideration to comments on the draft (e.g., from the New Horizons II INSRP) six months is required for this task.
- 200 days instead of the standard 260 for the SER development by the New Horizons II INSRP. Given potential familiarity with New Horizons a reduction from one year to nine months was assumed.

Presidential nuclear safety launch approval schedule for a spacecraft clone on an Atlas 551 without Star-48.

Task duration reduction assumptions for this schedule included allowing:

- 70 days instead of the standard 140 days for the acquisition and development of launch vehicle input. It was assumed that 70 days were needed for updates to launch vehicle information (e.g., changes to FTS, relevant information from recent flights, consideration of New Horizons INSRP comments) that was documented for New Horizons, time for document preparation, and internal reviews.
- 60 days instead of the standard 180 days for accident environment updates. Given similarity to New Horizons time would only be needed for updates and consideration of significant new information (e.g., hardware changes due to removal of Star-48, relevant New Horizons INSRP comments, new test data), document preparation and internal reviews.
- 80 days instead of the standard 160 days for development of the KSC draft Launch Vehicle Databook. The Databook should essentially be the same as that produced for New Horizons except for hardware changes and FTS differences, and any additional needed updates due to changes in the launch vehicle input and accident environment updates. Additionally, changes due to relevant New Horizons INSRP comments would need to be considered.
- 0 days instead of the standard 229 days for Preliminary SAR development and INSRP review since there is no need for such a document given New Horizons II is a spacecraft clone of New Horizons and is being launched on a very similar launch vehicle system (i.e., only meaningful difference assumed is no Star-48). It is reasonable for DOE to only produce a draft Final SAR and a Final SAR.

- 200 days instead of the standard 260 for the SER development by the New Horizons II INSRP. Given potential familiarity with New Horizons a reduction from one year to nine months was assumed.

This schedule assumes the full standard time (i.e., 180 days) for DOE development of the draft Final SAR and FSAR. Granted there is some relevant information (e.g., models) from New Horizons that is applicable to New Horizons II, but significant work would still be required since analysis is dependent on launch period and launch times and significant changes made in SAR Databook (e.g., removal of Star-48 and changes to FTS). Additionally, information gleaned during the New Horizons Presidential Nuclear Safety Review Process would need to be considered. These factors in combination with the minimum times required to put the document together and conduct internal reviews, suggested that the Standard development time for the task should be assumed.