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March 19, 2010

The Honorable Gabrielle Giffords
Chairwoman
Subcommittee on Space and Aeronautics
Committee on Science and Technology
2320 Rayburn House Office Building
Washington, DC 20515

Dear Madam Chairwoman,

The Aerospace Corporation is pleased to submit responses to questions from the Committee on Science and Technology regarding our support to the Review of U.S. Human Space Flight Plans Committee (the Committee.)

Your letter requested responses related to our analyses performed in support of the Committee, and we have answered in that context. In several areas of questioning, the Committee did not task Aerospace. In some areas, Aerospace has previously performed related studies or analyses for NASA. We are always available to discuss these studies with the committee if desired.

The Committee hired Aerospace to provide technical analyses as directed. We were participants in committee activities only when receiving tasks, discussing ongoing analyses and delivering our products to the Committee. We acknowledge that the Committee received information not known to Aerospace.

Several questions inquire about dates, schedules and costs, and specifically which Committee member directed Aerospace in these matters. The Committee designated Mr. Bo Bejmuk and Dr. Ed Crawley as the two liaisons between the Committee and Aerospace. All tasking was received and executed within this framework. We respond in more detail to specific questions in our responses.

We respectfully submit our responses to the committee. We stand ready to assist the committee in any way possible as you work toward developing the way ahead for NASA.

Sincerely,

Responses to

The Committee on Science and Technology

Provided by

The Aerospace Corporation

March 19, 2010

Question 1. The report of the Review of U.S. Human Spaceflight Plans Committee ["Augustine report"] states on page 70 that the Committee estimated that the design, development, test, and evaluation (DDT&E) cost to NASA is $3 billion for a program involving two commercial crew competitors and a NASA-provided "suitable version of an existing booster with a demonstrated track record of successful flight." It then goes on to say that "After multiplying by the historical growth factors and other multipliers associated with 65 percent confidence estimating (as will be discussed in Section 6.3), the cost carried in the Committee's final estimate of the cost of the program to NASA is about $5 billion"

a. The validity of the Committee's "final estimate" of $5 billion for commercial crew that was developed by applying historical growth factors and other multipliers to the $3 billion estimate is clearly greatly dependent on the reasonableness of the underlying $3 billion cost estimate to which the correction factors are applied. What was the source of the $3 billion estimate? Did it include all ground support/infrastructure costs? Did Aerospace independently develop or examine the basis for the $3 billion initial estimate for two commercial crew competitors and "suitable version of an existing booster with a demonstrated track record of successful flight"? If not, from where did Aerospace get the cost estimate? If it was from the Augustine panel, who on the panel directed Aerospace to use the $3 billion cost estimate in its subsequent analyses?

The Aerospace Corporation ("Aerospace") realizes there is considerable discussion around the "$3 billion" figure for a commercial transport capability, and we appreciate you inquiring about our role and perspective. As stated in the question, the Review of U.S. Spaceflight Plans Committee ("the Committee") stated on page 70 their assumption that "NASA should make available to bidders a suitable version of an existing booster with a demonstrated track record of successful flight, adding to the program cost."

Importantly, the Committee also stated on page 70 "The Committee then estimated the cost to NASA of creating an incentive for industry to develop the commercial crew transport capability for crew. This would probably be a significant fraction, but not the entirety of the cost of such a development."

This is the guidance the Committee gave to Aerospace: $3 billion would be carried in our affordability analyses as NASA's portion of the development. Aerospace did not independently develop the basis for the $3B initial estimate. The Committee did not ask Aerospace to independently verify the $3 billion figure. In fact, no verification could be performed given the Committee's statement that this dollar amount was simply NASA's portion of the total cost. Our role, as explicitly outlined in our task statement, was in some cases to develop our own estimates for certain elements where we were asked and qualified to perform the estimate, and in other cases to accept numbers from the Committee itself and/or the NASA analysis team. No traditional independent cost or independent schedule estimates were performed. Aerospace was not privy to all of the background material on the cost of commercially provided services which was provided in closed fact finding sessions to the Committee. In each case, we would seek to understand what was included in the estimate to assure there were no gross omissions or "double booking" and to uniformly apply historical cost growth factors to the NASA portions.

Specifically, the Committee's direction to Aerospace was that the $3 billion figure would include development of the capsule and launch abort system. An additional $400M, including $200M

(FY09) for a demonstrator flight and $200M (FY09) was allocated for minor modifications and integration to an existing launch vehicle with a demonstrated record of successful flight.

To our knowledge, this $3B estimate did not include all ground support/infrastructure costs. However, it was acknowledged by the Committee that these costs would be contractor/concept specific, and might be covered by other budget wedges present within a given integrated option affordability analysis. Also, facilities might be modified or made available to commercial contractors as part of a transition budget line, and then amortized across some number of flights during commercial operation. After including the $400M described above for a total estimate of $3.4M, Aerospace applied historical cost growth in the same manner as applied to other NASA developments. The Committee's final estimate of the cost of the program to NASA was approximately $5 billion. It was assumed that additional private investment funding would be required to complete the DDT&E.

As Aerospace developed and refined our affordability analyses of various Committee options, the Committee formed a working group of four members: Dr. Crawley, Dr. Ride, Mr. Bejmuk and Mr. Greason. This working group performed fact finding which provided specific assumptions and ground rules for our affordability analyses. Direction to use the $3 billion figure came to us from Dr. Crawley, who was the lead for the working group; however, the figure was consistently reiterated by all members of the working group when Aerospace interacted with them during the course of our analyses.

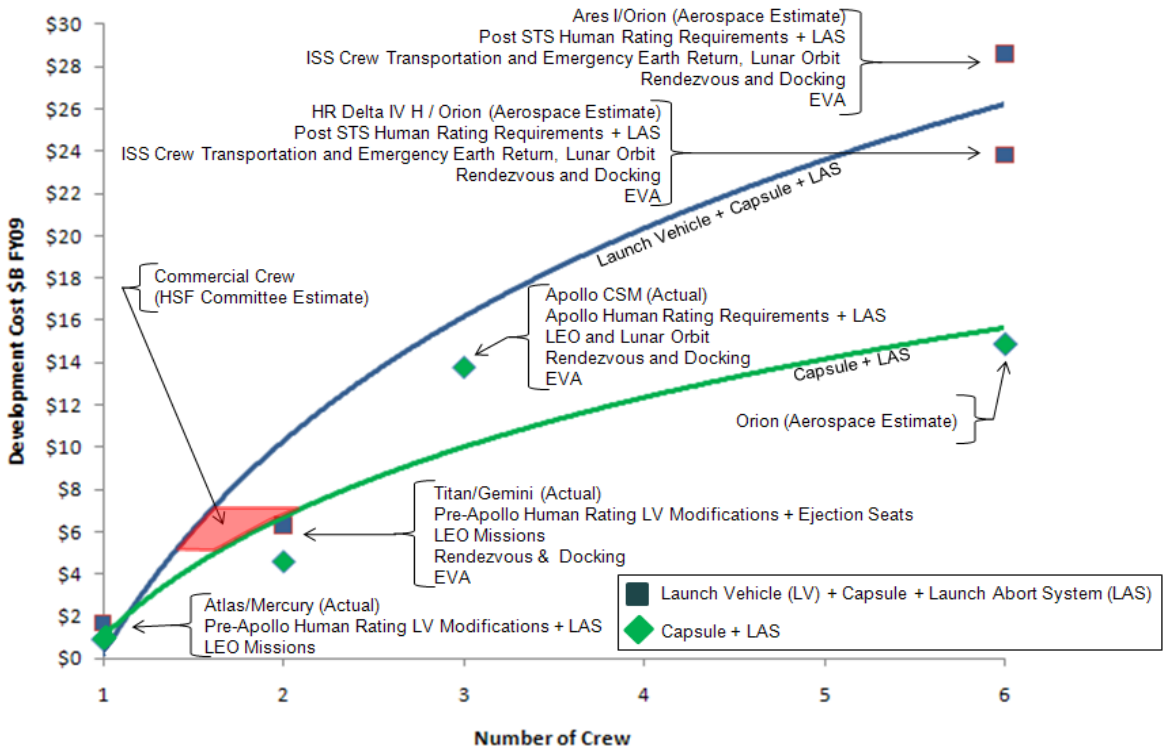
b. The Augustine report states on page 71 that "The Committee considered other factors that would support this estimate of the incentive cost to NASA. If this is to be a commercial venture, at least some commercial capital must be at risk. Alternate sources of capital, including private and corporate investment, would be expected." What was the percentage of the commercial crew development cost that was assumed to be paid for with non-government funds? Did Aerospace independently determine or validate that percentage? If not, what was the source of the percentage, and what is Aerospace's level of confidence in that percentage estimate?

The Committee assumed alternate sources of capital would be expected for the commercial crew development. While we engaged in detailed discussions about the $3 billion figure to be included in our affordability analyses, we did not receive any information about the Committee's view of the percentage required from alternate sources. It is possible the Committee received inputs from other sources not involving Aerospace's analyses. Aerospace is currently performing a business case analysis to address this key issue; however, that work is not yet complete.

c. Has Aerospace done any analyses to try to estimate the DDT&E cost of a commercial crew transport system? If so, what is the range of costs that Aerospace has come up with at the 65% confidence level for one or more such systems?

Aerospace has not performed a thorough, independent analysis to estimate the DDT&E cost of a commercial crew transport system. Aerospace did perform a comparison of the Committee cost estimate for the commercial crew system to historical programs as a cross-check on the existence of such a system in this cost range. The figure below shows actual and estimated development cost as a function of crew size for a range of capsule-based crew vehicles and launch vehicles, including Mercury, Gemini, the Apollo Command and Service Module (CSM),

Orion, Ares I/Orion, and Human Rated Delta IV H / Orion [Note: some of these specific examples for which Aerospace developed estimates will be discussed in later sections]. The lower curve (green) illustrates the cost per crew for the capsule and launch abort system (LAS) only. The upper curve (blue) includes the development cost of the launch vehicle. In the case of Mercury, Gemini, and Delta IV H, the launch vehicle costs are for modifications to existing vehicles to meet the definition for human rating in the era in which they were developed. The estimates for Delta IV H, Ares I, and Orion are for a 65th percentile confidence. In general, as the number of crew increases, the systems become more capable in terms of the degree of human rating, mission performance, and other critical capabilities such as rendezvous and docking and Extravehicular Activity (EVA).



For the purposes of illustration, the range of development costs associated with a commercial crew system is assumed to start at the $5B NASA contribution used by the Committee, and extend upward with an assumed commercial investment in these systems. The use of those resources, and a government acquisition approach from the Mercury–Gemini era, suggests that a single transportation system can be developed to transport a crew size of 1-2 to low Earth orbit (LEO). Gemini is the closest historical program to the commercial crew capsule. While we have chosen to plot development cost vs. crew size, the complexity of the system is a function of human-rating requirements, destination and capability including rendezvous and docking, EVA, etc. We would therefore caution against assuming that a 4-crew capsule would necessarily cost in excess of $12B as these other factors would come into play.

The Committee assumed that two commercial crew systems could be developed (starting with three competitors and down-selecting to two successful developments), within this range of resources, using modern commercial acquisition practices.

d. What would be the likely impact of using the range of costs identified in (c) on the options contained in the Augustine report that assume the use of commercial crew transport services to low Earth orbit? What would be the impact on the costs and timetables associated with those options?

As Aerospace developed our affordability options, we consistently stated that detailed assessments, estimates, and analyses would be required prior to implementing any new option. We also made these same points in our public presentations. However, the Committee did not ask us to determine likely impacts of identified costs and schedules for the commercial crew concept.

The Committee provided an estimated date of 2016 when a commercial crew capability would become available. If this capability were not available by this date, the backup plan was to continue to procure Russian Soyuz's until the commercial crew capability became available. The commercial crew concept relied on private investment to complete DDT&E and amortize fixed costs during operations to meet a price target. Other Orion-based architectures would not involve cost sharing arrangements, and as a government developed, owned and operated system, the government would incur the full burden of cost growth based on historical factors.

e. Has Aerospace performed any assessment or analysis of the total DDT&E cost of a human-rated EELV architecture, including the impact of Ares I close-out costs? If so, what did Aerospace determine the cost to be? Does that include the cost of a dedicated EELV launch pad and other ground support infrastructure, or is it assumed that an existing launch pad will be shared between commercial crew operations and national security/civil launch operations?

In a series of studies performed for NASA that predate the Augustine Committee, Aerospace developed DDT&E costs and lifecycle cost estimates for several human-rated (HR) Delta IV H launch vehicle configurations. Delta IV H was representative of a general class of human-rated Evolved Expendable Launch Vehicle (EELV) launch vehicles. Aerospace was asked to estimate costs to substitute an EELV for Ares I within an Ares I/Ares V architecture. The fact that Ares V was the envisioned end state levied constraints on what options could be considered. Depending on the configuration, DDT&E costs to human rate the Delta IV H range from approximately $5B FY09 to approximately $9B FY09, (65th percentile confidence) not including ground infrastructure development (either new or modified existing) costs. Ground infrastructure development costs were estimated at approximately $2.3B FY09. Aerospace estimated the Ares I contract close-out and contract transition costs to be approximately 0.3 $B FY09. These estimates assumed a conservative interpretation of NASA's human-rating requirements in order to be comparable to Ares I. Furthermore, the launch vehicle and upper stage were sized to lift the fully capable Orion and make maximum use of existing NASA developments including upper stage, test facilities, and Orion avionics. The launch vehicle itself was modified to increase redundancy and margins.

These assumptions are not on a par with what the Committee assumed for "commercial crew" in terms of performance and capability. Most importantly, the Committee assumed the utilization of an existing launch vehicle with flight performance history, whereas the Aerospace EELV studies assumed the launch vehicle would be modified, and a new or modified upper stage would be built.

None of the options examined assumed that an existing launch pad would be shared between commercial crew operations and national security/civil launch operations. It was assumed that EELV would leverage the existing launch pad infrastructure planned for Ares I.

f. In the absence of program management milestones that are used to track development progress and costs, did Aerospace assume proxy activities would be used by NASA to track DDT&E progress by potential commercial crew transportation service providers? What were these proxy activities and was the cost of implementing them by NASA included?

For the commercial crew transportation services, it was assumed that the COTS A-C activities and milestones were accomplished, and the resultant operational capabilities would be realized as currently planned by NASA. The Committee assumed a one-time $200M investment from NASA to augment the COTS A-C development activities. The commercial crew activities were assumed to be initiated with COTS-D as an open competition that would draw in not only the contractors performing COTS A-C but larger, established aerospace industry contractors. Aerospace made no assumptions regarding program management milestones or proxy activities.

g. What did the analyses in the Augustine report assume would be the per seat cost and price for the commercial crew transport services included in the options? What was the source of the per-seat cost and price estimates?

The Committee provided the commercial crew transport service assumptions that assumed a price of $200M FY09 per flight at a rate of 2 flights per year. Using a historical cost growth factor for operational systems, Aerospace increased the cost per flight to $250M FY09. The Committee did not define the crew capacity of the commercial crew vehicle. Based on the 2 Gemini-class crew module discussed above (see question 1c.), the cost per seat would be on the order of $125M FY09 but would vary with crew size.

h. What size non-NASA market and what non-NASA flight rate were assumed in the per-seat cost and price estimates and resulting cost to the government, and what was the basis of the non-NASA market size and flight rate estimates? Did Aerospace make use of market projections, and if so, who provided those market projections?

Aerospace was not privy to non-NASA market information the Committee might have received other than what was presented in public sessions. We did not see or review any market projections or flight rate estimates during our support of the Committee. To our knowledge, the Committee received testimony from prospective customers that there is a market for commercial crew transportation to LEO for non-NASA purposes if the price is low enough and safety robust enough. The Committee also received testimony from prospective providers that it is technically possible to provide a commercially viable price on a marginal cost basis, given a developed system.

i. How many competing commercial crew transport systems were assumed to be supported/used in parallel by the government in the options costed by the Augustine panel?

For estimating purposes, the Committee assumed that three contracts were initiated, and one competitor subsequently dropped out.

j. In the Augustine report, what was the total annual cost [from development phase through steady-state operations phase] to the government of the commercial crew transport services included in the options, and what was the source of that cost estimate? Did Aerospace independently validate that cost estimate?

Many of the integrated options incorporated a commercial crew to LEO capability. The Committee defined the NASA costs for the commercial crew transport service to be $3B FY09 DDT&E, with some unspecified amount of private investment to supplement DDT&E and/or ground infrastructure development, along with a $200M FY09 per launch cost. Using historical cost growth factors, Aerospace increased the $3B to approximately $5B, and the $400M per year for operations to the International Space Station was increased to $500M (2 launches).

The total annual cost to the government for commercial crew was based on the affordability analysis on the integrated options provided by the Committee. The $5B allocated for development was spread over 5 years with approximately $1.5B in the peak funding year. The total annual cost during operations was $0.5B per year for two flights per year.

As we stated in our response to question 1c, Aerospace did not independently validate the Committee cost estimate, as our operating parameters stated that other sources of capital would be available to the commercial providers. We did, however, perform a comparison of the Committee cost estimate for the commercial crew system to historical programs as an existence proof of the potential for a system in this cost range.

k. What characteristics were assumed for the commercial crew transport services included in the options—e.g., how many seats for U.S. astronauts per vehicle, how many flights per year, were the flights carrying NASA astronauts dedicated solely to government crew transfer operations, were the vehicles assumed to be reusable or not, and were the vehicles assumed to meet the International Space Station crew rescue stay-time and performance requirements? What infrastructure was assumed to be provided/maintained by the government?

The Committee provided the commercial crew transport service assumption of a rate of 2 flights per year. Explicit assumptions of reusability were not provided. There was no assumption made whether the crew capsule was reusable.

The capsule described by the Committee is a crew “taxi.” It takes a crew up to the International Space Station (ISS), or other LEO destinations, and potentially a different crew down to Earth. It is not required to provide long on-orbit storage, leave the LEO environment, provide the higher lift to drag (L/D) ratio needed for superorbital reentry (e.g., lunar return), provide habitat volume,

or provide other accommodations for long duration missions. It would have an on-orbit life independent of the ISS of days to weeks, but potentially be storable at the ISS for months. Other characteristics of the commercial crew transport services envisioned by the Committee such as the manner in which crew were manifested on flights, performance requirements, and infrastructure assumptions were not known to Aerospace.

We operated with the assumption that the "crew taxi" would have the capability to ferry 2-4 astronauts to/from ISS. The uncertainty in number of crew was to allow the maximum number of launch vehicle/capsule combinations to be considered, and not preclude offers at different price and capability points. There was no assumption provided regarding commercial pilots relative to civil servant passengers. The vehicle would fly twice per year at the $200M FY09 per vehicle ($250M with cost growth factor applied) for a total of $500M per year. If the number of seats was on the low end of the range (i.e., 2 crew instead of 4), this would clearly have implications for the number of vehicles that would be required to meet a static requirement and might require more frequent flights of a smaller (but perhaps less costly vehicle).

Question 2. On page 71, the Augustine report states that "a [commercial crew] capability in 2016 could be estimated with reasonable confidence." Was that schedule estimate independently developed or validated by Aerospace or was Aerospace simply directed to use it in subsequent analyses? If the latter, who was the source of the estimate and what was the basis of the estimate?

The Committee provided the schedule estimate for the commercial crew scenario as an input assumption, which was then used for the subsequent affordability analyses. As Aerospace developed and refined our affordability analyses of various Committee options, the Committee formed a working group, that performed fact finding and provided specific assumptions and ground rules for our affordability analyses. Dr. Crawley, as the lead of the working group, gave this information to Aerospace. Estimates to the Committee from providers ranged from three years to five years. This produced a start in early FY2011, assuming a year for program realignment.

Aerospace did not independently develop or verify the schedule estimate for the commercial crew capability.

Question 3. Has Aerospace performed any analysis or assessment of the length of time it would take to develop, demonstrate, and contract for an operational commercial crew transport service for use by U.S. government astronauts? If so, what was the result of that assessment? What would be the impact of using that schedule estimate in the analysis of the options included in the Augustine report?

Aerospace has not performed any analysis or assessment of the length of time it would take to develop, demonstrate, and contract for an operational commercial crew transport service. Aerospace examined the development time associated with human rating the Delta IV H launch vehicle and ground system. In that case, the ground processing and launch infrastructure was the critical path item with a 5-7 year development period, but the human rating modifications for the launch vehicle were close behind. If initiated this year, these estimates are consistent with an operational ground processing and launch infrastructure for commercial crew in the 2016 time frame.

Question 4. What are the acquisition-related steps that would need to be followed by the government in the development and procurement of as-yet-to-be-developed commercial crew transport services, e.g., development of a COTS-like demonstration program; COTS RFP preparation and release; competition for COTS awards; negotiation of COTS agreements; DDT&E phase; demonstration phase; RFP preparation and release for commercial crew transport contracts; contract competition, award, negotiation, potential protest resolution, etc.; and certification for operations involving U.S. astronauts before commencing commercial crew transport services to the International Space Station? Historically, how long has it taken to complete such acquisition steps in the development of new aerospace systems to be used by the government?

This is a critical question. While we raised these questions in the development of our work for the Committee, we were not tasked to develop this analysis. Subsequent to the release of the Committee Report, we have met with the NASA Administrator and key staff to discuss these issues. To our knowledge, NASA is currently evaluating these steps. Based on Aerospace's prior experiences on a wide range of government acquisition activities, the acquisition-related steps are numerous, and include such steps as described in the Question 4 above. These steps typically take on the order of many months.

Question 5. What role did Aerospace play in the development and analysis of the options contained in the Augustine report? For example, did Aerospace develop all of the assumptions and input data for the different options or were there circumstances under which you were directed to use specific input data or assumptions by members of the Augustine panel? If the latter, what specific input data or assumptions was Aerospace directed to use by panel members and in each case who directed you to use them? Did Aerospace independently validate those input data or assumptions?

Aerospace had no role in the development of Committee options, nor were we present when they were developed. The Committee passed new options to us for affordability analyses as they developed them. A large and diverse NASA and Aerospace team supported the discussions of the ground rules and assumptions for each of the options.

The input data for the options came from a variety of sources. Costs for the various elements were generated by combining data from the Constellation Program (PMR09 and PMR08 Rev1B data) with analogies and additional NASA or Aerospace data sources, when available, to inform the cost data and assumptions for systems that deviated substantially from the Constellation Program.

Our role was to integrate inputs from multiple sources and assure consistent treatment of all elements throughout the assessment process. Aerospace evaluated the manifest for a given integrated option architecture to assure that the number, type, phasing, and size of vehicles were appropriate for the stated mission objectives and destinations. Costs for government-developed systems were benchmarked against data that Aerospace and/or the NASA analysis team had access to. Aerospace used analysis products from studies performed to answer earlier Committee questions on the Constellation Program, International Space Station (ISS), and launch vehicle concepts to cross-check the Committee inputs. The EELV human-rating studies, which pre-date the Augustine Committee, were used as appropriate to estimate EELV-based architectures and capture infrastructure and industrial base maintenance costs. NASA estimated shut down and transition costs were included as appropriate.

Question 6. What is required to be able to proceed to carry out any of the options included in the Augustine report with a high confidence level understanding of its cost and schedule? Given the time and resource constraints that Aerospace faced, what is the difference between what Aerospace did to support the development of the options and what is needed for a high confidence level understanding of the cost and schedule of each option?

As stated previously in this response, to the Committee, in public, and to the NASA Administrator, the only appropriate forward path is to develop detailed program baselines. These include detailed schedules, program baseline cost estimates, independent cost estimates, and comprehensive discussions with potential vendors. This is the normal approach Aerospace takes and the process requires several months after a program baseline is developed.

Our work in support of the Committee was at a higher, more general level. The Committee repeatedly stressed to Aerospace that we were not directed to develop executable baselines, schedules, and costs. Rather, we were to treat various options as consistently as possible to allow the Committee to develop top level findings, such as an assessment of the technical risk posture for Constellation as currently being performed, budget availability to execute the program of record, and general availability dates for other options (some of which had not entered the design phase). We realize the tendency to treat Aerospace's work as executable baselines. While we stand solidly behind the work we did for the Committee, it is important to reiterate what we were asked to accomplish.

Given the schedule constraints on the Committee, Aerospace performed cost and schedule analyses at the appropriate level to address the high-level questions posed within the compressed timelines. Certainly, with more time and resources, analyses with greater fidelity could have been performed. However, Aerospace did not determine the time and resources required to provide more detailed cost and schedule analyses of each option.

Question 7. How was the confidence gained from actual progress in completing DDT&E activities factored into Aerospace's cost and schedule estimates for options incorporating the program of record?

Aerospace built cost baselines for each of the scenarios that incorporated data from a variety of sources, including NASA-supplied data, estimates generated by Aerospace, and assumptions defined by the Committee members. Historical mean cost growth factors based on actual historical performance of 77 NASA system developments were derived. These factors were applied consistently and appropriately across the options, taking into account systems already in development, such as Constellation, versus concepts in earlier stages of development. Credit for cost growth already incurred is applied to Constellation program elements that are underway. In contrast, the historical cost growth factor is applied in full for projects not yet initiated.

Question 8. How long did Aerospace have to carry out the cost estimation and schedule analyses for each of the options considered by the Augustine panel? What caveats, if any, would Aerospace apply to the results of its analyses?

Aerospace's team supported the Committee on a compressed timeline when evaluating the affordability of integrated options. The full set of options evaluated included, but were not limited to, the Constellation Program and other architectures that targeted various beyond LEO destinations, including: lunar surface, Near Earth Objects (NEOs), Lagrange points, and others. These cases were analyzed over the course of several weeks.

The framework for the affordability analysis was assembled from existing software, databases and algorithms over the course of a couple of months. It benefited from several years of Aerospace and NASA investment. Once the framework was established and validated, the affordability analyses for each of the integrated options provided by the Committee were performed on short timelines, typically a few days. In order to compare in-development systems with "paper concepts," a uniform affordability analysis methodology, informed with historical cost growth data, was applied to each option. Our direction from the Committee was to focus on capturing the macro-level issues versus delving into substantial detail on various systems.

As previously stated, our only caveat was that these analyses were directed and developed to be used as guideposts for comparison among options. We do not claim them to be traditional independent analyses of all the elements of each program.

Question 9. Did Aerospace perform an Independent Cost Estimate (ICE) or Independent Schedule Estimate (ISE) for the Constellation program or its major elements? What would be required to do an ICE and ISE, and how long does Aerospace estimate it would take to complete them?

Aerospace did not perform a traditional parametric or grass-roots Independent Cost Estimate (ICE) or Independent Schedule Estimate (ISE) for the Constellation Program or its major elements. In order to perform an ICE/ISE for the Constellation Program or its major elements, Aerospace would require technical, design and programmatic data depending upon the phase of the project. The required elements for an ICE/ISE include: design description documents, project Work Breakdown Structure (WBS) definitions and descriptions, Master Equipment Lists (MEL) containing mass, a description of power modes by subsystem, a block diagram of launch vehicle and capsule (or other elements), descriptions of the launch vehicle and capsule subsystem including heritage, lists of hardware suppliers, and an Integrated Master Schedule with major development milestones.

Based on past experience that includes ICE assessments of elements of the Constellation Program such as Ares V and Altair, an ICE/ISE of the Program or its major elements would typically be a multi-month (~3 to 6 month) process. A traditional ICE/ISE also includes a project and/or program level reconciliation. Aerospace was tasked to perform a high-level schedule assessment of Constellation, which found that there was a potential 3-4 year impact to the Orion / Ares I Initial Operational Capability (IOC) milestone due to the effects of the FY10 budget reduction, technical cost-risks, and ISS extension to 2020.

Question 10. What would be required to do an ICE and ISE for a proposed commercial crew transport system, and how long does Aerospace estimate it would take to complete them?

The data and timeline required to perform an ICE/ISE for a proposed commercial crew transport system depends on the level of maturity of the systems and the technical and programmatic

data available for the assessment. For systems early in their development lifecycle or with a limited amount of available data, the time required to perform these analysis may be less than estimated in Question 9, but may have a higher level of uncertainty in the results. For more mature designs, with a larger set of technical and programmatic data, the time to conduct a complete analysis may be similar to those required to perform an ICE/ISE for the Constellation Program and its major elements (please see Question 9).