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SPACE TRANSPORTATION AT CROSSROADS – AN EVOLUTIONARY FUTURE

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ABSTRACT:
Space transportation is at a crossroads; the current path doesn't provide for maturing advanced more efficient technologies to be used in the next generation space transportation system. Using the same technologies and process isn't likely to provide an affordable/sustainable system. An alternate path (which we have named, ***An Evolutionary Future***), should provide a greater opportunity that leads to the establishment of routine access to space. This alternate approach is established on the evolutionary use of existing assets while operating within existing budgets in order to achieve the greatest gain with rapidly dwindling resources. This paper will examine several NASA resources, including budgets, and propose how they may be modified to achieve the Evolutionary Future.

PREFACE:
The US Space Program should consider stepping back and re-assessing its direction. The country is risking its prestigious position as number one in the world as space leader. When we terminated the Apollo/Saturn program we were focused on replacing it with an affordable/sustainable transportation system that would permit the country to invest in greater exploration and development of space for the benefit of all mankind. The next step in this focus to develop an affordable/sustainable transportation system should be to build upon our experience and continue to improve on large reductions in recurring cost of our transportation system. This cannot be achieved by going back to technologies of the past using totally expendable hardware for each mission – this was the major lesson from the Apollo/Saturn program. The commercial sector of the country knows that the only economic way to use the disposal approach is through mass production of the disposable hardware. This country presently cannot afford (a colossal amount of the taxpayer's money) to fly missions at a rate that would justify a mass produced transportation system. Instead of discarding what we have and starting over to build a new system from scratch with existing technology, we should consider better use of what we already have and spend our resources improving its affordability.

INTRODUCTION:
As you may be aware, the Government is planning to retire the Space Shuttle in 2011 and fund the development of a Heavy Lift Launch Vehicle (HLLV) capability, which is intended for space missions beyond low earth orbit. It is intended to supplement a robust commercial launch service industry focused on low earth orbit missions. But the current path also requires that our astronauts travel to the International Space Station (ISS) via Russian spacecraft until our domestic launch vehicles achieve a manned-rated certification (suggested to be 2014). Some of these commercial launch service providers are using space hardware built outside the U.S., thus taking jobs out of the country. Our Space Shuttle orbiters are on a path to be placed in museums. The current path places the U.S. at risk of losing the position of being the space leader in the world. The current path has little hope of succeeding as scheduled and may risk the termination of our manned space program that we have invested our resources over the last fifty years.

THE CURRENT PATH:
The current policy is changing the Government's roll from provisioning and operating space transportation systems for low earth orbit (LEO) to outsourcing this as a service provided by the commercial community. The Government is planning to retire its shuttle space transportation system as soon as the ISS is complete because

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of safety and affordability considerations as well as the need to free up the funds needed to develop a new space transportation system for beyond LEO service. The Government is to develop the capability and explore space beyond LEO with the objective to be affordable and sustainable. There will be a gap from shuttle retirement until the U.S. commercial capability is ready to perform this ISS support function. This gap in supplying the ISS with crew rotation and supplies is to be accomplished by buying services from Russia. The concept is to free up funds needed to develop the capability to explore beyond LEO.

The current path greatly relies on vehicles in which we do not have actual cost data and adversely compares them to a 30 year old program with extremely well known cost. Let us examine the economics of this decision: The shuttle has demonstrated it can provide a seven crew plus ~36,600 pounds of payload [multipurpose logistics module (MPLM) plus 20,000 pounds of actual cargo] to the ISS in a single launch for a total program cost of $829M in 2007 or a crew of seven plus ~33,000 pounds of payload to the ISS in a single launch for ~$600M in 2009. In comparison the Russian capability will require two crew flights (one crew member short) and four cargo flights to provide a similar capability as one shuttle flight. Russia will charge the U.S. $318M for the crewed flights plus $177M-189M for each of the four each cargo flights for a total cost of $1,050M. The Government has already contracted with Russia for transferring 42 crew members thus providing this service to 2016 when it is expected to have U.S. commercial service to provide this capability.

The Government has two existing commercial servicing contracts[i] with developing capability to be provided from 2009 -2016 for delivery of 44,100 pounds each to the ISS. One commercial provider has been awarded $1.6B, and has flown two test flights; but has not demonstrated capability to meet his commitment of 12 delivery flights to the ISS at an estimated $3,023/lb. The other commercial provider has not flown his first test flight and is still building is ground launch complex capability. This commercial provider has been awarded $1.9B and plans to fly an American produced space vehicle. However this vehicle is made up of a Russian-built first stage with Russian rocket engines provided through an American company with other hardware supplied by unknown sources. This commercial provider is committed to fly eight flights to the ISS at an estimated $5,386/lb. It is noted that the present space shuttle payload delivery to the ISS is estimated at $30,000/lb, assuming no charge for delivery of a crew of seven. This is based on a demonstrated annual operating cost of $3.0B (FY09) and at five flights per year during 2009 and 20,000 pounds of actual ISS cargo carried in an MPLM each flight. Please note that a Shuttle derived cargo vehicle (the Shuttle-C) could deliver far more payload to LEO then any present operating vehicles and would be extremely affordable if the Space Shuttle could recover the propulsion module and return it back to earth.

The U.S. has signed contracts with the Russian Federal Space Agency to fly American astronauts on round trips to the International Space Station. Most of the contracts cover flights carried out over several years.

Year[ii]

2007: $719 million to fly 15 people -- $48 million per seat
2008: $141 million to fly 3 people -- $47 million per seat
2009: $306 million for 6 people -- $51 million per seat
2010: $335 million for 6 people -- $56 million per seat
2011: $753 million for 12 people -- $63 million per seat
Total: $2.25 billion for 42 people -- average cost per seat, $53 million

The higher price represents a 12.5 percent boost since 2010 and a 31 percent increase since 2007. Projecting this cost into additional years is presented in Figure 1 below. You should note that the present cost of utilizing Russian Launch Service ALREADY EXCEEDS the marginal Space Shuttle Costs (the cost of operating the Space Shuttle without including the fixed costs.) Please also note that if current price increase trends continue by 2013 when using the newspaper values, the cost per seat via the Russian Launch Service will exceed the average cost per seat of the entire Space Shuttle Program annual budget and assuming the payload is delivered for free. When using a set of revised values, Figure 1 shows that Russian Launch Service will exceed the average cost per seat of the entire Space Shuttle Program annual budget before 2020. To that end, NASA's proposed 2012 budget calls for almost $800 million in seed money next year -- and almost $4 billion during the next five years -- to develop domestic space taxi services.

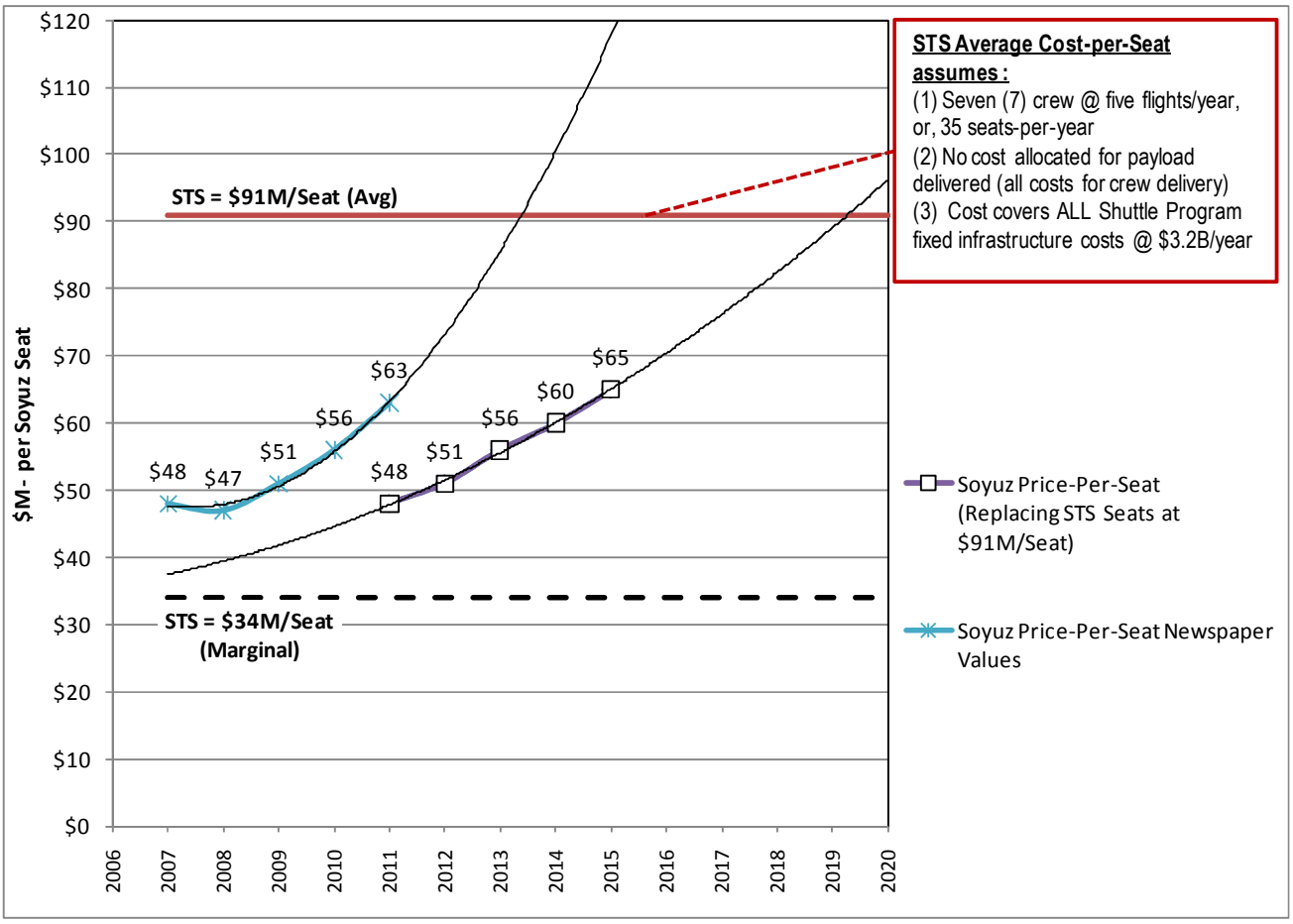

Figure 1: Current Cost Path for Crew Delivery via Russian Sources

THE ALTERNATE PATH - AN EVOLUTIONARY FUTURE:

In these days with the cry to reduce Government spending, the only affordable approach to maintaining a manned space program is for NASA and the country to capitalize on better use of our fixed assets. The policy is to rely more on the commercial capability to provide transportation to LEO and free up NASA to develop the technologies to provide a more affordable and sustainable capability to explore beyond LEO. During the last thirty years the shuttle program has included the cost of maintaining and operating the fixed assets required to support its operation in the cost of the shuttle flights because these assets costs were not shared (for the most part) by other programs.

To best share these NASA fixed assets and focus on the present space policy, would be to use the shuttle as a platform for demonstrating advanced technologies, required to lowering the operating cost, in an unmanned mode while supporting the other two shuttle vehicles as a commercially operated space transportation system for delivering both cargo and crew to LEO. These commercially operated shuttles would fly unmanned for the commercial cargo flights. These commercially flown flights would only pay for their direct cost of operations which would put them on an even playing field with other space vehicles operating in the world.

Several organizations, including USA, are trying to persuade NASA, Congress, and the White House to privatize the Space Shuttle. Indeed, one entrepreneur offered NASA $4B to purchase the Shuttle program, but was told that NASA does not have the authority to sell the Space Shuttle program. One would question the logic that NASA is able to hold a competition to GIVE the Orbiters away to museums, but cannot hold a competition to SELL the Shuttle vehicles to entrepreneurs who would continue to operate the Shuttle at KSC.

Space Shuttle Capabilities are as follows:

1. Deliver ~54,000 lb of payload from its payload bay;
2. Deliver 7 passengers from its crew cabin, and
3. Bring ~45,000 lb of payload back to earth.
4. The Shuttle can greatly reduce the cost of processing and launching a satellite by ensuring that it is working before being released from the cargo bay to its on-orbit destination. Therefore, a satellite delivered by the Shuttle should be charged a premium versus a satellite delivered by a single shot launch vehicle.

But MOST IMPORTANTLY, the Shuttle can achieve all the above capabilities in one mission! All other launch vehicles are single purpose. NASA never fully stressed the Space Shuttle capabilities over all other options. We spent ~$100B to develop the Space Station and now we must rely on another country to visit it with no backup capability. With such an enormous investment, why is the State Department or the Pentagon allowing such an enormous risk to this country's investment?

HLLV FUNDING:

Recently, Congress allocated several billion dollars over the next several years to develop a new Heavy Lift Launch Vehicle (HLLV). Since the new vehicle won't be ready for several years, any benefits of commonality with the Space Shuttle would be greatly diminished because most Shuttle workers would have retired or moved on to a different career. Development of a new HLLV will be extremely costly and unsustainable and by examining each component of the Space Shuttle, we may be able to redirect this funding for a more useful purpose. The Space Shuttle capabilities were never fully expanded by systematic upgrades. Shuttle derived options would also be possible in the future that would be more affordable and sustainable.

Solid Rocket Boosters – SRB:

The purpose of developing a HLLV is to provide a method of placing large space objects into space and beyond low earth orbit (LEO) at one time at a low frequency of only a few flights per year (<4). If we include amortization cost of developing ANY type of booster for the HLLV, we can confidently state that "*there is nothing that can be developed in the near term that will be cheaper than utilizing the Space Shuttle SRB's in their current configuration*". Simple math will show that for every dollar spent on development adds the burden of including the development cost pay-back into the recurring cost. This recurring development cost pay-back can easily exceed the re-occurring cost of flying the Space Shuttle SRB. This would suggest it would make far better use of the funding to improve the existing Shuttle SRBs by replacing the toxic propellant-based hydraulic power unit (HPU) system for the hydraulic thrust vector control (TVC) with a much simplified TVC system. This simplified approach has been studied and it was desired to make this change on the Ares vehicle. The simplified approach would replace the distributed hydraulic system along with the hydrazine powered HPU with electro-hydro-static actuators (EHA) powered with thermal batteries resulting in a cost reduction of 17-20%. A fully reusable fly-back booster option could be more affordable if the launch rate were sufficient to achieve the economics.

Space Shuttle External Tank – ET:

The Lightweight ET was used from STS-6 to about STS-91 and has a ~ $20M per tank cost savings versus the newer Super Lightweight ET design. Like all Shuttle ETs they were fabricated at NASA-Michoud (MAF) and have a relative high mass fraction. Since any HLLV will require a large diameter propellant tank, what could possibly be the purpose of losing the highly skilled knowledge base that can fabricate an extremely efficient, large diameter propellant tank? Even if NASA gave the go ahead today to resume Shuttle flights, it will take many months and a considerable effort to deliver the first new External Tank. However, the savings in time and development money would be very large compared to a clean sheet design. The ET tooling, skills, and infrastructure capability should be retained until future directions become firm.

OMS/RCS/MPS/Fuel Cell Systems:

Many trade studies have been conducted individually on the orbiter maneuver system, reaction control system, main propulsion system (OMS, RCS, MPS), and fuel cell systems and/or their components. The trade studies

were usually flawed because they looked at the performance of only the single system or component and normally did not consider the labor cost of processing each of these systems plus the maintenance and operations cost of the facility and ground support equipment (GSE). A far better use of the funding allocated to HLLV development would be to develop an integrated OMS/RCS/MPS/fuel cell system. How? By converting the toxic propellant based OMS into a system that is based upon LOX/LH2. By converting the toxic propellant based RCS into a system that is based upon compressed gaseous oxygen (GOX). By converting the fuel cell system that utilizes MPS LOX instead of a special grade of LOX. As a consequence the fuel cells will need to be purged more often which will result in GOX as a waste product. This "waste" product could be utilized by the RCS. By integrating these systems, for example the ~5,500 lb of residual LOX/LH2 in the MPS after main engine cutoff (MECO) on the Space Shuttle can be utilized. An integrated OMS/RCS/MPS/fuel cell system will add payload capacity and reduce the processing time in the orbiter processing facility (OPF) several days as well as greatly reduce the number of systems, number of commodities, and the number of interfaces between the flight vehicle and ground systems; thus reducing the time at the pad as well.

NEW MANNED HEAVY LIFT LAUNCH SYSTEM CAPABILITY DEFICIENCIES:

Planning for the new expendable manned heavy lift launch system will not have many MAJOR capabilities of the existing Space Shuttle. Some of these lost capabilities are: airlock and EVA; down payload from space (Westar 6 and India's Palapa B-2); work platform in space for building or repairing hardware in space (Hubble Space Telescope and ISS); retrieval of satellites from space (Long Duration Exposure Facility); retrieval of satellites from space, provided repair and re-deployed (Solar Max); provide functional verification of spacecraft just before release in space (Hubble Space Telescope and all commercial satellites); retrieve spacecraft that failed proper orbit in LEO and redeploy into proper orbit (Westar 6 and India's Palapa B-2). The above capabilities have been accomplished by the Space Shuttle and present planning for the new manned heavy lift launch system will not have any of these capabilities. Support lost to the ISS could be a major impact to ISS utilization through 2020.

- *The ISS support will be compromised, e.g., hardware change-out, assuming spare equipment is already at the ISS, requiring a work platform with RMS in space will not be available*
- *Install / replace rack elements that otherwise doesn't fit through hatch*
- *Temporally augment the crew size to accomplish large unplanned task*
- *Return either hardware or science to ground will not be available*
- *Guarantees full utilization through 2020*
- *Safety issues with re-boost and disposal (million pound comet)*
- *Two week stays of Shuttle crew and utilization multiplier to ISS*
- *Up-mass limitation, and down mass loss*
- *Space X and Orbital are years away and uncertain safety experience with only very limited support*
- *Replace and install major components too big to fit in EELVs*
- *Repair and decontamination of spills, depressurization, etc.*
- *No EVA airlock*
- *Evolvable to Heavy Lift Cargo with no infrastructure changes. Compatible with Space Transportation System (STS)*
- *Natural path from commercial Shuttle to commercial Heavy-Lift capability*
- *Limited rescue capability*
- *No landing on a runway*
- *No payload return for aborts*
- *No additional assembly capability*

HLLV FACILITY COSTS SAME SINCE IT USES THE SAME OR SAME TYPE OF FACILITIES:

According to the Augustine Report[iii], NASA will still have to pay at least $400M per year if no domestic rockets are launched using Shuttle facilities (i.e., NASA purchases ALL launch services from Russia or commercial provider such as Space X). However, the Augustine Report further stated that any Shuttle derived launch vehicles would require $1.5B per year just to maintain the same Shuttle facilities required by any HLLV design. Since a HLLV will utilize the same Shuttle facilities, then any HLLV design must pay $1.5B per year to maintain those facilities.

SUPPORT AND NASA OVERSIGHT COULD SHIFT TO NEW VEHICLE:

An analysis was conducted on the cost of operating the Space Shuttle using the contracts and charges by NASA centers. [iv,v,vi,vii,viii,ix,x,xi,xii] Based upon this data, we determined that six missions per year would cost $691M per flight or an annual cost of $4,145M. The pie chart (Figure 2) below shows both the fixed and flight operational cost. However, NASA oversight (fixed cost) to the Shuttle program Kennedy Space Center, Johnson Space Center, Marshall Space Flight Center, and Headquarters (by KSC, JSC, MSFC, & HQ) is a full 48% of the total cost!

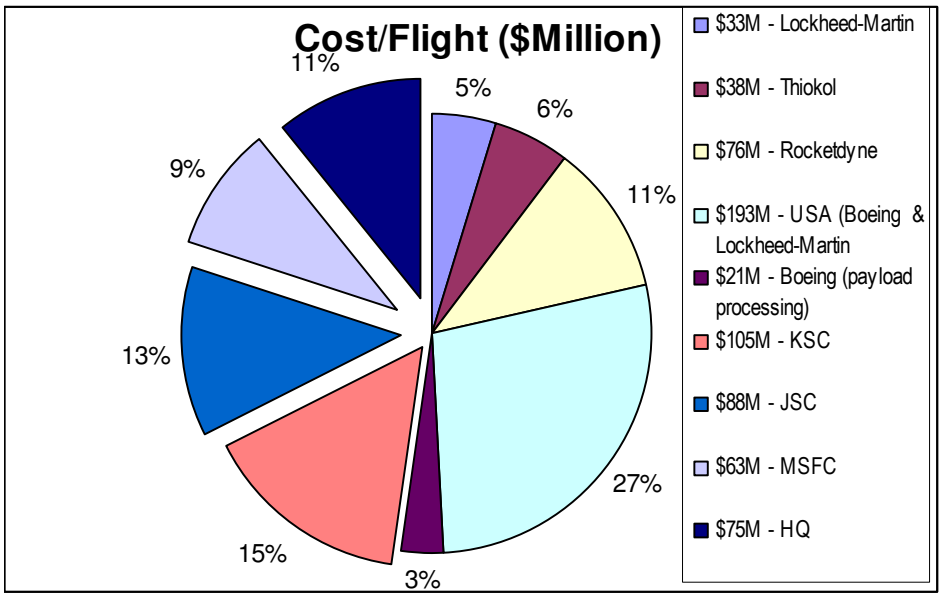

Figure 2: Cost/Flight from Contract Analysis 2008

What you should conclude from this is that any NASA operated launch vehicle will carry this government infrastructure and oversight burden. The only way of reducing the government oversight and infrastructure burden and reduce the cost into space is to separate these cost from the vehicle launch operations cost by the Government setting up a funding line to cover these cost and not pass them on to the launch vehicle operator such as to privatize the government launch vehicle program. Nobody (in Congress, the Whitehouse, or NASA) is talking about shutting down Stennis Space Center (SSC), MSFC, JSC, KSC or laying off the civil servants at these facilities or the astronauts. Therefore, this 48% of the $4,145M per year Shuttle budget will not be affected by shutting down the Shuttle program. And in its place, NASA has budgeted $1.3B per year to purchase launches from commercial vehicles plus about $2.85B (FY2015) per year to develop the new HLLV and Technology Demonstrations. Instead of $4.145B/year on the Shuttle program, NASA will spend $5.65B per year for at least the next 5 years on a replacement program with no possibility of a HLLV launch from KSC for the next 4 to 10 years. Why was the maintenance of buildings charged to the Shuttle Program? What you don't see in the pie chart above (but included in the fixed costs on the left side of the pie chart) is the $25M per month for maintenance of the KSC buildings or the $8.33M/month for IT & communications services at KSC. If we just look at the contracts of Shuttle hardware contractors, the cost of each Shuttle mission would have been reduced to $340M at 6 missions per year.

WHY LOOK AT ONLY HARDWARE COSTS:

On page 463 of the reference document, shows that 16.4% of the Space Shuttle program costs are for non-hardware activities "program integration". These activities may not be eliminated by developing a new vehicle. Attention must be focused on any architecture that drives down these non hardware costs. Improvements to the Space Shuttle could also be focused in reducing this cost. The point is, why spend

enormous funding in developing a new vehicle when we have not done all we could to reduce this cost in the Space Shuttle program.

RY ($ millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
TOTAL SPACE SHUTTLE	**3,315.3**	**3,266.7**	**2,981.7**	**2,983.7**	**95.7**
FLIGHT AND GROUND OPERATIONS	**1,066.7**	**1,121.8**	**1,031.2**	**955.9**	**0.0**
Launch and Landing (KSC)	746.3	780.4	705.5	632.5	
Landing Operations (DFRC)	3.0	3.1	4.0	4.0	
Mission Operations	214.5	236.5	221.4	220.8	
Flight Crew Operations	87.6	87.6	86.3	83.0	
Space and Life Sciences	11.2	12.6	12.1	13.1	
Flight/Ground Operations Transition & Retirement	4.2	1.6	2.0	2.4	
FLIGHT HARDWARE	**1,717.2**	**1,674.6**	**1,460.9**	**1,413.0**	**0.0**
Orbiter	620.3	504.8	459.1	638.4	
EVA	0.2	0.2	0.2	0.2	
External Tank	298.7	313.2	253.6	169.2	
Reusable Solid Rocket Motors	326.0	369.0	301.6	114.9	
Space Shuttle Main Engine	264.5	240.0	193.8	178.0	
Solid Rocket Boosters	165.2	154.1	136.8	98.2	
SSC Test Support	25.6	33.2	30.0	24.7	
Flight Hardware Transition & Retirement	16.7	60.1	85.8	189.4	
PROGRAM INTEGRATION	**511.4**	**470.3**	**489.6**	**614.8**	**95.7**
Systems Engineering and Integration	90.1	86.7	74.0	77.4	
Safety and Mission Assurance	25.1	30.6	54.8	42.2	
Flight Software	111.1	112.4	100.9	107.4	
Flight Operations and Integration	58.0	52.2	54.8	55.0	
Management Integration and Planning	34.9	31.1	26.7	26.7	
Business Management	66.8	66.5	62.1	64.1	
Propulsion Systems Engineering & Integration	18.5	19.5	16.6	18.0	
Space Shuttle Propulsion Systems Integration	15.5	20.6	19.3	20.7	
Construction of Facilities	20.1				
Safety and Sustainability	3.4	1.7			
Mission Directorate Support	29.7	8.6	12.2	12.2	
Contract Administration	26.5	26.0	25.5	23.4	
Closed Accounts	8.9	1.0	1.0	1.0	
Program Integration Transition & Retirement	2.7	1.4	1.5	1.7	
Severance and Retention		12.0	40.3	165.0	95.7
HURRICANE RECOVERY	**20.0**				
Hurricane Recovery	20.0				

Figure 3: FY2008 Actual Shuttle Detailed Budget

SHUTTLE EXPERIENCED MANPOWER IS IRREVERSIBLY LOST:

If the Shuttle program terminates without being privatized or used as a technology test bed, trained and qualified workforce will be mostly lost. Therefore, to develop Shuttle derived hardware will take advantage of the existing infrastructure but will experience a great loss of workforce, e.g., the experienced workforce that fabricate propellant tanks at NASA-Michoud, assemble segmented solid rocket boosters, prepare large staged-combustion engines, and prepare a spacecraft for manned flight at KSC will be lost! Because it may take 5 to 10 years to develop a heavy lift launch vehicle, experienced employees will have moved on to different careers or gone into retirement. As each day passes, it will become more difficult (more costly) to re-start the Shuttle program because contracts with suppliers either have or are ending. Even now, it would take many months for NASA-Michoud to build a new ET if given the order today.

THE OTHER PATH – AN EVOLUTIONARY FUTURE:

Space Transportation is at a crossroads. The current path will be challenged to succeed at reducing the cost to orbit or foster space tourism because it puts great reliance on domestic commercial vehicles and/or foreign governments. The current path will spend a colossal amount of taxpayer money to develop a new launch vehicle, but will not improve upon the cost of getting into space. Instead An Evolutionary Future is proposed that could return Americans to the moon before the end of the decade and foster the space tourism industry by

utilizing a privatized Space Shuttle. The same amount of funding that was going to be wasted on developing a new vehicle should be utilized on technologies that would greatly reduce the cost of access to space.

According to Aerospace America, 33 rocket families conducted 75 launches in 2009 and 66 launches in 2008[xiii]. The total commercial market is only $2B[xiv], which will be **shared** by the US, Russians, Europeans, Indians, and Chinese launch service providers. Although several US companies are building spacecraft that can transport up to 7 astronauts or space tourists into space at a time, this is not going to stimulate the space industry because they are charging ~$25M per seat. Although there are 10 million millionaires[xv], how many are going to pay $25M for a ride into space? What should be concluded from this section is that the domestic launch service providers that utilize an all expendable launch system will need government subsidies via high priced government missions for many years to come in order to remain in operation. Furthermore, manned launch services to the ISS and any space tourist flights will be near the end of the decade and will be few and far between. As a result, don't expect these commercial companies to hire but very few, if any, of the workers displaced by the termination of the Shuttle program.

What Is The Other Path? What Is An Evolutionary Future?

Succinctly, "*An Evolutionary future*" is the following:

1. NASA creates a line item in their budget that pays for infrastructure and other fixed costs that would remain if there were no Space Shuttle, Space Launch System (SLS), or any other HLLV Program.
2. Privatization of the Space Shuttle where the government is just one of many customers who pay for goods delivered
3. NASA would promote the unique Shuttle capabilities by developing a Shuttle-C vehicle that would require the Shuttle to retrieve the Shuttle-C propulsion module and return it back to the earth.
4. NASA would foster the Space Shuttle business case by setting a goal of landing a man on the moon before the end of the decade via guarantee flights each year on the Shuttle and Shuttle-C vehicles.
5. NASA would assist the Space Shuttle business case by spending some technology development funding on substantial Shuttle upgrades in return for guarantee mission costs of less than half to a third of what they are today and the possibility of more than 12 Shuttle missions per year.
6. NASA would foster the space tourism market by assisting in developing 40+ passenger space tourist buses and space hotels.

The Evolutionary Future: Other Capabilities – What Is Possible?

The use of the Space Shuttle could be a logical step in implementing the Shuttle-C. The Shuttle-C could easily compete on the commercial launch service market if the existing Space Shuttle was utilized to bring back the Propulsion Avionics Modules as touted by Rothschild, Talay, & Henderson at the AIAA/JPC (AIAA-2010-697233).

It isn't fiscally responsible to spend millions of dollars per mission to increase the payload capability of the Space Shuttle by a few pounds when large amounts of payload could be launched into orbit with the Shuttle-C. The unique capability of the orbiter is to carry a crew with manned-rated payloads into LEO and to return payloads and crew to earth. More importantly, the Space Shuttle could foster space tourism like no other vehicle.

If compared to a luxury greyhound motor coach (for example a MCI 102A3), the Space Shuttle cargo bay could transport at least 47 space tourist passengers with 40 feet of length & 6.5 feet of width to spare not including the seven seats in the crew compartment. Additionally, there is room for considerable cargo to be included on each flight. This capability allows the reduction in cost for carrying passengers. It would only seem logical that a space hotel developer could develop a large capacity space tourist bus that could be placed in the cargo bay. Transporting a very large number of passengers at a time greatly reduces the marginal costs to each passenger, thereby making space tourism affordable to a much larger market. How large would the commercial airline industry be if everybody were transported by fighter jets?

RATIONALE TO TERMINATE THE SPACE SHUTTLE PROGRAM BASED UPON INCOMPLETE OR QUESTIONABLE DATA:

The decision to terminate the Space Shuttle program was initiated several years ago with the understanding that the Constellation program was going to replace the Shuttle. However, since the Constellation program is cancelled, the Shuttle program termination should be reconsidered. When the decision to terminate the Space Shuttle program was announced right after the Columbia Accident, three reasons were expounded; the Shuttle is too old, it is unsafe, and that a new HLLV will cost less to operate. All of these reasons should have been questioned as they are inaccurate and easily disproven.

Shuttles Orbiters Are Too Old:

First, the Orbiters were designed for 100 flights or ten years each but have only 39 flights on Discovery, 32 on Atlantis, and 25 flights on Endeavour. Furthermore, procedures have been implemented to routinely replace seals and other age sensitive parts. An extensive structured inspection program was put into place to allow the extension of the age limit, which allowed these Orbiters to continue operation beyond the ten years. Therefore, the effect of time has little bearing on their flight worthiness.

Shuttles Are Unsafe:

An adjoining article expounding the fallacy of stating that the Space Shuttle is more unsafe today than in any previous time has been recently submitted by the Space Propulsion Synergy Team (SPST). The SPST have concluded that the Space Shuttle is as safe as any other vehicle flown to date and that it is safer to fly it today than it was any time earlier, certainly STS-1. SPST has utilized their extensive experience and knowledge to state that the Shuttle is safe and questions the maturity of the analytical models being used to show otherwise.
The Columbia Accident Report stated that the Shuttle is unsafe due to the use of ceramic coated tiles on a side mounted launch vehicle. True, the ceramic coated tiles have a quite fragile coating. We propose that where possible, the LI-900 silica tiles should be replaced with AETB-8 ceramic coated tiles with TUFI surface treatment. IF critics are truly concern about debris impacting the orbiter tiles, why not change the pitch attitude in which the shuttle flies? The Shuttle vehicle ascends at a + 4 degree pitch attitude in order for the SSME to thrust through the center of gravity of the total vehicle. During the first part of the Shuttle ascent, the speed is too slow to cause a transport for any damage to the tiles by the debris. After the Shuttle has traveled through the heavy atmosphere, any debris that leaves the ET will not have the transport again to cause any damage to the orbiter tile. However, during a certain small portions of the Shuttle's ascent, debris from the ET or SRB has the chance to cause damage to thermo-protection system (TPS) as is evident from the Columbia accident. The region of the ascent needs to be defined and understood so that the avoidance maneuver can be implemented to increase safety of flight. Therefore, during this small portion of the ascent the pitch attitude should be changed to ~ 0 deg. This will prevent any debris from having transport from the ET or SRB and from doing damage to the Orbiter TPS. This option assumes there will not be a negative impact on the structural capability of the vehicle and the need for re-certification. This may result in a small reduction in payload capability.

Shuttles Are Too Costly:

Terminating the Space Shuttle program will not eliminate the costs it was carrying for the agency's infrastructure support associated with the program and the Government over-site cost of the program. The contracting of commercial services being performed at these Government sites does not pass on this infrastructure support cost; therefore, the comparison was not apples and apples. The contracted cost being quoted never included this additional cost. A new HLLV will again most likely pickup these infrastructure support costs unless the Government/agency sets up a new budget line that fund these costs. Separating these costs from Shuttle will make it very competitive to other commercial options, allowing it to be competing apples to apples. A Space Shuttle operated by a private enterprise will be able to:

1. Provide a continuous manned-access to space via a domestic source.
2. Provide a platform (the Shuttle-C) by which lunar missions or any beyond earth orbit mission could be made.
3. Provide a means to recover a Shuttle-C propulsion module. Thus greatly reducing the cost of operating the Shuttle-C.

4. Provide a means to promote the space tourist industry by transporting a large number (up to 40) of space tourists at a time who only pay less than $5M for a two-week adventure via escape pods in the Cargo Bay.

A private company will be able to assume all costs to operate the Space Shuttle. The US government (NASA, Department of Defense, etc) will only pay for launch services. A transitional period of a few years will be needed to restart the ET production and for the private company to re-certify the new suppliers and contractors. In addition, the NASA can be providing the technology maturation needed to allow up-grades to the Shuttle that will reduce the recurring cost of its operation.

A privatized or commercial Space Shuttle will complement President Obama's Space Policy of commercial companies ferrying astronauts to the International Space Station. The intention of his space policy may have been for private companies to develop and fly their own launch vehicles, but every new launch vehicle must go through a very costly learning curve in which reliability is demonstrated and/or improved. From that point of view, a properly managed Space Shuttle (and Shuttle-C) program will always be cheaper than any Shuttle derived program (such as Constellation) since there are no development costs with the Space Shuttle and more importantly, no learning curve. The added benefit to the NASA is that the reliability of ISS support service is already established.

SUMMARY - AN EVOLUTIONARY FUTURE IN QUESTION:

It is dreadfully clear that the US manned space program is at a crossroads. The current path leads to a colossal waste of money (retiring the Space Shuttle, hiring the Russians to launch our crews to the ISS, and outsourcing the ISS supply missions to the commercial providers and dreaming of an expensive SLS with no defined mission) while risking a revolt by the taxpayers when the Congress keeps on spending more than income trying to fund a space program that they cannot afford. The Kennedy Space Center will become a mostly under- utilized launch center the next several years. However there could be another path; the Obama administration should consider setting about AN EVOLUTIONARY FUTURE. Using the same funding already allocated for the next five years, NASA should develop and mature advanced technological systems using an existing Shuttle that would drastically lower the recurring cost of space access while continuing to fly Shuttle as a commercial venture competing for the ISS resupply task until 2020. Even though the restart of Shuttle is expensive, it may be the best option, within the NASA budget, to retain a U. S. manned space capability until commercial capabilities have been safely demonstrated. Only after the NASA has demonstrated a lower recurring cost of access to space should the U.S. consider returning to the moon or anywhere else beyond earth orbit with architecture that it can afford. The existing PATH presents the world an image that the U.S. is weak and giving up its leadership position in Space Development to others in the world. Therefore, the path of An Evolutionary future will retain our image as leaders as well as providing a role-model for other government agencies to live within our means allowing the country to balance its annual budgets.

If the country doesn't follow the "THE OTHER PATH" major capabilities will be lost:

- The ISS support will be compromised, e.g., hardware change-out, assuming spare equipment is already at the ISS, requiring a work platform in space will not be available
- Install / replace rack elements that otherwise doesn't fit through hatch
- Replace and install major components to big to fit in expendable launch vehicles (EELVs)
- Temporally augment the crew size to accomplish large unplanned task
- Return either hardware or science to ground will not be available
- Guarantees full utilization through 2020
- Repair or refuel satellites or spacecraft presently in space
- Retrieve high value satellite, left in non-functional orbit, for re-deployment
- Work platform with remote manipulator system (RMS) in space for building or repairing hardware in space, e.g., propellant depot in LEO
- Limited rescue capability

The commercial sector may choose to use the newly matured technology to enable a business case for an orbital hotel with 100's of space tourists a year. Now is the time to contact our congressional leaders to save the manned space program, thousands of aerospace jobs, and this nation's future as an aerospace leader by following the THE OTHER PATH – ***AN EVOLUTIONARY FUTURE***.

RECOMMENDATIONS:

First the administration and NASA must define the rational for why man needs to explore or settle space beyond low earth orbit and get the public's buy-in. Once this is achieved, NASA needs to develop a roadmap that establish the process and timing for pursuing this primary objective of man's venture into space that requires a very reasonable funding profile. This roadmap (strategic plan) must be accepted by the American people before an architectural approach can be developed.

NOTE:

1. This technical paper represents the views of the authors, but they do not necessarily represent the positions of their organizations.
2. Cost analysis presented in this paper has not been verified as official by NASA or its contractors and may not reflect final values for ISS operations.

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[i] John Yembrick, Josh Byerly, "*NASA Awards Space Station Commercial Resupply Services Contracts*", CONTRACT RELEASE : C08-069, Dec. 23, 2008

[ii] Halvorson, Todd, "*Cost of Ride on Soyuz rises again for US – Russia charging about $63M per seat"*, Florida Today, 16MAR2011.

[iii] Augustine, Norman; et al, "Seeking a Spaceflight Program Worthy of a Great Nation", OCT2009, http://www.nasa.gov/pdf/396093main_HSF_Cmte_FinalReport.pdf

[iv] "*NASA extends Boeing payload ground ops contract*", December 26, 2001, The original PGOC contract was initiated in January 1987 with McDonnell Douglas Space and Defense Systems with total value of $1.9B when completed in July 2002, http://spaceflightnow.com/news/n0112/26groundops/

[v] PRNewswire, "*United Space Boosters awarded NASA contract for Space Shuttle's rocket boosters*", April 5, 1984. $222.9M contract is for 21 Shuttle flights. http://www.highbeam.com/doc/1G1-3215619.html

[vi] Flight International, "*NASA SRB Order*", 31July – 6 August 1991, 68 SRB flight sets for $2.6B.

[vii] "*Lockheed Martin completes negotiations with NASA for Production of Space Shuttle External Tanks*", 35 tanks for $1.15B, 31Oct2000, www.lockheedventures.com/news/press_release/2000/lockheedmartincompletes

[viii] "*NASA EXTENDS SPACE SHUTTLE MAIN ENGINE CONTRACT*", $2.05B contract with Pratt and Whitney Rocketdyne, Inc. began 01Apr2006 to end 30Sep2010, http://www.montebubbles.net/nasa_news.htm

[ix] Thiokol Corporation, UNITED STATES SECURITIES AND EXCHANGE COMMISSION, Form 10-K, The current Buy III Space Shuttle contract awarded to the Company in 1991 to build 142 solid rocket motor boosters for the NASA Space Shuttle program has approximately $1.0 billion remaining through its projected completion date in fiscal year 2000. fiscal year ended June 30, 1996, http://edgar.brand.edgar-online.com/EFX_dll/EDGARpro.dll?FetchFilingHTML1?ID=697725&SessionID=y8cjW68chGFYL47

[x] Total SFOC award value to $16.8 billion for services from late 1996 through SEP2006 . http://www.unitedspacealliance.com/about/history.asp

[xi] "EG&G Technical Services wins $1.5 billion NASA contract", $1.5B to EG&G for maintenance of KSC over 5 years, JUN2008. http://thesop.org/story/business/2008/06/19/egg-technical-services-wins-15-billion-nasa-contract.php

[xii] "Abacus Technology Corporation Awarded NASA Kennedy Space Center Small Business Prime Contractor of the Year – 2009", November 18, 2009, $900M contract for 9 years in providing IT & Communications to KSC. http://www.spaceref.com/news/viewpr.html?pid=29645

[xiii] Aerospace American, "*Space Launches Spike Upward*" OCT2010

[xiv] FAA, "*The Economic Impact of Commercial Space Transportation on the U.S. Economy: 2002 Results and Outlook for 2010*". Associate Administrator for Commercial Space Transportation, March 2004

[xv] "World now has 10 million millionaires", http://www.msnbc.msn.com/id/25353615/ 24JUN2008