Comments on **Exploration Beyond LEO** document
SUBMITTED BY **John K. Strickland, Jr**
email: ***Email Address Removed***
THIS DOCUMENT **MAY** BE MADE PUBLIC.
(Text included in BODY of email):

HUMAN SPACE FLIGHT PLANS COMMITTEE - 2009
SUBGROUP 3 Questions - JKS Input 7-21-09
John K. Strickland, Jr ***Email Address Removed*** **This Document may be made public.**

Basic assumptions for my answers to these questions:

- The space program should be fundamentally Goal-based, not technology-based. Everything that is developed should have a specific reason and support a specific goal or set of major goal categories, that include **Exploration, Science, Space Development** (such as space solar power) and eventually Settlement. The current space program should not just be about Science nor should it just be about Exploration.
- Make sure that **if** we continue to work towards human moon missions as the next objective, we know **why** we are returning to the moon and agree on the most important things we need to do there.
- Exploration and Development phases should **not** resume until space access and operating costs have been brought down by about 1 order of magnitude, with means in place to continue the access cost reductions.
- The current phase of Station re-supply can be the starting point for a transition of transport and logistics to private service, ending with a greatly reduced cost of access to the station, assuring its longer-term usefulness.
- Use of Fully Re-usable boosters (for crew and cargo separately) that are designed, built and operated by private companies via **launch contract guarantees** to support NASA operations in LEO and beyond.
- Assume use of no-loss, solar powered Propellant Depots/Refuges in LEO, lunar orbit (and elsewhere as needed), to reduce required mass for each exploration spacecraft and protect crew lives.
- Adhere to a fundamental philosophy of designing fully re-usable in-space vehicles that would be re-used for a designated number of times until their calculated risk of use exceeds that of the first (previously untested) use.
- Adhere also to a fundamental philosophy of designing an integrated and modular **space transportation and logistics system** that can be adapted to access cis-lunar space, the Lunar surface, near-Earth asteroids, Mars orbit and Mars surface for both humans and cargo.
- Combine all projected payload counts per year for human exploration, space development and large science payloads to support the projected flight rate of required heavy lift cargo and crew-carrying boosters.
- NASA should get out of the rocket booster (crew and cargo) business to concentrate on designing the exploration vehicles, hardware and associated equipment.
- The entire Human space program should be oriented in its efforts to a process of **continuous reduction of transport and operating costs**, leading to points (a) where both lunar and Mars exploration can be supported simultaneously, and (b) where space development operations (at least in cis-lunar space), like resource mining and space solar power, becomes economically feasible.
- Space Development goals (using space energy and materials commercially) should be put an a more equal footing with exploration, to prove in the short term that the human space program can

provide a very valuable service to mankind other than just inspiration and information about the universe. **If it is not within the scope of this commission to address Space Development issues, I recommend that they should be covered by a separate commission.**

1. Destinations and Sequences of Exploration Beyond LEO:

A. Design and establish re-usable cargo tugs in earth orbit to replace the shuttle when used with an HLV.

B. Establish Depot/Refuges in the LEO used for lunar or Mars mission support, and to re-fuel the cargo tugs.

C. Develop re-usable Earth to Lunar orbit and back ferry vehicles, which can use aero-braking and then orbit perigee trim up to regain circular Low Earth Orbit after a return from the moon, and re-rendezvous with the Depot.

D. Develop fully re-usable crew and robotic lunar ferries or landers, which can operate as either a cargo vehicle without a crew cabin, or with a crew cabin and a much smaller cargo size.

E. Design robust lunar bases that can support extraction of lunar oxygen in sufficient quantities within a few years of the bases establishment to provide all oxygen propellants for return flights to lunar orbit.

F. All lunar base build-ups would use the base-first, (with shelter or rescue capability in place before a crew lands) strategy.

G. All base designs should provide heavily radiation-shielded or buried crew habitats as soon as possible, preferably as soon as a crew is landed, by using tele-operated equipment first to prepare the habitat units.

H. All base build-ups would use a **carefully designed sequence** of **unmanned** cargo landings, designed to unload, install, protect and support later delivered items, with tele-operated capability, and culminating with the first crew landing.

I. Develop large habitation, redundant deep space vehicles for Earth Orbit to Mars Orbit and Return missions.

J. Develop a large, fully re-usable manned crew and cargo lander for Mars surface operations, with an integral aero-shell, which can successfully land on Mars using rocket braking **during** deceleration in Mars atmosphere and without using parachutes. This large vehicle must fit (empty of propellant) within the cargo space and mass limits of the proposed HLV.

K. Set a serious goal of Initiating human Mars surface operations within 1 decade of resuming human Lunar surface operations. This decade would give time for (a) reduction in space operation costs and (b) development of Mars Vehicles.

Discussion and details:

I. Access to Cis-Lunar space: The new Administrator should re-issue requests for trade-off studies for cis-lunar and lunar surface access, based on the engineering work of the last 4 years, (so as not to waste any of the recent work), but this time **specifically including re-usability and re-useable vehicle modes in the studies**. The objective is to reduce the cost of payload (per launch and per pound) and cost of crew time. Increases in vehicle weight and fuel use is a secondary problem, subservient to the first two objectives.

Specifically, re-usable designs should be included both for an Inter-LEO-to-lunar orbit ferry and a modular lunar lander. Various designs and methods for the LEO-lunar orbit shuttle should be considered and simulated, such as using aero-braking to get back into LEO, etc. The cost of building expendable stages should be compared to the cost of bringing the stages back to LEO, and the cost of the extra fuel and tankage to do so. Alternatives such as using expendable large propellant tanks combined with recoverable engine pods (with small tanks just large enough to self-recover them) might also be considered.

II. Resumption of Human Access to Luna:

(a) Lunar base design should start with a plan to steadily reduce access costs and allow eventual development of a lunar materials based industrial economy. The base operations plan should include early and significant use of ISRU (In-Situ Resource Utilization) to produce LOX. Development of lunar infrastructure equipment such as LOX plants should progress in parallel with, not after, lunar vehicle development, so the equipment is ready for testing on early flights. (Current plans call for development of equipment able to produce amounts of lunar-derived LOX sufficient for breathing and fuel cells, but not for rocket fuel. This would need to be scaled up by a factor of 10 or more). The plan will also support scientific exploration, astronomy, geology, etc., improving as access costs (and cost of crew time on the lunar surface) are reduced. Crews should be able to be fully protected from radiation hazards as early as possible by covering or burying habitat units under lunar regolith, and the equipment to do this (power supply, unloading crane, hab unit, excavator, etc), should be available when the first crew lands. A specific list of the required delivery order of cargoes to the lunar surface should guide equipment development.

(b) The **crew-carrying lunar lander** should be designed as a re-usable single stage with a small crew cabin/escape capsule, sitting on a flat-bed deck, which would <u>only</u> separate in case of failure of the main vehicle. This would eliminate the risky return of each crew to lunar orbit on a single **non-redundant** ascent stage , which mode will inevitably lead to crew deaths and subsequent severe media recrimination. The basic vehicle should be designed for re-use from the beginning, but with modifications to allow re-use before a supply of stored LOX with propellant transfer equipment exists at a base site. This initial version would carry extra propellants in tanks, instead of cargo, on the flat bed, beside the crew cabin. Versions after LOX production is available would carry heavy cargo or habitats instead of the extra fuel tanks. Establishing volume LOX production at any lunar base should be a high priority to eliminate LOX propellant re-supply flights from Earth. Landing of any crew on the lunar surface assumes that survival equipment or self-rescue equipment already has been landed there.

(c) The **cargo carrying lunar lander** should consist of the crew mode descent stage with just a (flat bed) cargo platform without a cabin, and the first cargo should be a tele-operated crane that can unload itself and then unload successive cargoes. With no crew cabin or cargo (once unloaded), the cargo mode lander should be able to return to lunar orbit on its own and dock at the lunar orbit depot with a minimum of extra propellant. The lander size and extra propellant tank space should be scaled to the largest initial payload needed. The extra propellant volume would then be used to expand cargo-carrying capacity when the LOX plant is operational. Ideally, the heavy oxygen (LOX) for further missions would then be supplied from the lunar surface and the lighter methane or hydrogen fuel from the Earth. The base-first decision made 2 years ago is the right initial path for maximum crew protection. The hard part is picking the "right" base site. **(See question 2 for base site discussion.)**

(d) **Lunar Base Build-up Sequence.** Assuming a base site is selected and the Depots are in place, a rapid series of HLV launches would bring base equipment from LEO to lunar orbit, and then to the lunar surface. During the preparations for D-day in World War II, a lot of attention was paid to the sequence of loading and unloading cargo ships. In this case the physical size of the cargo vessels is much smaller, so the cargos are sequenced individually by their trip order. Here is an abbreviated example of such a sequence using robot cargo landers which each return automatically to and dock with the orbiting depot for more fuel and cargo.

LUNAR BASE BUILD-UP SAMPLE SEQUENCE:

1. Thermally shielded tele-operated cargo crane and transporter to unload and move cargo from robot landers. It should come equipped with arm like manipulators to allow cables to be unreeled and plugged in, etc.
2. Thermal shelters and or blankets to protect additional equipment to be landed later from freeze damage.
3. Power supply unit with electrical cabling to keep other equipment powered and avoid freezing during lunar night. This unit could be a compact nuclear reactor, a self-erecting solar panel unit with batteries, etc.
4. Tele-operated robot excavator to dig trenches for habitat units or to fill pouches over habitats with regolith.
5. Initial crew habitat unit with stores, anti-dust airlock system and attachment points for additional units. Must be able to be plugged into power unit, but have emergency power backup itself..
6. Self-rescue crew cabin to reach lunar orbit in an emergency.
7. Pressurized and un-pressurized rovers for crew to use (capable of being plugged into power unit or thermally protected).
8. Scientific equipment for crew to use.
9. Pilot Scale ISRU units for crew to test with actual lunar materials under actual lunar conditions, and sized large enough to provide oxygen in an emergency.
10. Lunar Propellant depot and means of moving propellants (LOX) from tankers or ISRU units to depot and then to lunar landers for return flights, etc (either by buried pipes or via a mobile insulated tank truck).
11. INITIAL CREW LANDING in re-usable lander with self-rescue capability of crew cabin alone.

III. Steps Beyond Cis-Lunar Space:

Re-usable Mars Ferry In order to eventually land heavy vehicles with crews and cargo on Mars, we need to start testing scaled Mars lander and ferry designs in Earth's upper atmosphere (at Mars-equivalent pressures and entry conditions). (Any vehicle much heavier than the 2011 Mars Science Laboratory rover's entry vehicle would impact the ground at hypersonic speed before any parachutes could be deployed). Such test vehicles need to be able to use decelerating thrust at the same time they are experiencing heating and drag from atmospheric re-entry conditions. Current vehicles trying to do this would have their engines and associated plumbing melted, either from the re-entry heating, or from the rocket exhaust forced back against the bottom of the vehicle. Engineering studies (on computer simulators) should be funded immediately to start solving this problem. A vehicle with a semi-square bottom profile could be used with the engines (at the corners) canted to the outside to prevent damage from rocket exhaust during descent, and the bottom of the vehicle needs to be designed as a heat shield, sealed against re-entry heating, with engine bell openings flush with the bottom. I assume a minimum of 4 engines would be needed.

The relatively fixed main engine directions means an effective means for attitude and trajectory control during both landing and takeoff (different from current fully gimballed rocket engine mount designs) , must be created. This could be thrust variation between engines or medium-sized side-mounted vernier engines such as used on the early Atlas vehicles. Such a Mars ferry vehicle, since it has a integral heat shield, would be immediately and fully re-usable once delivered back to Mars orbit. This vehicle must be large enough to deliver substantial large payloads to the Martian surface, and its large aeroshell, which must be one integral unit, is a major rational for having a true HLV

2. Mode of Surface Exploration (Purposes of surface exploration should also be addressed)

(a) Lunar base operations and thus site selection decisions are much more dependant on orbit geometry and support by solar energy than on geology, since lunar geologic boundaries are much less distinct than those of Mars geology, and there is little or no chance of ore bodies or concentrations. Polar Bases are the only current option without support for development of compact nuclear power sources for bases subjected to lunar night.

(b) Lunar and Mars surface exploration can be accomplished with a combination of humans, humans on local “golf cart” style rovers, humans on pressurized rovers, and tele-operated robots next to and apart from humans. Design work for lunar dust reduction inside habitats should have a high priority.

(b) Very careful consideration for placing an initial Mars base at or next to:

I. Boundaries between different geological areas and rock types for mineral use and scientific investigation

II. A source of water reachable by drilling or digging for human use and propellant creation.

III. Relatively close to the equator.

IV At relatively low elevation for greater protection and ease of landing.

3. Strategy for Coordinating Human and Robotic Exploration
(Integrating of and inter-program support between Human and Robotic Programs):

a. Tele-robotics at lunar base sites. There is significant practicality of reducing crew time and performing crew related safety and /or construction work at a lunar base or landing site, even before crew arrival, using tele-operated robots operated from Earth. Such use would greatly amplify what tasks can be performed on the lunar surface at a modest cost, compared to use of crew time.

b. Tele-robotics and robots on Mars. Once humans have a base anywhere on Mars or in Mars orbit, with effective global comsat capability, remote tele-robotics operations should be planned as a major extension of useful crew time. In addition, “intelligent” (AI) robot “companions” could be provided to assist astronauts in exploration and base operation if future tests prove them to be useful.

c. Deep drilling for life on Mars. Robots cannot do the kind of kilometers deep, large scale drilling that, for example, characterizes terrestrial oil drilling operations. This is the kind of drilling that will probably be needed to reach the miles-deep zones where Martian bacteria might be present in liquid water or brine. This rationale can be used to justify placing manned Mars bases at sites of biological interest.

d. Mars ISRU testing. To support re-usable crew and cargo landers, any Mars base should be able to supply sources of propellants from local supplies, such as CO_2, water, etc. Including an ISRU test package on the canceled 2001 lander failed when the equipment was displaced by science instruments on the re-scoped Phoenix mission. Pure science is one of the major but not the only rationale for space activities, and infrastructure development can and will reduce the cost of science operations. Since this kind of payload does not need to be on a rover, a single dedicated fixed International lander could be used to support a series of ISRU and science experiments such as seismographs and weather instrumentation.

e. Mars manned landing site selection. Mars orbiters, landers and their instrumentation are crucial to landing site selection. The existence of methane sources, near-surface ice at low latitudes, and other minerals useful to a human base and/or features desirable as targets for scientific exploration, can only be found using such instruments. Starting with the current and future probes, orbiter and lander designs should include instruments specifically for eventual selection of human base sites. Searches for areas of high heat flow, permitting near-surface liquid water would be desirable.

4. Launch Vehicles - Mass and Shroud Diameter (designed, built and operated Privately to support NASA)
(TOPIC OVERLAPS AREA BEING CONSIDERED BY LEO ACCESS SUBCOMMITTEE)

I. **HEAVY LIFT VEHICLE**
A. Should be the maximum reasonable size achievable with reusability by the time the HLV is needed.
B. 33 feet in diameter and at least 120 tons to LEO is reasonable.
C. Volume and mass must be compared to projected volume and mass for a re-usable Mars ferry or lander with integral aero-shell to allow retrofire during re-entry into Mars atmosphere and landing.
D. Most HLV payloads can be launched with no propellants assuming existence of LEO Depot and tugs.
E. If first version is **not** re-usable, plan transition to re-usable HLV with modular first stage or Phoenix-type vertical lander when feasible.

II. **CREW LAUNCH AND RETURN VEHICLES**
F. No use of solid boosters for interim crew launcher.
G. Transition to horizontally launched (flyback first stage) crew launcher when technology is available for safety reasons (avoid vertical crew launches from pad.)
H. Must be either on top of vertical rocket or under horizontally launched flyback aircraft/booster.
I. Must not use fragile exterior structure for re-entry shell (no fragile tiles).
J. Recommend using external and redundant active regenerative cooling for leading edges and hottest surfaces.
K. Recommend eventual transition back to a compact aerodynamic vehicle capable of landing on runways instead of a capsule.
L. Crew vehicles should all be fully re-usable, including highly integrated “service module” sections, not including any expendable solar panels, etc. which are too bulky for re-entry.
Discussion and details:

(a) A <u>quickly developed</u> **air-launched 2-3 stage orbital crew vehicle** would greatly enhance crew safety as well as costs, since the fly-back stage would obviously be re-usable and the possibility of launch pad accidents would be eliminated. The fly-back stage concept (airplane) should be supersonic, with a separation speed of at least 2000 mph or more, and is based on existing published engineering descriptions of large supersonic aircraft such as the old Mach 3 capable **XB-70 Valkyrie, Blackbird,** and other current programs such as DARPA's **Blackswift** (focusing on use of the Mach 4 jet engine). If engineering is favorable, higher speeds, possibly rocket-assisted but not requiring scramjet engines, could be considered. (Tradeoff comparisons between putting extra boost fuel in the upper stage or using rocket-assisted propulsion in the airplane for a speed boost just before separation would be useful). The airframe (fuselage) should be designed as vertically shallow to accommodate the upper stage (below it) on takeoff. Improvements of "intelligent" and explosive-bolt-free release attachments should be part of the design. I assume that scram-jet engines will **not** be ready for inclusion in a "quick and dirty" design. NASA support of scramjet/hypersonic research should be resumed, in cooperation with the Air Force, to advance the availability date of a usable scramjet engine/airframe design. This would then be available for a second generation fly-back stage. The crew vehicle's cabin would also serve as an emergency re-entry capsule if the entire vehicle was deemed unable to survive re-entry. COTS funding should be used for this development by a private company.

(b) Pure Rocket – DC-X derivative. A much cheaper development alternative but with higher payload costs would be a DC-X derived 2 stage to orbit vehicle, with the first stage landing vertically like the DC-X and the second stage returning from orbit with the crew and landing horizontally. The top of the second stage crew vehicle would consist of a crew cabin which again could be separated from the rest of the vehicle in a launch emergency and also could serve as an emergency re-entry capsule.

(c) A **true, re-usable HLV** (of 100 tons or more to LEO) is needed, as Dr. Griffin has pointed out. It should replace the current Ares V design if possible, or it could be a second generation vehicle. A re-usable large HLV is a requirement for building any Space Solar Power system and for starting along the road that would allow any kind of lunar economy based on movement of physical materials to develop. A large HLV is also required to place a fully re-usable Mars ferry (with integral airframe and heat shield) in LEO for transport to Mars orbit.

Arguments that the HLV launches would be too infrequent to support development costs are negated by the results of building the Erie Canal in 1825. This caused a trade boom by reducing transport costs between some cities by a factor of 100, and allowed the rapid populating of much of the US interior. Achieving Cheap Access to Space (CATS) could do the same thing. In addition, the extreme cost of the crew time required for detailed assembly work in a vacuum, when smaller modules need to be combined, can be drastically reduced by simply using a launcher large enough to launch integral payloads: those already fully assembled and in one piece – ready to use. This extreme crew time cost needs to be charged against the slightly lower development cost of an expendable HLV like Ares V. The use of multiple rationales, including Space Solar Power, lunar access, crew safety and large, integral vehicle, logistics and science payloads can multiply projected HLV vehicle use rates to support their development costs.

(d) Re-usable HLV designs Due to the physical size of such a large booster, there are no current air-breathing designs which are implementable within a decade, so the vehicle would probably be entirely rocket-powered. The design focus should be on discovering ways of recovering very large integral first stages **or** first stage segments intact with minimal refurbishment needed for re-use.

(1) A hexagonal cluster of 6 super-strap-ons surrounding a similar sized core stage is one possibility. How the individual boosters are recovered after separation is then up to the designer. This version could not easily support engine-out capability.
(2) Another existing concept is a recoverable engine pod, which would include all the turbo-pumps and

propellant interconnect plumbing to allow an engine-out capability similar to the Falcon 9. Note that the engines, pumps, valves and associated equipment are the heaviest (and most expensive) portion of a booster.
(3) If a very large stage can be designed to land itself vertically like the old Gary Hudson Phoenix concept, this is another way of first stage self-recovery.

5. Propellant Depots: (This item should be higher in the list due to its importance and time priority)

(a) Each should be combined with an emergency crew refuge module with radiation shelter.
(b) Should be capable of robotic re-supply by commercial fuel supplier.
(c) Standard micro-gravity capable design allows use in LEO, Lunar, Cis-lunar (L-points) and Mars orbits.
(d) Capable of being launched ready to dock and use. (Refuge modules could be docked at special port)
(e) No-loss design using solar power panels to re-condense all boil-off of propellants.
(f) Suggest using Methane rather than Hydrogen as standard fuel to also reduce boil-off rate.
(g) LOX should be standard Oxidizer since it can be extracted from dry lunar rocks in bulk.
(h) Depots **not** in low planetary orbit can use sunshades to reduce size of solar array.
(i) Depots should not store any hypergolic propellants for safety reasons.
(j) Needs multiple docking ports designed to accommodate a full complement of (1) tankers, (2) manned and cargo-only Earth-Lunar Ferries and (3) manned and cargo-only Lunar Landers, which would stay docked at the Lunar or LEO Ferry until the next flight.
(k) A lunar base 1/6 G propellant depot (and **external** fuel transfer methods) is also needed.
(l) **All in-space vehicles should be designed to dock with and re-fuel from the standard depots.**

Discussion and details*:* The true large HLV (discussed under item 4) would allow placement of ready-to use but empty standardized propellant depots combined with crew refuge units in both LEO, lunar orbit(s) and other critical locations like L1 or L2 as needed, to facilitate the operation of the different types of re-usable vehicles. All depots should be designed to prevent loss of propellant due to boil-off by (1) using sun-shades where possible to reduce heat input from the sun, (2) super-insulation like the new aerogel-based super-insulating material, and (3) re-condensation of any remaining loss using solar energy. All of these methods can be easily incorporated on a purpose-designed propellant storage tank, but not on launch vehicles. These Depot units should be designed so that they are truly ready to use, with little or no crew construction time, and **no** crew residence needed to maintain the facility. Multiple docking adapter locations for ferries, landers and tankers (from Earth) should be provided on the depots. Private companies can then use any economical re-usable tanker size that can dock with and unload propellants into the depot either automatically or with tele-operated human oversight. Standard in-space propellants should be LOX and Methane.

6. Technology Research & Development - Role and Scale
(a).NASA needs a **permanent, guaranteed** R & D funding mandate of at least **1-5 %** of its total annual expenditures.
(b) It needs an independent DARPA-like directorate to best administer the funds to support future programs and needs. This position is supported by the just released NAS report "*America's Future in Space*".
(c).The most immediately critical R & D efforts should include technology development in support of hypersonic, air-breathing and various re-usable launch vehicles and technologies, such as electromagnetic launch.

Details:
Resumption of abandoned / under-funded long range technology development & operations programs:
NASA has abandoned critical long-range technology programs repeatedly in a short-sighted manner as administrations and priorities have changed over the last 40 years, and budget limits have squeezed against inflexible or over-budget programs. These programs need to be re-instated, in the right order, and funded on a sustained basis. Some funding could be re-directed from in-house booster development for this. Priorities should include at least:

1. Hypersonic / Scramjet engine / air-frame technology (in cooperation with the Air Force & DARPA).
2. Regenerative & re-cycling life support systems for crews far away from the Earth.
3. Low or partial gravity biology studies (on the ISS) with small mammal life cycle focus to prove that mammals can live and reproduce in low gravity environments such as 1/6 G (lunar) and 37 % G (Mars). This could be accomplished by completing the planned Large Centrifuge Facility and launching it to the space station.
4. Space Nuclear Power Sources and Space Nuclear Propulsion.
5. Advanced non-chemical (ion, plasma, electro-magnetic, tether, etc.) propulsion methods and technology.
6. Micro-gravity material sciences and material behavior (physical and chemical).
7. Food crops and photosynthetic plant growth in space and on planetary surfaces.
8. Stable funding for upgrades and maintenance to the Deep Space Tracking Network and antennas.
9. Construction and Maintenance of launch site and launch range facilities.

7. International Partner Involvement
(a) Involvement should be as fully integrated as possible and practical.
(b) An international exploration commission should be created to coordinate cooperation.
(c) As individual countries are willing, they can contribute specific critical portions of equipment.

Details: Integrating US and other International Robotic and manned programs and goals:

This should be done when it is clearly in the US national interest. Common science goals should be high on the priority list, since where science information comes from does not matter, as long as publication agreements of results and calibrated data are honored. Common docking and rescue structure agreements should also be negotiated. An international coordinating committee could assist in targeting the highest unmanned mission and instrument development priorities among participants. Manned lunar and Mars expeditions should be international efforts if possible, with each separate vehicle or infrastructure equipment item created by a specific nation or working group to spread costs around and reduce internal interface problems. The US should be one among equals in these efforts, and not act as the dominant partner.

8. Role of Commercial Entities

Achieving Re-usability via Launch Contract Guarantees as a foundation to space economics:

(a) Role of Private Companies: They should be allowed to play a prominent or leading role in designing, constructing and operating all re-usable hardware, including in-space hardware, but focusing first on launchers. Most NASA (or any other government agency) managers and those from the "Space-Industrial Complex" Companies closely dependent on NASA do not have the instinct and drive to put reduction of fabrication costs and operating costs first. This is not a condemnation, it is just a statement of reality. Private company involvement in design, construction, and operation is especially important for the air-launched crew vehicle and the true large HLV.

Functional purpose, economics and engineering should have equal sway in strategic design decisions, while structural and safety issues must always be subservient to engineering oversight.

(b). (Putting the horse back in front of the cart.) NASA should not attempt any new large missions such as Orion/Constellation without first having crew access to space/LEO based on re-usable boosters. The current plan is equivalent to putting the cart (the next costly series of missions presumably using all-expendable boosters and vehicles) in front of the horse (the lower cost booster and vehicle system)! Elon Musk has recently estimated that it might cost about a billion dollars to create a fully-re-usable launch vehicle based on the existing two stage Falcon 9 carrier. This is the cost of a single shuttle mission including annual operational and personnel costs, and is a fraction of the billions that will be spent developing the Ares I. It would be worth the cost of several shuttle missions to be able to create a single medium-large re-usable booster design. The mere existence of this vehicle (allowing very inexpensive fuel delivery flights to LEO) would force other major competitors to create their own re-usable designs or forgo further business after some point.

(c) Use of Launch Contract Guarantees Such a vehicle could be had without immediate government financing, by offering launch contract guarantees to any company which can launch cargo below a set cost per pound. A Launch Contract Guarantee is a legal agreement that if a company demonstrates its ability to launch on time and at or under a set cost level, the Government, (NASA, NOAA, Air Force, etc), will use a specified number of launches for a specified period of time. This would encourage the entrepreneur and possible investors to proceed with development of the vehicle(s).

(d) Enhancing COTS funding with alternative launcher strategies. One strategy might be to switch to one of the current alternative launcher proposals, either John Shannon's SDHLLV vehicle with a side-mounted payload or the much more unofficial Direct system using the Jupiter shuttle derivative with a top-mounted payload, and then use some of the saved Ares funding to finance COTS and /or launch contract guarantees. The alternative launchers would be more than sufficient for station re-supply, station additions and crew launch, if a re-usable space tug was one of the first payloads.