Heavy Lift Launch and Propulsion Technology

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Synopsis:

I. Background/Objective

NASA has requirements for heavy lift launch to extend human and robotic presence throughout the solar system. NASA desires to enable exploration of multiple potential destinations, including the Moon, asteroids, Lagrange points, and Mars and its environs in the most cost effective and safe manner. NASA is in the planning phase to develop strategies for enabling a heavy lift launch system.

The respondent[1] has designed and published an affordable, sustainable and scalable heavy lift launch vehicle propulsion architecture[2-10], that fills a long standing gap in commercial launch vehicle engine stage configuration phase space, promises order of magnitude advances in cost effectiveness and mass efficiency, and solves many of the outstanding problems in fundamental rocket science, through modern improvements in materials and fabrication technology, propulsive efficiency, and design for reusability. This dual fuel architecture also reforms and maintains NASA management and operational institutions and infrastructure, through the accelerated time frames and developmental cost reductions afforded by the judicious leveraging of domestic inventory and assets, international coproduction agreements, and a continuous transition into the second generation propulsion advances expected in the very near future.

At the same time, NASA desires to develop liquid chemical propulsion technologies to support a more affordable and robust space transportation industry. This approach will strengthen America's space industry, and could provide a catalyst for future business ventures to capitalize on affordable access to space. It will also leverage a broader range of American ingenuity to keep our nation on the leading edge of human space exploration capabilities.

This research work should have been pursued back in 2001 with the SLI (Space Launch Initiative), canceled after an investment of only $100 million dollars. The time and money lost has been immense. The potential of realistic heavy lift launch vehicle and propulsion is years off at best, a decade at most. To continue to move forward in any meaningful manner in the near term, any solution should be pursued using existent civil commercial engines, with a multiple fuel, booster assisted architecture in the smallest possible form factor, such that development and production may proceed as fast as possible at the lowest possible costs, in configurations that allow reengining and scaling as propulsion advancements progress.

The vehicle and booster architectural paradigm I have proposed satisfies these strict propulsion and launch requirements. It utilizes single space shuttle main engines in a ground started, booster assisted, single stage to orbit configuration, with heavy lift payload capacities that may also include upper stages. Easily recoverable modern, efficient and powerful liquid fueled hydrocarbon boosters will increase the mass and mitigate the vibration environments and final accelerations of their large integrated payloads. Relatively inexpensive engines are now flying, or sitting in storage, or available from our most trusted primary international space partners. Modern five meter stage manufacturing is available right now.

This dual fuel hydrogen core and hydrocarbon booster configuration is not represented in the existing commercial medium and heavy lift booster inventory. Such a booster would be a natural evolutionary extension of our existing domestic, national, international and commercial launcher fleet, while still adequately satisfying basic requirements for a national civilian human space flight program, without infringing or competing with the markets currently operating or in development for EELVs and COTS.

Most importantly, several diverse engine upgrade, development and replacement paths already exist across the cryogenic liquid fuels under consideration – hydrogen and kerosene. The space shuttle main engine nozzles were scheduled to be upgraded to integrated channel wall nozzle technology of decreased costs, simpler manufacturing processes with greater resistance to damage. The Air Force has in place a research and development program for a comparatively novel full flow, closed cycle, staged combustion approach, with fuel to oxidizer mixture ratio biasing across the preburner and turbopump seals, and the incorporation of hydrostatic bearing technology into an Integrated Powerhead Demonstrator - or IPD. Several high power kerosene and hydrogen engine design concepts came out of the original SLI work, and coproduction of the RD-180 was another program near completion when work suddenly stopped. Pratt and Whitney (Rocketdyne) has done much preliminary work on SSME derivatives and the RL-60. The already developed Russian RD series engines and NK-33/43 are already among the least expensive and most efficient hydrocarbon engines ever produced – many still residing in real world inventories, and coproduction agreements are being pursued to maintain and reactivate their manufacturing bases. This launch vehicle architecture also represents a credible method of flying actual commercial versions of small, residual and storable fuel - roll control, orbital maneuvering, attitude control, staging and fuel settling engines, in a variety of real world orbital, vacuum research and development flight test settings, allowing many outstanding issues of modern rocket science to be solved - as new space policy suggests.

II. Market Research

Market analysis does not support development of such a modern booster configuration at this time. The demand for launch vehicle services is easily satisfied by current commercial and international offerings. What is required is executive office direction on such an effort, as well as congressional approval and authorization, for the funding that would allow any development and flight test operations to proceed, based upon scientific needs and NASA directives to complement and enhance commercial technology.

The respondent has previously provided ample reasoning for the necessity of launch vehicle evolution based upon simple logistical and accounting arguments alone, along with many persuasive future global programs and missions, and the Obama administration has now provided a space policy framework such that advanced propulsion and launch vehicle development may proceed again in earnest. What is lacking now is unambiguous executive and congressional commitment to fuel and stage configuration choices.

The choice is relatively clear, do the executive and legislative branches intend to move forward now on retaining and continuing hydrogen powered core propulsion on future heavy lift launch vehicles? Or do they intend to defer completely to future private commercial design, funding or development programs? Or do we continue to maintain the worst case scenario of the program of record – Constellation, that has already consumed an order of magnitude more funding than a commercial launch and propulsion sector which has exceeded its technological capabilities and time schedules in every domain of measurement, instead committing ourselves to solid rocket boosters incapable of attaining levels of modern propulsive efficiency, reusability, cost and schedule demonstrably needed to solve the real problems of civilization. If the answer is the former, private interests can assist you in bringing forth robust and modern reusable launch vehicle systems into rapid commercial operation, while the existing vehicle suppliers bring their commercial offerings online over the next five years. But if the answer is the latter one, then many of the problems previously solved for you are already obsolete by many years, and it is long past time to move on to other and more pressing and urgent areas of national scientific inquiry and intellectual discourse. In any case the answer is moot, and human space flight may further sink into the oblivion of irrelevance.

The decision to be made is whether or not to continue discussion of an improbably large national heavy lift launch vehicle architecture already thoroughly described in the literature, or rather now to discuss the numerous strategies for the commercial implementation any of these new propulsion and launch vehicle technologies, with an urgency and scale more in line with capabilities and funding profiles envisioned. In the first scenario, NASA is the prime contractor for a nationally owned and operated research vehicle, in the second scenario, NASA is critical enabling technologies partner for commercial vehicle operators; the operative missions being advanced launch vehicle propulsion research in a national research setting.

I have not yet been legally or financially authorized to make any executive and representative decisions, and so I defer to those who are currently in positions of power, to exercise their authority over the laws of nature. Nevertheless, an open mind is required because some of those elected regional representatives do believe that a nationally owned propulsion and launch vehicle development effort is still necessary to pursue tasks that may have little relevance to the problems of modern day society, whereas others still fully understand that the commercial space sector is underfunded to the point where they are still unable to develop the modern and sophisticated propulsion elements that would be required to credibly address some of the extremely difficult social, economic, and technological problems nature has presented to us, allowing the dire environmental situations we face to continue to deteriorate, with no solutions in sight.

My responses will be split between evolutionary hydrogen systems represented by my own architecture and the commercial technology that would complement the hydrogen cores with hydrocarbon boosters. This does not naively assume that small filament wound solid rocket motor boosters will not provide the additional thrust for the initial launches, or at some point in the future SRBs may provide additional lift. SRBs represent future augmentation to launch vehicle propulsion rather than developmental programs, as costs associated with super heavy lift launch vehicles and propulsion is out of scale with any funding.

Industry involvement early in the development phase is essential for NASA to formulate a strategy to meet the national objectives of enabling heavy lift systems and developing propulsion technologies that are both affordable and used by multiple customers. Any resulting acquisition approach will utilize these guiding principles :

a. Focus on affordability and low development and recurring costs.

Cost is the primary development and technology driver as it is the high cost of the commercial space transportation industry that limits the scientific and business goals and activities of the stakeholders. Obsolete heavy lift launch vehicle paradigms of SRB boosted hydrocarbon or hydrogen cores have been ruled out on cost of development considerations alone, leaving only the current paradigms of clustered EELV/COTS heavy evolution, or hybrid designs using existing SSMEs and RD-180s or NK-33s/AJ26s as interim engines pending development of future indigenous second generation reusable replacements.

b. Maximize competition.

Complementary to cost is performance. Clustered expendable designs are scaled up versions of launch vehicles currently in production, operation or development, and provide very little actual cost incentives. By using minimal five meter hydrogen cores powered by space rated reusable SSTO capable engines, the added value of the use of industry hydrocarbon assets, the recovery of hydrocarbon booster stages, and the easy achievement of low Earth orbit by the integrated core stage, could provide the four existing primary and major EELV and COTS producers with the technology boost necessary to spur innovation, which in turn would incrementally lower costs of the already expensive major launch service providers, and dramatically lower the programmatic and infrastructure costs of any major national space endeavors.

c. Satisfy multiple users inside and outside of NASA.

Stakeholders, Customers, Supply and Demand, Product Value and Quality, Entropy and Exergy. This requires in depth discussion in an entirely separate paper, as it is well beyond the scope of this RFI.

d. Apply the appropriate set of performance measures and incentives.

Metrics for this specific launch vehicle and propulsion effort include cost, schedule, and performance. The goal is to bring an evolutionary launch vehicle propulsion program to operational status within five years, using Constellation contract and termination costs, 21st Century Spaceport and heavy lift funding. Cost is measured in dollars per mass delivered, amortized over the full developmental and operational value of the system, product or service delivered. Quality and value of that mass is calculated separately. Performance is measured by force, (exhaust) velocity and (vehicle) acceleration integrated over time and space, yielding position, momentum and energy in a well defined path through dynamical phase space.

Both cost and performance are tied to value and quality, not always measured in dollars and SI units.

The value and quality of the product, service or system drives demand, and is driven by demand, in a process known as evolution. Performance metrics based upon real physical measurements enable the development of theories and models based upon prediction, giving results with precision and accuracy also amenable to quantitative measurement, modeling, and discussion, allowing the description of evolutionary systems in terms of entropy[11]. Scientific and engineering decisions optimize entropy.

After considering strategic issues of an international, diplomatic and national security nature, tactical design management, oversight and review will be quickly established and implemented using physical evaluation metrics in order to optimize value and quality with cost, schedule, and performance demands. Individual, component, system level, and organizational actions must converge to clear long-range goals while quickly adapting and responding in real time - to real world scientific and engineering exigencies.

e. Leverage existing industry programs.

Operational and legacy propulsion assets represent cumulative historical investments unmatched by any expected future funding profiles, and thus can greatly reduce launcher schedule and development costs. The launch vehicle architecture proposed already maximally leverages the space shuttle main engine inventory and its entire development, test, operational and flight history, along with numerous other structural advantages gained through the Ares I upper stage development program, while interfacing nearly seamlessly with the spectrum of EELV fleet and COTS propulsion and launch vehicle efforts, along with the variety of advanced propulsion research and developments programs well underway.

f. Review all requirements from a zero-based approach.

This launch vehicle architecture satisfies requirements for a NASA funded reusable heavy lift research and development vehicle for fast tracking modern reusable launch vehicle technology into operations. Cost accounting will mimic that of a purely competitive commercial orbital space transportation system. Customer and user base will also include military, civil and commercial research and development tasks, so that technology transfer into the commercial space transportation and development sector proceeds.

g. Maximize the use of small businesses.

The proposed payload for this launch vehicle architecture is the commercial propulsion program itself, extended as rapidly as possible into the full orbital and vacuum regimes of low earth orbit space flight. The form of the vehicle is driven by the requirement to satisfy the broadest set of applications across the spectrum of cryogenic liquid and storable fuel engines, and their anticipated performances and missions.

III. Inputs

Using the information above with the overall goal is to provide heavy lift systems and propulsion technologies that are both safe and affordable and will serve multiple customers. NASA is inviting industry, academia, international and other non-government research organizations to provide inputs in the following specific areas :

1. Propulsion Systems

a. Provide information regarding your potential launch or space transportation architectures (expendable, reusable, or a hybrid system) that could meet multiple customer needs (e.g., NASA, DoD, and Commercial). Describe potential reference missions. Describe the engine or engines required to meet your requirements to include those for different stages and potential in-space utilization. Outline known development efforts and technology insertion; sharing of information, sharing of facilities; etc.

The heavy lift launch vehicle and propulsion architecture I have proposed is a dual fuel hybrid system, incorporating the most valuable liquid fueled assets from the combined STS, EELV and Constellation programs, into fully recoverable, retrofittable and reusable, high flight rate, low Earth orbit space flight operations capable of supporting robust commercial spaceflight research and development activities, and a reasonable prototypical unmanned and manned deep space exploration program, within the anticipated budget constraints that are predicted to be relevant over the next five years. The potential prototypical reference missions would start with simple equatorial space launch and propulsion to low Earth orbit in the near term, and leads to integrated upper stage landings on asteroids, the moons of Mars, and Ceres.

Engines required are the existing inventory of space shuttle engines remaining from the shuttle program, hydrocarbon booster engines coproduced with the Russians, an entire suite of rapidly evolving storable fuel engines from the private sector for numerous attitude control, reboost, rendezvous and landing tasks and the second generation reusable hydrogen and hydrocarbon engines currently in the conception stage. Upper stage propulsion will include numerous high I_{sp}, solar and nuclear powered development efforts. Known developments are the Pratt & Whitney RD-180 and Aerojet NK-33/AJ26 coproduction efforts, Pratt & Whitney RL-60 high energy upper stage design, RS-25 second generation SSME development, Aerojet and Air Force Integrated Propulsion Demonstrator (IPD), and a Falcon BFE based on the RS-84. SpaceX is also actively engaged in first stage recovery and three abreast clustering of this stage, for the anticipated future low Earth orbit heavy lift capacities, and has shown a general interest in high energy hydrogen powered upper stage engines and their clustering, demonstrating the veracity of this approach.

Technology insertion for this particular architecture is straightforward given clear separation of powers among the stack components - hydrogen core stages, hydrocarbon boosters, OMS engines, the attitude control system, and direct integration of the core stage into the LEO mission and the upper stage into the exploration, discovery and exploitation missions to low gravity bodies that are anticipated in the future. Presumably these technology insertions would also work in reverse - industry developed breakthroughs and innovations would be retroactively reinserted into the research and development environment for further exploration and refinement. This is how evolution proceeds - producing well adapted systems.

b. For vehicle providers, provide your top-level requirements including: operability and affordability (low life cycle cost); safety (minimize catastrophic failures, loss of vehicle, etc.), and performance (thrust, ISP, throttle range if any, mass to LEO/GTO,etc.), and both current and future upgrade plans.

For reusable launch vehicle architectures to break through the existing barriers to cost reduction, the ability of the entire ground started core stage propulsion system to reach low earth orbit is essential. The existing suite of space shuttle main engines is ideally suited for quick demonstration of this hypothesis. The minimum payload capacity is estimated to be twenty five metric tons - with a 25 metric ton vehicle, giving a rough estimate of 50 metric tons of payload, vehicle core stage tankages and engines into orbit, classifying this particular configuration as the minimum heavy lift launch vehicle and propulsion design. Future upgrades involve increasing the number of boosters rather than increasing the core tank diameter, further reducing stresses on the core stage propulsion system, moving it into upper stage flight regimes and making it even more attractive to dual use, second generation, deep throttling engine applications.

Provide rationale as to how these requirements were derived.

The failure of the Constellation program has clearly demonstrated the inadvisability of super heavy lift. This requirement was derived by the observation that a large orbital debris problem now exists, and the existing expendable launch vehicle fleet of EELVs and COTS vehicles are not cost effective enough to enable the high flight rates and low operational costs necessary to support future mission requirements. The dual fuel, booster assisted recoverable, reusable and retrofitable stage configuration proposed by the respondent provides a technology bridge between the conventional and small scale propulsion efforts of the commercial space sector, and large scale space transportation systems anticipated in the near future.

c. Identify strategies to lower propulsion system costs and improve operability including overhead; improved manufacturing processes; lower staffing; and elimination/tailoring of specific government requirements.

Costs and operability may be improved immediately, by not demanding human rating of the vehicle. Kennedy Space Center (KSC) Vehicle Assembly Building (VAB) assets will be converted to four bays feeding multiple pads at two separate launch sites (SLC 39 A and B) with simple dollies and railroads. Horizontal to vertical transitions, stacking, mating and pad transportation operations will be streamlined into flexible operational procedures as flight rates to low Earth orbit increase as costs begin to decrease.

d. Describe methods to effectively manage to a lower per production unit cost (for example, lot buys, design to cost, cost incentive structures, non-traditional business arrangements, anticipated business, sensitivity to business base, etc.).

Once a functional design is selected and flight tested, production lots can be ramped up at facilities designed to handle the kinds of unit and volume runs that can be expected for the space rated hardware necessary to engage the public in new large scale space transportation and life habitation developments.

e. Describe how you would leverage any existing efforts to include hardware, designs, analysis, and facilities to save cost and accelerate schedules.

Boeing and Pratt and Whitney Constellation contracts, in particular the P&W space shuttle main engine contracts will have to be renegotiated for maintenance and documentation of the existing SSME engines. Variable cryogenic tankage designs incorporating both separate and common bulkheads, ground started and vacuum stacking arrangements, longer lengths, different diameters, and the various primary fuels would be required on a periodic basis for the flight testing essential for implementing the aggressive cost reduction techniques that will be necessary to compete in any future competitive commercial markets.

Existing industry and commercial launch vehicle vendors would be called upon to provide boosters for the hydrogen core stage, and small businesses would be called upon to outfit and space rate those stages, and to provide the orbital and attitude maneuvering engines, sensors, guidance, navigation and attitude control systems and a host of accessory payloads, related to the primary mission of the spaceport based disassembly and reassembly of the core tankage into new useful assets such as fuel depots and habitats, solar power satellites, and interplanetary exploration spacecraft, as well as return shipping back to Earth. Much of this work will begin immediately upon the commencement of test flight operations at the ISS. The international space station is thus given an assignment not predicted during its initial development.

f. Describe potential acquisition strategies for enabling development of large propulsion systems and pros and cons of the strategies.

There are two opposing strategies to quick implementation of heavy lift launch vehicles and propulsion, the traditional NASA method of in house executive direction, and the new commercial approach, which funds external research and development in order to drive commercial expansion - the 'Embraer Effect'. In order to guarantee success, both approaches could be accommodated within the existing budget, if the form factor of the vehicles were small enough and versatile enough to satisfy external R&D demands. The problem, of course, is that any in house effort will consume funds away from missions for these new vehicles, although proposed missions are far enough in the future that they can be safely ignored.

A balance must be struck between the potential of small commercial new space companies to quickly grow into the performance and capabilities required of low Earth orbit space flight, with respect to the existing large and costly EELV and STS infrastructures that we already possess, which are flying today. These approaches are seen as complementary across a spectrum of government and commercial value.

I have proposed this rational, affordable and complementary compromise plan in order to salvage useful components of Constellation – Ares I upper stage fabrication technology and space shuttle main engines, so that commercial research and development and their asset applications can be quickly brought online, without consuming the funding necessary to implement this new strategy. This isn't Constellation redux. This plan drives the commercial space sector into full maturity through its investments in reusability and maintains, reforms and improves the NASA management, employment and infrastructure bases into the government funded research and development organization that the previous administration dismantled, while being modest enough in performance and capabilities, and honest enough about workforce issues.

2. Basic Propulsion Research

a. Provide general areas where you believe gaps exist in liquid chemical propulsion technologies that could lead to breakthroughs in mission affordability and capability. Liquid chemical propulsion technologies include discipline focused research into such things as materials, manufacturing, combustion processes, propellant chemistry, and other propulsion system elements (such as tanks, valves, feed lines, and health management). Identify strategies for insertion of these technologies in new propulsion systems and also how to make them available to the industry for multiple applications.

The primary barrier to order of magnitude improvements in launch vehicle and infrastructure costs for future advanced mission scenarios is the cryogenic tank insulation. Space rating of upper and core stages of modern cryogenic launch vehicles must adhere to strict orbital debris regulations. The greatest danger to low Earth orbit operations is the shedding of material from spent or otherwise discarded upper stages. Cryogenic fluid handling technology is fundamental to almost all of modern condensed matter physics, and so problems of space rating the large cryogenic core and upper stages and converting them to space habitats, fuel depots and asteroid exploration missions, are amenable to methods of engineering science. With the investments in creative insulating, anti-icing and deicing technologies, along with the active management of the cryogenic boiloffs and tank pressurization throughout the launch and cruise phases, cryogenic stages could to be space rated at the outset, with a variety of functions that include habitation, fuel and regolith management and resource exploitation. A true space exploration program can proceed.

Large cryogenic fuel tanks engineered to the physical limits of their structural efficiency have converged to industry standard fabrication methods, which are now amenable to the benefits of mass production. Future engines will be designed such that they can operate in both ground started single stage to orbit configurations, and in the vacuum started and operated manner required for propulsive BEO operations.

In order to inject these very advanced and risky technologies into the private sector, they must be thoroughly vetted at the operational level, and the government operated research and development architecture such as the one I have proposed is an ideal way to accomplish timely insertions, without compromising the ability of our existing EELV and COTS fleets to meet important national objectives.

b. Describe methods to effectively manage the strategies for technology insertions, including nontraditional business arrangements.

The programmatic and infrastructure decisions described herein are fairly straightforward once credible trade studies have eliminated most of the fiscally unviable operational heavy lift launch vehicle solutions formerly proposed by NASA and industry. I have repeatedly pointed out these are top level executive decisions that can only be mandated by the president and congress since they involve government assets.

The commercial space sector has already demonstrated considerable flexibility and adaptability in its abilities to adopt alternative business relationships and to quickly respond to evolutionary advances in technology. The philosophical changes that I have exposed with regards to reusability, recovery and on-orbit assembly and retrofit, mission operations and goals, and the top level scientific engineering of the reasoning behind such activities, are now of such critical national security importance - they can only be implemented when a consensus is reached among all of the active participants, the public and congress.

Consensus was self evident during the post Sputnik Apollo era, but for entirely different reasons, and the current situation demands that a consensus should be self evident, merely by perusing current events. Thus I patiently await executive office thoughts on these matters, at the national and international levels.

c. Identify how you would plan to bring existing mid-level Technology Readiness Levels (TRLs) to operational levels at an affordable cost through test programs, ground demonstrations, and flight demonstrations.

The Cape Canaveral Air Force Station (CCAFS) and Kennedy Space Center (KSC) represent a golden opportunity to test, fly and commercialize small and large conventional liquid fueled launch vehicles and their propulsion systems with almost no caveats beyond cost. The real estate value is immense.

With Space Florida participation at SLC 36 and 46, any small launch vehicle tests may be performed, greatly reducing the costs of technology development in these launch and orbital space flight regimes. The entire spectrum of the ever increasing capabilities of the suborbital flying wing, rocket planes and experimental rocket businesses will be at the disposal of engine, airframe and sensor developers with rapid turnaround daily flights and nearly real time performance of experiments and collection of data.

This proposal encompasses the scaling up of the already planned commercial activities up to the level of previous nationally funded space development efforts - STS and ISS, without burdens of cost and risk. Risk and cost can be more effectively managed at the prices and schedules of these suborbital and small commercial launch vehicle and spaceflight organizations, within the framework of actual commercial operations, so that advanced technologies can be thoroughly vetted before insertion into large national and commercially operated EELV and COTS systems that are vital to global and national security needs.

d. Describe how you would envision working with multiple customers (including DoD, NASA, and commercial) to identify top priority technologies and their associated payoffs.

The level of participation thus far has been on the level of the 'commentary' necessary to bring the problems of Constellation under an increased level of public, congressional and presidential scrutiny, to ensure that a national dialogue illuminated its severe technical, fiscal and management deficiencies.

In order to understand and remediate the deficiencies that have led to this critical national failure, the author and his collaborators embarked upon a multi-year effort to analyze technological paths forward, the most successful example of which is the current administration's plan to commercialize LEO access. There is no need to make any fundamental changes to the current policy other than to placate dissent and to obtain the most satisfactory result from previous development efforts, expenditures, and legacy assets. Bulldozing the existing infrastructure and mothballing the engines is not necessarily the optimum result. Since heavy lift launch vehicle and propulsion technology is clearly still on the development agenda, we only wish to obtain the optimum result for the minimum investment in a technology (conventional liquid fueled, vertical, heavy lift launch) which, other than not meeting its cost, schedule and efficiency goals, has otherwise been a great success, and has resulted in order of magnitude improvements in space flight. It is hypothesized that shed of its responsibility for SRBs, human transport, and winged return, it could easily meet those cost, schedule and performance goals, and possibly deliver the breakthroughs needed to bring order of magnitude improvements to those metrics - originally promised, but not yet delivered.

This national dialogue on these complex and interrelated global planetary physics problems can only result in a clearer understanding of the complexities and details of human space flight and the associated knowledge of science, technology, engineering and mathematics necessary to comprehend these issues. Ignoring the clamor and dissent, it has significantly enlightened the electorate on costs and capabilities, and sharpened the understanding of the value of space flight technology in improving our quality of life.

Not only must this process proceed, it must be scaled up significantly in the very near future in order to cope with the escalating environmental dilemmas posed by a vastly overpopulated planet supported by the continued atmospheric combustion of carbon. Somebody has to take this initiative. It is regrettable that the easily predictable timeline of contemporary events has inevitably stepped in to force the issues, just as it is easily predictable that current events will continue to drive this dialogue, and its responses.

The respondent has already in the several previous decades engaged in the due diligence necessary to illuminate and identify numerous potential solutions to our distinctly human planetary condition, in the form of alternative energy research and industry creation, closed ecological life support systems and its industry creation, in superinsulated carbon neutral Earth home designs and space commercialization. At the very least, the continuation of these activities is advisable, but a more active role can be envisioned.

e. Describe approaches for utilizing the unique capabilities of our nations colleges and universities in addressing technology gaps, including identification of gaps these academic institutions may be uniquely qualified to address. Discussion may include a vision for the development of the next generation of scientists and engineers in the space launch propulsion arena through outreach, partnerships, and direct involvement in the technology program.

Solutions to fundamental problems of the human condition encompass a three fold approach to analysis; quantum and condensed matter physics in the microscopic regime, astrophysics and space exploration in the macroscopic regime, and planetary sciences, biology and medicine in the mesoscopic human world. Astronautics and astrobiology must be elevated to the level of national scientific discourse, and funding priorities on par with microscopic solutions that have already demonstrably improved our daily lives. The quickest way to accomplish this, is to reach out to and incorporate those institutions which already participate in the funding, construction and operation of spectroscopy research laboratories across the world, and who generally view space science and astronautics as competitive to limited funds available; our university astronomy, physics, chemistry, the engineering sciences and the biomedical communities. The best way to ensure this is by executive order and congressional mandate to reduce space flight costs. Once a serious application of national intellectual capital is directed at this problem, it will be solved, opening up the astrophysical world into our ever expanding economic, social and political aspirations, relieving the environmental pressures of an ever growing population restricted to the surface of Earth.

f. Describe how you would leverage any existing efforts to include hardware, designs, analysis, and facilities to save cost and accelerate schedule. Identify any existing assets in which you require or obtain benefit to support the technology maturation in a timely, affordable, and efficient manner.

The entire Ares I upper stage development project at Marshall Space Flight Center in Huntsville would be redirected into five meter core and upper stage development for hydrogen and kerosene propulsion, using the heavy lift development funds provided for in the budget. Kennedy space center would escape decommissioning costs and be retrofitted into 4 bays, feeding multiple launch pads at two separate sites, under 21st Century Spaceport funding. Hardware development funding will come from the renegotiation of the existing upper stage Constellation propulsion, structures and avionics contracts. The space shuttle main engines are exempt from any development and production costs, and the hydrocarbon engines are simply purchased from our international partners or domestic coproduction sources, until such time that more modern engines can materialize at the normally slow pace of advanced rocket engine development. Meanwhile, a viable and robust commercial orbital space transportation market can proceed unhindered.

3. Program and Business Management

NASA is seeking industry inputs into methods to manage these programs to include effective and affordable business practices.

Fully amortized accounting practices over the entire life cycle of the program must be compared to the current industry and commercial prices and capabilities, which can simply be bought off the shelf. Until an executive and congressionally driven launch vehicle design succeeds in solving mission requirements at a cost less than current market prices for such services, it makes no sense to invest in its development. Neither Constellation, nor the EELVs or COTS vehicles satisfy the mission requirement for reusability. An executive and congressional mandate of reusability and recovery in our orbital space transportation systems is required to close the business case for high technology cryogenic launch vehicle propulsion.

a. Describe processes for the overall management of the program to most effectively develop propulsion systems and technologies.

First step is to consistently fund fundamental high energy cryogenic hydrogen and kerosene propulsion at relatively high levels. Astronomy, propulsion and space habitation need to be made national priorities in order to generate the level of enthusiasm required for its widespread public support, and thus its strict program oversight, and to propel propulsion technology to the forefront of public astronautics research.

b. How would you propose to participate in systems analysis and assessments?

Scientific and engineering judgments are obtained by arguing the empirical data, constructing models in the mind, in mathematics, physics, software and materials, and then further comparing them to new data. This involves making decisions that limit or expand the set of accessible states of systems under study, or in their models and hardware constructions, which optimizes the overall production of entropy based upon our abilities to consider internal and external perspectives of evolutionary systems which already possess a considerable amount of momentum. Geometric approaches to evolving dynamical systems optimize our current trajectory, so that future goals can be achieved from the path we are now taking.

The goal that we wish to achieve with this launch and propulsion research and development program is full reusability in a future cryogenic heavy lift low Earth orbit launch vehicle within just five years time, through recovery of the first stage hydrocarbon boosters, and the single stage to orbit capabilities of the hydrogen powered core stage, which permits recovery, retrofit and reuse of the propulsion and vehicle. Analytical and qualitative value base decisions have already been made restricting the effort to this task.

c. How would you propose to serve in an advisory capacity for the program providing input on content and objectives and evaluation of performance and results?

The respondent proposes a five (5) year, five hundred thousand dollar ($500,000) contract running from now through the end of the Dawn mission to the planet Ceres in 2015, based upon the estimated cost and valuation of the performance thus far, equivalent to a McArthur Foundation Fellowship award and grant, producing four quarterly reports and one annual report per year, for five full years, at $20,000 per report.

The only other responsible position is NASA chief of staff, interfacing directly with the executive office when confidence levels are reached in regards to previous due diligence and commitment to the project. (Opps, I just noticed that Dave Radzanowski got the job. Ok, forget that then. Congratulations Dave!)

This offer is valid only if a commitment is made *right now*, at the presidential and congressional levels. The ideal location from which to direct such an effort would be the NASA Software IV and V facility in Fairmont, West Virginia, the home state of Senator Jay Rockefeller, the Chairman of the U.S. Senate Committee on Commerce, Science, and Transportation, in very close proximity to Washington D.C., making any presumed strict congressional oversight of this project open, transparent and accessible.

d. Identify barriers to competition and mitigation strategies.

The single barrier to competition within the commercial space transportation sector is economic failure. The costs of low Earth orbit transportation and space flight must be reduced to a critical transition point where continuously decreasing costs and ever increasing capabilities produces more demand for their vehicles and services, in contrast to the present situation where the costs of basic space transportation have been increasing dramatically because of flat or decreasing demand for their expensive products, and a perceived lack of relevance to national priorities and grass roots space development efforts that can capture the imaginations of large sectors of the population, creating a solid base of public support.

The commercial space transportation sector has begun the tentative process of creating the competition that will incrementally reduce costs and increase capabilities, but the scope and severe magnitude of the expected future scientific, environmental and national security problems and their solutions, of a global and international stature, glaringly obvious and unambiguous for everyone to see, demands the order of magnitude improvements in the full reusability of the powerful, complex state of the art equipment that only our national, scientific and engineering funding priorities can provide. The commercial space sector and the federally funded research and development establishment, which forms an integral component of the solution strategies for these clear global economic, environmental, social and political problems, are complementary, and cannot be developed from an antagonistic, competitive environment or perspective.

e. Discuss procurement approaches to include alternative business arrangements.

Two stage to orbit small kerosene boosters will soon proliferate the medium lift launch vehicle market, whereas the only indigenous American efforts in large, heavy lift, side mounted, booster staged vehicles, have been the space shuttle and the Delta IV Heavy, both now overly expensive and underutilized assets. Both of these efforts also required alternative cooperative business relationships within the competitive commercial launch vehicle provider industry in order to maintain operations under fiscal deficiencies.

Given the escalating costs and decreasing flight rates as payload and launch vehicle mass and volume increases, unless breakthroughs in decision, design, manufacturing and operations in this domain occur, alternative and cooperative agreements between the government and commercial industry are inevitable. The shuttle and EELV programs, and even COTS and CRS, are de facto government subsidized efforts. The fact that they have survived and thrived under alternative cooperation, subsidy and award structures, is a testament to their success in satisfying clear national priorities requiring guaranteed access to space. However, their failure to provide inexpensive access to space has now reached the level of a national security problem, and these same systems have become the primary barrier to accomplishing that goal.

The goal of inexpensive and widespread access to low Earth orbit has now subsumed and exceeded the desire of a limited small fraction of the scientific, space advocacy and industrial community for a robust deep space human exploration program, and obsoleted many previous and existing conceptual means of achieving that goal as illusory at best, and delusional at worst. Unless these goals achieve widespread public support, and are placed upon a firm technological footing and a strong foundation of honest and reasonable fiscal support, they will not be achievable even with the creative and ambitious cooperation among the various and diverse participants. These are costly and time consuming lessons Constellation has delivered. If these lessons are ignored then any subsequent attempts to relearn them will surely fail.

f. Discuss effective methods of utilizing international partnerships while maintaining appropriate safeguards for U.S. developed technologies.

United States propulsion technology excels in the hydrogen domain, obviating any Russian hydrocarbon engine importation and technology coproduction issues. Russia has recently expressed a willingness to cooperate on future in-space upper stage propulsion efforts, and is already closely involved in the ISS.

g. Recommend process improvements and efficiencies, both in the acquisition phase as well as the performance phase, along with identification of non-value added steps and requirements.

Clearly outside trade studies are appropriate for second opinions, and this RFI and the associated BAA and trade study contracts are a step in the right direction. However, this respondent has already spent a great deal of time on this process, derived an achievable result, made difficult but necessary executive decisions, published the appropriate commentary in order to facilitate the desired result, and the Obama administration has codified that result into the various line items in the Fiscal Year 2011 NASA budget.

I am confident that further honest and fiscally sound trade studies will converge to either of these two results – the administration's decision to leave heavy lift launch vehicle development to evolutionary and incremental commercial launch vehicle designs, or for executive and congressional direction and a clear mandate to maintain current large investments in hydrogen powered core stages for LEO transport, with an emphasis on indigenous commercial and international cooperation on the storable fuel in-space and upper stage propulsion, hydrocarbon fuels for booster augmentation and the mandate for reusability, recovery and retrofit of the upper and core stages and the return of the hydrocarbon boosters, in order to greatly increase efficiency of existing government assets, and reduce programmatic infrastructure costs.

The respondent is grateful for the opportunity to present and argue these results for your consideration, but regrets that there is no longer any motivation to continue this research, when many other reasonable, credible and serious scientific and personal security problems await even a modest funding and review.

IV. Summary

These thoughts only represent a snapshot of my thinking at this time. I have already made the decision to move on to urgent terrestrial matters, such as agriculture and employment - as my job here is done.

The information obtained will be used by NASA for planning and acquisition strategy development. NASA will use the information obtained as a result of this RFI on a non-attribution basis. Providing data and information that is limited or restricted for use by NASA for that purpose would be of very little value and such restricted/limited data/information is not solicited. No information or questions received will be posted to any website or public access location. NASA does not plan to respond to the individual responses, but will provide an update to development and acquisition plans.

This RFI is being used to obtain information for planning purposes only. The government does not intend to award a contract on the basis of this RFI or to otherwise pay for the information solicited. As stipulated in FAR 15.201(e), responses to this notice are not considered offers, shall not be used as a proposal, and cannot be accepted by the government to form a binding contract. Inputs shall be compliant with all legal and regulatory requirements concerning limitations on export controlled items.

All responses should be provided in MS Word document format via electronic media. Font should be Times New Roman, size 12. Responses should not exceed 50 pages total. Responses are requested to be submitted in Microsoft Office products in a user friendly environment to facilitate review. One hard copy and 3 CDs or DVDs are requested. This RFI will be issued and posted from Marshall Space Flight Center. Please submit responses no later than May 21, 2010, to NASA/MSFC Office of Procurement, Attn:PS52/Melinda E Dodson, Contracting Officer, Marshall Space Flight Center, AL 35812 or via email at melinda.e.dodson@nasa.gov. Additional questions should also be provided to Melinda E Dodson via e-mail. An ombudsman has been appointed -- See NASA Specific Note "B".The due date for responses is not extended. Documents related to this procurement will be available over the Internet. These documents will reside on a World Wide Web (WWW) server, which may be accessed using a WWW browser application. The Internet site, or URL, for the NASA/MSFC Business Opportunities home page is http://prod.nais.nasa.gov/cgi-bin/eps/bizops.cgi?gr=D&pin=62

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