The Space Case – The Case For Space

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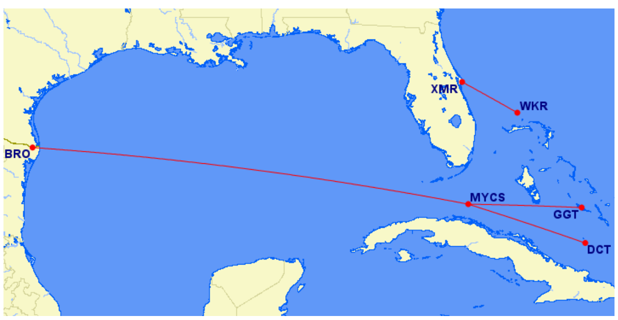
The tenure of the human species on planet Earth is over. We have irreparably raised the carbon dioxide levels of the atmosphere beyond what can be resolved with terrestrial based science and engineering solutions if we wish to continue to feed seven to nine billion humans with arguably delusional beliefs. For humanity to continue with life as we know it on this planet, we must either terraform it beyond any recognition, forever losing immense biological diversity and richness of environment to development, or we must move our human unique constructions into space. By using Earth as a biological repository for cultivating and propagating radiation and impact protected habitats, generations of future humans can live, work and raise families in space, under reality based conditions, without fear of catastrophe. In this paper I will discuss the specific technological and engineering breakthroughs required to do this.

The immediate problem is NASA inability to field a reasonable reusable launch vehicle in a reasonable amount of time at reasonable costs or even any reusable launch vehicle in any way shape or form at all. Now is clearly the time to make the case to the public for large scale private space development efforts. NASA Space Launch System (SLS) and the Orion Capsule (MPCV) are headed for cancellation soon, with a looming government shutdown due to a lack of agreement on any continuing resolution funding legislation. SpaceX and Blue Origin appear to be willing to take over the former space shuttle pads 39A and 39B at the Kennedy Space Center (KSC), to use for their own fully reusable hydrogen and methane powered Moon and Mars rockets, as well as for near term launching of private passengers into space. SpaceX has just recently flown a new prototype Falcon 9 reusable booster configuration successfully.

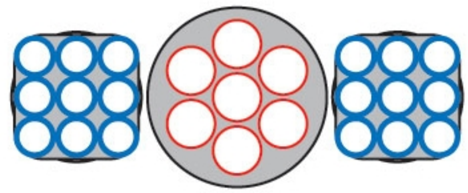
Modern launch vehicle and spacecraft design, stacking, staging and integration technologies indicate that most of the techniques for fielding high fidelity and high cadence space architectures are possible. Indeed, many of these technologies are very close to implementation and can soon be tested in space. Reusable SpaceX boosters are on the verge of becoming a new reality, and I have identified two viable downrange booster landing sites in the Bahamas - Walker's Cay for high inclination flight from Florida, and either Cay Sal, Ragged Island and/or Great Exuma in the Bahamas for long range ballistic landings of center crossfed Falcon Heavy booster cores launched into equatorial orbits from Brownsville, Texas. Recent simulations have indicated that the large center booster cores surrounded by cross fed boosters have a high enough attainable delta V such that they will require no downrange landing sites, and can fly direct trajectories to low earth orbit, high earth orbit or escape velocity, with enough residual fuel or payload remaining to perform useful insertion or landing maneuvers upon reaching their destinations. On such flights from Florida, early staging outer boosters can either fly directly back to the launch site, or land at suitably located downrange landing sites in the northern Bahamas, for instance, Walker's Cay.

Downrange ballistic booster landings result in significant fuel savings and orbital performance increases which can be passed on to the customer. The cost in retrieving landed boosters is minimal. Once technical skill in precision booster guidance and landings is achieved, overflight and landing rules can be developed to encourage land based point to point booster delivery for crew and cargo. Booster assisted space planes are also envisioned for core booster recovery and passenger delivery.



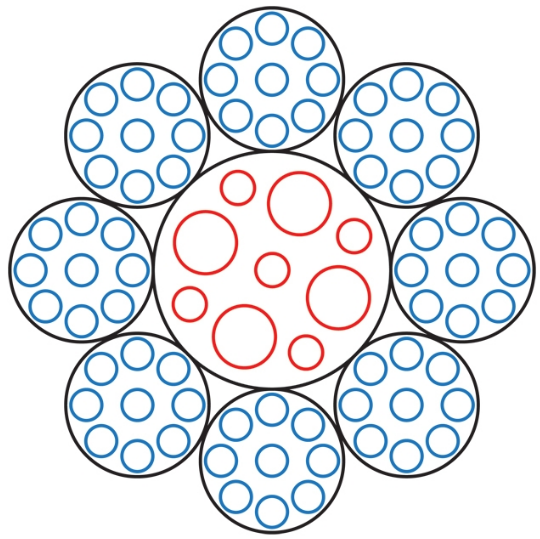
Bahamas Space Ports Great Circle Mapper

Booster Staging, Cargo Delivery and Vehicle Return



- Return to the launch site with cross feed.
- Ballistic short downrange with cross feed.
- Hypersonic long downrange with cross feed.
- Low earth orbit with aerodynamic reentry.
- High elliptical orbit with aerobraking.
- Escape velocity with free return.

Engine and Booster Clustering, Stacking and Staging



- Inline staging, two stage to orbit.
- Parallel staging, two stage to orbit.
- Parallel staging, two stage to escape.
- Parallel staging, three stage to escape.
- Small engine cluster with center engine.
- Single large engine with landing engines.

Booster and Core Stage Cross Feeding

- Outer booster to core stage cross feed.
- Outer booster to adjacent booster cross feed.
- Simultaneous booster and core stage cross feed.
- Dual fuel methane and hydrogen with no cross feed.

These recent technological developments in launch vehicle configuration and design, long anticipated, now make it abundantly clear that in the very near future space transportation will involve very large, fully reusable, cryogenically fueled (methane and hydrogen) parallel staged, cross fed launch vehicles, with the wide variety of staging and vehicle return options necessary to embark on space development. What remains to be developed are habitats and destinations for this private space development effort. Given the cost and complexity of designing, constructing and operating even fully reusable launchers, the question naturally arises of how we can afford to construct large space habitats for all of humanity.

This question is most easily answered by considering fortuitous details of our solar system structure. The Earth and its Moon are very nearly a double planet system, and the axial tilt of the Moon is very nearly perpendicular to the plane of the ecliptic. Mars is a water soaked sub-terrestrial planet, with a surface gravity of less than half of Earth's, and it possesses two small moons in orbits that are in the equatorial plane of the planet. Similar to Earth, Mars also has a roughly 24 hour long day and a nearly identical axial tilt of roughly 24 degrees. Furthermore, Mars has a carbon dioxide atmosphere which protects the surface from at least some of the radiation emanating from the sun and deep space, as well as from most small meteorite impacts. Thus, Mars already possesses abundant amounts of two vitally important compounds necessary for life – water and carbon dioxide, and the soil of Mars also contains abundant amounts of phosphorus. The atmosphere of Mars contains a roughly 1.89% nitrogen content and 1.93% argon content as well. Its atmosphere also provides aerobraking opportunities which greatly simplify surface landings. The Moon, although airless and generally waterless, due to fortuitous orbital geometry, possesses near its poles areas of nearly eternal horizontal sunlight, with adjacent deep, dark, cold reservoir craters with trapped volatiles. The lunar regolith is also rich in oxygen as well as a wide variety of metals, and thus it provides nearly unlimited materials for shielding and construction. The poles of the moon provide the strong optical and thermal gradients necessary to power the extraction and recovery of those resources it does possess. Thus we are confronted with a solar system geometry that, while not optimal, is clearly of a structure that is suitable enough for any planetary development and colonization efforts to proceed, even without considering asteroids, comets and the planet Ceres. The earth-moon system also provides geostationary orbits, which have already been commercialized, and both the earth-moon and earth-sun Lagrange points provide a large number of viable destinations.

In a series of white papers over the last year, I have described how these destinations can be reached with reusable rocketry, and how human habitation may be developed by these same reusable launchers. The fundamental premise is to bootstrap into a space based economy. Reusable launch vehicles using sequential booster staging will soon enable low cost delivery of large numbers of fully equipped and space rated launch vehicle core and upper stages to almost any space destination we wish to develop, with all of the necessary docking port nodes, inflatable habitats, solar arrays, thermal management and impact protection engineered and built into and onto the stages themselves for immediate deployment. Thus the fundamental building block units for space architecture development are the launch vehicles.

In other words, mission accomplished. Most of the pieces of the space puzzle are now firmly in place, for not only fully reusable launch vehicles and spacecraft but for development and colonization as well. Upper stages must be fully space rated as controlled free flight vehicles. Derelict spacecraft, such as Envisat in low earth orbit, must be recovered and salvaged. Large rocket bodies and other hazardous space debris must be removed from their offending orbits. Retired geosynchronous communications satellites must be utilized as deep space equipment and material resources, and landings on the poles of the Moon and Mars must be attempted, to determine and test the feasibility of local resource extraction. Low earth orbit space tourism destinations must be developed independent of the International Space Station (ISS) to provide a near term funding source and testing ground for space development concepts. Competitive commercial launch vehicle manufacturing and service industries, with multiple markets, must remain the core businesses of any private space development effort, as per the SpaceX paradigm.

We already know what future multi-use launch vehicle–spacecraft–satellite–space ports will look like – solar power satellites pointing at the sun with precise static and active attitude control systems, attached to large arrays of habitation modules connected together by long rows of cubic, multi-port, pressurized docking and berthing nodes. Habitation modules will consist of pressurized inflatable spheres installed into the upper fuel tanks of the upper and core stages of large reusable launch vehicles. In this manner, large 'Star Trek' like spacecraft can be quickly assembled and constructed, in both low and high orbits, where they can be augmented by harvesting and salvaging dozens of retired communications satellites. These large space ports and their attendant space ships will be serviced by reusable capsules and space planes, flying regular space tourist and cargo delivery flights, from space ports located the world over. Equipped with large articulated robotic arms and servicing spacecraft, the space age will have begun.

Shielding the inhabitants of these large spacecraft from both solar and galactic cosmic radiation will be accomplished by filling every available internal space with pure water, shipped directly up from Earth. Water will arrive in the form of residual cryogenic hydrogen, methane and oxygen fuels and oxidizer, which fortuitously is breathable, and for which every habitat already possesses large tanks to contain. Life support will consist of Sabatier reaction technology as backup, but primarily by large hydroponic plant grid arrays, powered and lit by the abundant and continuous solar power that is always available in deep space. Impact protection will be provided in the form of hardened and non-friable carbon fiber foam insulation covering the cryogenic fuel and oxidizer tanks, and by the large aluminum and carbon composite fuel tanks themselves – containing the impact protected inflatable habitats, cargo and water.

Complementary to the slow, methodical, profitable build up of space cities in low and high earth orbits will be resource utilization flights directly to the surfaces of the Moon and Mars. By leveraging the efficiency of reusable booster cross feed staging, entire fully functional core stages may be delivered intact to the surface, to begin in-situ resource utilization (ISRU) activities immediately upon landing.

The immediate value of the Moon is in daily flight opportunities using unique lunar direct trajectories, where hydrogen powered landings can deliver large amounts of residual fuel water and where the weak lunar gravity and abundant polar sunlight simplifies implementation of large scale hydroponic systems. Landed lunar systems will likely consist of large vertically standing core stages with a rotating collar, from which large deployable solar panel and thermal radiator arrays are suspended and on top of which a large lightweight parabolic light concentrator and reflector is deployed, which will direct polar light through a transparent airlock hatch and down the entire length of the interior inflatable habitat spheres. Visitors will cable elevator up the entire length of the lunar core stage and then enter from above, and residents will hunker down deep within the cable suspended complex of hatches, spheres and airlocks.

The primary purpose of such facilities will be providing power for the robotic industrialization of the poles of the Moon. Deep, dark, cold trap reservoir craters represent ready made refrigeration systems for cryogenic liquids, and the landed empty fuel tanks represent ready made storage solutions. While it may be difficult to predict just how the engineering evolution of large, distributed and automated lunar polar industrial complex operations might proceed, it is clear that any advances in the condensed matter physics of superconducting, thermomagnetic and thermoelectric devices will be what drives it forward. The need for experimental advances in materials, structures and devices is still dire, and extracting and storing cryogenic volatiles on the poles of the Moon will accelerate any new developments in this field.

National funding is demonstrably insufficient for large scale space development and industrialization efforts, and NASA institutional barriers prevent any significant progress in propulsion and architecture. Private capital must now step forward to fund and develop the enabling technologies for this endeavor. This includes in particular advanced reusable and restartable second generation hydrogen and methane engines with self contained pressurization, thrust vector control and startup sequence fluids and gases. Helium will most likely not be available in any large quantities in the future, and thus it is imperative that it be eliminated from the start up and pressurization sequences of all modern cryogenic engines. The same goes for the spray on polyurethane foam tank insulation widely used by the launch industry.

The debates over the benefits and disadvantages of hydrogen fuels over methane will continue for some time, however, clearly hydrogen is more appropriate for human rated destinations in near earth space, where an overabundance of carbon dioxide must be actively removed from a habitat's atmosphere, and methane is more appropriate for deep space applications where an over abundance of plant growth can be utilized to absorb excess carbon dioxide that the methane provides. High intensity hydroponic plant growth is easily capable of consuming the carbon dioxide emissions of a few numbers of inhabitants, and thus excess carbon dioxide must be supplied externally. Alternatively, excess methane produced by conversion of human produced carbon dioxide is more easily stored, particularly in cold lunar craters and in deep space. With respect to structural and mass limitations of hydrogen tankage, if the goal is the efficient delivery of large diameter space habitation using ultra clean tankage then clearly hydrogen has an advantage in near earth space development and colonization efforts, mainly due to its increased Isp, but also to its extremely clean burning properties in reusable high performance closed cycle engines. It also lends itself well to cryogenic tankage self pressurization schemes utilizing the engine bleed gases. On the other hand, for reliable multiple engine starts in deep space, methane has the advantage in that new innovative start sequences may be developed that do not use expensive and difficult to obtain and store helium gas, and where innovative long term, low boiloff, thermal management techniques apply.

Regardless of the outcome of the battle of the deep cryogenic fuels, with the caveats of the previously mentioned problems of upper and core stage and engine restartability and reusability, helium scarcity, friable tank insulation and the thermal management of cryogenic fuels in deep space, the process of the commercialization and development of space has begun, and it can be expected to proceed as long as the financial and environmental basis of civilization permits it. There is no shortage of methane fuel, aluminum for the fuel storage and habitation tankage and people willing and eager to work on a project.

It will be a race against time and money, but there appears to be no other viable options for this planet. Rainfall and weather patterns have been adversely affected by the increased warming and pollution and thousands of potentially hazardous asteroids still remain undetected, with no asteroid survey mission in sight. Large scale, thin film, expandable parabolic reflector technology is expected to be applied to the problem of asteroid deflection, and can equally be applied to problems of large scale space solar power, which can in turn be applied to problems of solar irradiance concentration, attenuation and modulation. Space tourism and colonization is now seen as a value added feature to global space imperatives, due to the fortuitous circumstance that launch vehicles are, by design, well adapted to human space habitation. What is clear is that with rapidly falling launch costs and vastly increased flight rates obtained through the use of clean burning cryogenic fuels and full reusability of launch vehicles, orbital space tourism alone will be able to fund the development of the necessary technological solutions to global problems.

The problem of the unrestricted growth of an industrial economy on a finite two dimensional planetary surface containing a fragile active biosphere can only be solved by removing the offending processes to space where they can be allowed to grow and prosper indefinitely – the Moon, Mars and the asteroids. These processes include energy production, resource extraction, refinement, production and storage, automated machining, manufacturing, habitat construction and operation, and agricultural production. By engaging in broad spectrum asteroid detection and orbital cleanup and deflection operations, we can assure that habitats dug deep into asteroid bodies and the Moon and Mars will be secure for an eternity. By keeping Earth as a pristine natural biosphere we will ensure that those habitats will be well stocked.

Space based geoengineering solutions combined with space colonization and terrestrial terraforming, along with the already acknowledged need for population reductions through sex education and birth control, energy conservation and efficiency through design, and materials and device improvement, are the only immediately viable paths to preserving the environment and the biosphere of the planet Earth, and ensuring the survival of all its current inhabitants, including, but not limited to, the human species. Large scale commercially funded space development activities can no longer be considered as optional, but rather as critical drivers of the technologies needed to solve these urgent energy related problems. Since NASA and the United States government are no longer in any position to fund these endeavors, it is now incumbent upon corporate capital and investment to recognize these fundamental facts and act appropriately, through self preservation, in order to jump start the necessary technologies and markets.

I have outlined the rational methods by which very large space development efforts may proceed, in the quickest possible haste, on the largest scale imaginable, and at costs previously not considered possible, and which when pursued, are capable of solving the most intractable problems of the modern world. If those who would enjoy the fruits of investment capital leading to growth and profit want to continue to enjoy the world that has made their lives possible – they will take note of and respond to these issues. National and international leaders take note as well. There are no reasons that governments the world over cannot participate in this grand adventure of space colonization, through things that they do best. This means adopting a reality based perspective on cost, schedule, performance and value of science and engineering projects they embark upon in relation to the clear global problems that must be solved. It also means deferring to private and commercial ventures whenever those metrics can be improved.