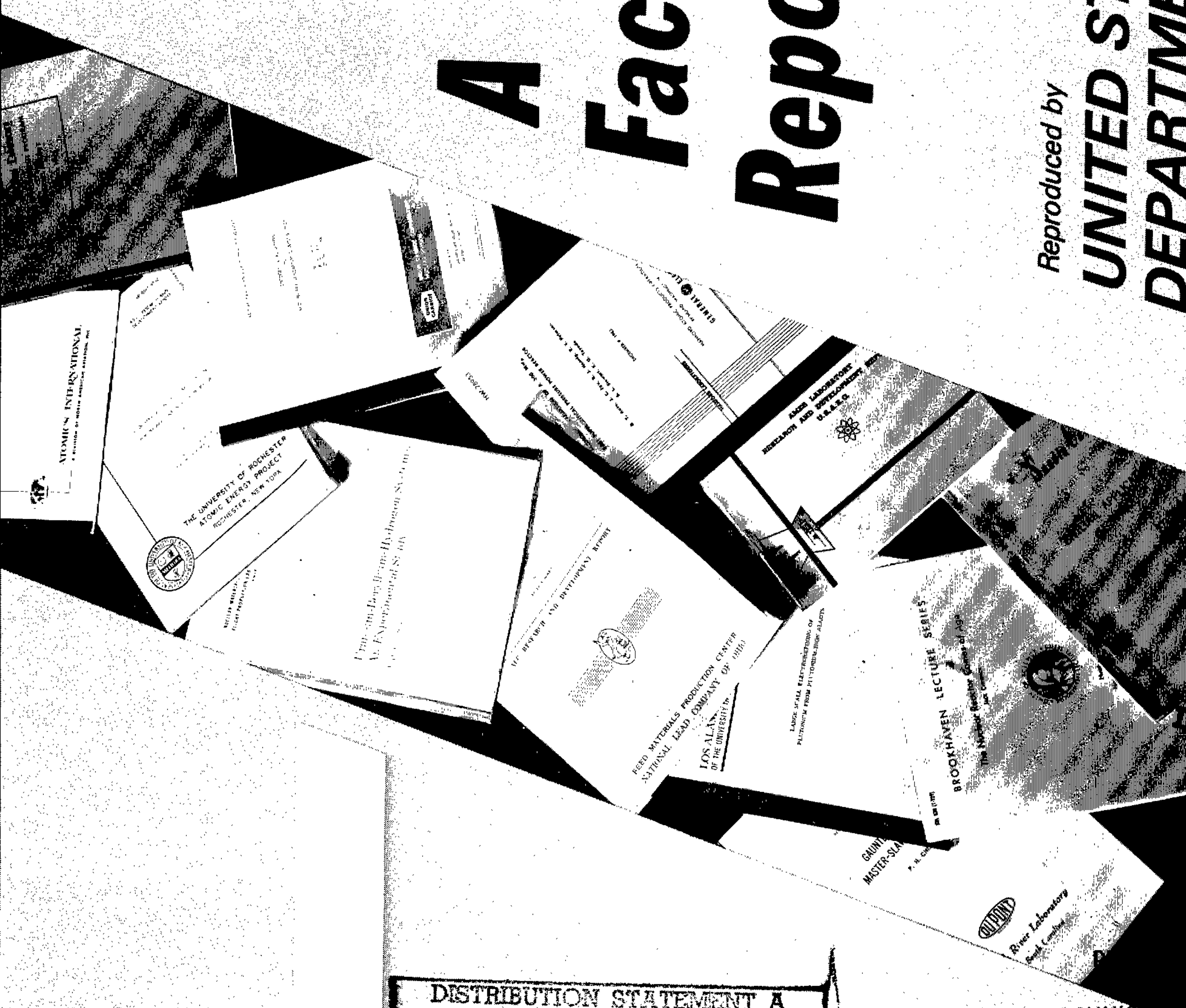
A Facsimile Report

Reproduced by
UNITED STATES DEPARTMENT OF ENERGY
Office of Scientific and Technical Information
Post Office Box 62 Oak Ridge, Tennessee 37831



Accession Number: 2902

Publication Date: May 23, 1990

Title: Securing America's Access to Space (Paper)

Personal Author: Rendine, M.; Wood, L.

Corporate Author Or Publisher: Lawrence Livermore National Laboratory, Livermore, CA 94550 Report Number: UCRL-JC-103946

Comments on Document: Presented at the U.S. Space Foundation Space Launch Forum, Colorado Springs, CO, 23-25 May 1990.

Descriptors, Keywords: Space Launch History Status Payload HLLV Technology ALS

Pages: 00010

Cataloged Date: May 10, 1991

Document Type: HC

Number of Copies In Library: 000001

Original Source Number: DE91-000412

Record ID: 21986

Source of Document: NTIS

CONF-900-211--1

UCRL-JC--103946

DE91 000412

OCT 05 1990

Securing America's Access to Space

Michael Rendine
Lowell Wood

This paper was presented at the
U.S. Space Foundation Space Launch Forum
Colorado Springs, CO
23-25 May 1990

May 23, 1990

Lawrence Livermore National Laboratory

SECURING AMERICA'S ACCESS TO SPACE*

Michael Rendine and Lowell Wood

University of California Lawrence Livermore National Laboratory
Livermore, CA 94550

ABSTRACT

We review pertinent aspects of the history of the space launch capabilities of the United States and survey its present status and near-term outlook. Steps which must be taken, pitfalls which much be avoided, and a core set of National options for re-acquiring in the near term the capability to access the space environment with large payloads are discussed.

We devote considerable attention to the prospect of creating an interim heavy-lift space launch vehicle of at least 100,000 pound payload-orbiting capacity to serve National needs during the next dozen years, suggesting that such a capability can be demonstrated within 5 years for less than $1 B. Such capability will apparently be essential for meeting the first-phase goals of the President's Space Exploration Initiative.

Some other high-leverage aspects of securing American access to space are also noted briefly, emphasizing unconventional technological approaches of presently high promise.

Introduction.

The human race is presently entering the second third-century of the Space Age. Three decades have passed since men initially lived in space, and two since men first walked on the surface of another planet, the Moon. The human agenda in space now includes President Bush's splendid challenge to establish permanent human settlements on the Moon and to send expeditions to Mars.

Remarkably enough, the ability of the American nation to even enter the space environment has not increased uniformly during these intervals; even more remarkably, it hasn't increased during the past two decades in other than a few comparatively unimportant respects, and has decreased by several-fold in a number of other, rather crucial measures. Most remarkably of all, this faltering of fundamental capability to access space has occurred in the face

* Prepared for invited presentation at the U.S. Space Foundation Space Launch Forum, 23-25 May 1990, at Colorado Springs, CO.

This work has been performed under the auspices of the U.S. Department of Energy under Contract W-7405-eng-48 with the University of California.

of continually increasing levels of National wealth, general technological capabilities and both economic and politicomilitary interest in exploiting the space environment. It is not easy to find parallels to this National programmatic failure in the preceding two centuries of our history. Indeed, the Vice President very recently likened our Nation's present situation with respect to space exploration to that which confronted the Ming Dynasty, just before it chose to recall its world-exploring fleet and burn it at dockside.

It is imperative that we rapidly rectify our National space access posture, which has come to command the attention and concern of the most senior levels of the National leadership, for very many reasons. The newest of these is that ***the President has called, less than 3 months ago, for the demonstration of all the technologies crucial to the settlement of the Moon and the exploration of Mars during "the next several years"; getting into low Earth orbit the necessary equipment, deep-space transportation vehicles and propellants is quite clearly the most crucial technology of all and undeniably will require National space launch capabilities well beyond what we presently have.***

Historical Perspective.

Speaking just a few weeks ago to the National Space Symposium, the Commander-in-Chief of the United States Space Command decried the National inability to launch military spacecraft in an operational mode, or at a cost which is not ". . . a significant part of the National treasury." Likewise, the Commander of the Eastern Space and Missile Center has recently and publicly assessed its capabilities as limited by old and fragile launch facilities, manpower-intensive launch vehicle processing, and vulnerable to crew overwork.

These remarkable conditions have arisen while we are in universally acknowledged competition with another nation which routinely and sustainedly conducts 4 to 5 times as many space launches as well do every year, puts several times more mass into space annually than we do, has a genuine and repeatedly demonstrated operational space launch capability— and accomplishes all of this on a national economic base which is variously estimated to be 2 to 5 times smaller than our own. It is sobering indeed to reflect that, if we launched like the Soviets do on a GNP-weighted basis, *the U.S. would average a space launch every day or two,* compared to our actual average rate of less than 2 per month. Our overall space budget, if scaled from the present one by number of launches, would be between $250 and $600 billion dollars annually. Since the Soviets clearly don't spend in these terms, how it is possible for them to be so much more economically efficient than we are, moreover in an area which appears to be replete with high technology, the American specialty?

Moreover, all of our major expendable space launch vehicles --- everything except the Shuttle --- derive from ballistic missile boosters which were designed for economic mass production and were required to be launchable on virtually a moment's notice, diverse through their fuels and technologies may be. How they evolved from this condition into space launchers which are neither inexpensive nor operationally responsive is a classic example of local optimization of technical performance and programmatic acquisition, far from a global optimum.

Essentially all existing launch vehicles are stressed to nearly the limit of their materials and propellant energies, with each of a quarter-century of "performance improvement" seemingly involving either higher stresses, thinner margins or a greater endowment of strap-on solid-rocket motors (a notably short-range "fix"). One result of this is that the current state-of-the-art is represented by one of our current space-launch boosters which generates almost 70% of its payload's orbital speed with its zero-stage solid cluster and first stage, although its exhaust velocity is nowhere near as large a fraction of orbital speed.

This "local optimization" style of development of space-launch boosters has undeniably resulted in vehicles which require extraordinary handling during all phases of assembly and pre-flight integration. Moreover, since these vehicles were never designed to support high launch rates, neither the vehicles themselves or their payloads have ever faced up to the *sine qua non* of sustained high launch rates, namely horizontal booster assembly and booster-payload integration, the single most notable key to the remarkable space launch capabilities demonstrated by the Soviets.

The Current Situation and the Surprise-Free Future.

Our newest major launch system, the Space Transportation System, is inherently limited in its launch rate and growth by its basic attributes of being man-carrying and by its notably complex upper stage, the Shuttle orbiter. The most capable of the Shuttle orbiters is presently rated to deliver 48,000 pounds of payload into low Earth orbit, though full capability has yet to be flight-demonstrated. America's highest capacity expendable launch vehicle, the Titan IV, can potentially deliver 39,000 pound payloads to orbit. In comparison, the Saturn V booster of the Apollo Program flawlessly carried a set of 220,000 pound payloads into Earth orbit, a weight-lifting record that has recently been duplicated, in kind if not degree, by the Soviet *Energiya*.

A cursory survey of the prospects for near-term improvement in our National heavy-lift space launch capabilities is not highly encouraging. Realistically viewed, the Shuttle-derived launch vehicles are a decade away, even assuming a level of overall institutional commitment substantially above that of the recent past.

At that, the perceived cross-linkage between the Shuttle and, for example, Shuttle-C with respect to launch failures and the consequences thereof may continue to chip away at institutional commitment, dragging it down to a fatally low level. Critics may assert that either Shuttle-C is so closely related to the Shuttle itself that a launch failure in either system will necessarily ground the other also (and large American payloads and Americans themselves may be effectively denied access to space again for a few year hiatus), or else that Shuttle and Shuttle-C are sufficiently unrelated that no great savings in developmental time or cost can be argued for Shuttle-C (and that it then looks like a technologically obsolescent version of ALS).

Finally, the probable actual cost of developing Shuttle-C — somewhere around 10 billion present-day dollars, when the seemingly inevitable cost growths and schedule slippages are taken into account — put it in the moderately big leagues of national space commitments, further diminishing the likelihood that it could become available in the '90s.

The Advanced Launch System (ALS) was estimated last Fall by its program manager to be on a track of 13 years duration and $17 B in cost, so that it is probably two decades distant and will cost over $25 B, when typical business-as-usual multipliers are considered. Moreover, the level of institutional commitment which it enjoys — never very high to begin with, as indicated by its development being scheduled <u>last</u> year to average only <u>half</u> of the technology-limited pace — is even now diminishing rapidly, and formal acknowledgment that it has become a technology-base-only program, presently seems only a matter of time.

From a pragmatic National standpoint, anything as costly as ALS which is burdened with a first-deliverable as far away as its forecasted first payload launch has severe life-expectancy problems. From a somewhat more abstract programmatic standpoint, ALS has two nearly fatal flaws: first, in order to secure initial funding, it was originally marketed to some portions of the policy community as <u>the</u> SDI deployment system, which burdened it nearly ruinously in other political quarters and still plagues it through the present time; second, it was gifted with an exceptionally broad scope, being virtually required to be all things to all users, so that it continues to thrash in an excessively large trade space, just as the SDI itself did in its youth. (The latter has persisted only by sharpening its focus markedly, which the ALS program has yet to do.)

In an ideal world, the ALS program would be told to develop a single, technologically advanced Saturn V-class booster, and then would be given the seven years which its program manager says would be sufficient for this task -

— and the requisite funding to execute exactly this program, at the technology-limited pace. That such a track, which would give the Nation capability which it manifestly requires and moreover would do so sooner and more cheaply than all other alternate approaches, somehow cannot be taken is an important diagnostic of our National problem with respect to access to space.

The origins of the National problem of large-scale access-to-space exemplified by Shuttle-C and ALS are probably more obvious to a sociologist than to the aerospace or policy communities: we Americans are a rich and capable people prone in eras of low stress to instant-gratification behavior, with very little appetite for sacrifice or long-term investment in ordinary circumstances; when we decide we want something, we want it immediately, moreover with deferral-of-payment of as much of the cost as possible into the distant future.

With respect to space access, we haven't had the sharp and pressing need to loft large payloads as we did in the Apollo Program, and we are therefore caught in a classically American "chicken and egg" situation, where no rational program leader is going to engineer his hardware into an apparently "unflyable" configuration which requires a non-existent heavy-lift booster, and, since no programmatic requirement for such a booster therefore ever arises, its creation is never commenced.

Of course, if such a booster magically came into existence, many programs would line up to use it, happily singing in chorus about how greatly their efforts were benefitted by its availability. In the meantime, we're stuck in a programmatic "local optimum" which is incontrovertibly not a global one: no funds are expended for the heavy-lift space launch capability which no program absolutely requires, though many programs would benefit markedly by its availability.

Moreover, when we tentatively decide to go out and fix this problem, we figure that in any non-crisis situation we have to create a politicoindustrial "Grand Coalition" to obtain its funding, and we therefore design a programmatic pie so large — so that every one can have a good-sized slice, of course — that its economic load starts to buckle the supporting political structure, necessitating such severe shaving of peak-year-cost that the program runs at well under half its technology-limited pace, thereby generating risks and inefficiencies so large that the entire program is very likely to die young, far short of its goal.

The bottom line is that we currently may have only the illusion of a National program to reacquire the ability to put large payloads into space. It may well be that nothing realistic presently exists, or will exist in the reliably foreseeable future. In particular, we must confront the real possibility that *the President's call to demonstrate the technologies critical to the Space Exploration Initiative during the next several years is simply not being answered in the crucial area of space launch.*

General Observations and Recommendations.

The situation certainly isn't hopeless, however, even on time-scales as short as a half-decade. More than one industrial design currently exists for a heavy-lift space launch vehicle, 75% of whose total dry mass is existing hardware. Çonsidering the gestation intervals of our most successful ballistic missile boosters, a start-to-first-launch period of four years is reasonable for these — or any realistically competing — designs, provided that the Government will manage the program the way in which it invariably does, whenever it's really serious.

Reasonable estimates deriving from already-scoped designs indicate that $800 M of *value* from the Government should suffice to first-launch of such a interim heavy-lifter, if the Government chooses to manage this program the way it does others in which the National interest is judged to be seriously at stake. By *value* is meant not just funds but GFEed materials and sub-systems provided from existing production lines, the use of which may be quite advantageous in maintenance of a fast-paced overall program schedule.

First-year program costs should be sufficiently small — well within the non-painful aggregate reprogramming capabilities of member-agencies of the Space Council — that this effort could be commenced essentially any time, regardless of the position of the decision-point within the annual budget cycle, just as the Landsat rescue and the NASP safety netting were accomplished.

Thus, an up-front, not-to-exceed allocation of five years of time and $1 B of value should provide adequately for a program to create and flight-demonstrate an interim heavy-lift space launch vehicle, moreover with 25% contingency in both basic quantities. This system can serve National needs for high-capacity access to space until at least one of the longer-term developmental programs comes to fruition.

Specific Observations and Recommendations.

It is programmatically crucial that National investment be minimized in developing and demonstrating an interim heavy-lift space launch capability, for the reasons just sketched. The program office executing this development should be given a total budget not exceeding $1 B and a lease-on-life no greater than 5 years, and should be charged with executing the first launch within this time and budget. Only if it can convince a senior oversight body annually that it's on-track should it be continued into the next year, even within these relatively stringent bounds. This office should be freed of essentially all administrative regulations and required to comply only with Federal Acquisition Regulations and applicable public law, should be staffed with at most a dozen-and-a-half extraordinarily capable and dedicated individuals who are committed to the program for its duration, and should report programmatically directly to the National Space Council, regardless of the Department in which it may be housed administratively. Obviously, it should be provided with procurement authority equivalent to DoD's DX/BRICKBAT.

Furthermore, this program office should be charged explicitly to stay out of the way of long-term developments such as Shuttle-C or ALS. Its sole mandate should be the creation and demonstration through first launch of interim National heavy-lift space launch vehicle, possibly serving also as a technological and programmatic pathfinder for these long-term efforts, but behaving in no sense as a competitor of them. Grandiosity is the ancient but still pervasive enemy of space launch efforts, and this program must be spared this hazard, by charter and by supervision.

The near-term interim space launch capability to be developed and demonstrated should have low cost for the Nth launch and high ultimate launch rate included in its goal statement, but only as distinctly secondary items. Its first, second and third priority goals should all be "Demonstrate heavy-lift space launch capability at the earliest possible date." Attainment of this single primary goal is quite likely to sweep in attainment of all the secondary goals.

In the course of well thought-out execution of this highly focussed program, at least the demonstration first launch will necessarily be carried out from National facilities which are not currently in use. The existing launch complexes are already choke-points for National space-launch capabilities, so that austere operations at unused facilities will be a *sine qua non* for the demonstration heavy-lift first launch. The SLC6 issue is still vivid in the legislative and program analysis memories, effectively precluding large up-front investments in concrete and steel for the interim heavy-lift space launch capability.

Transport of people into space should be left to the Shuttle and, eventually, to the National Aerospace Plane, NASP. The interim heavy-lift space launch vehicle cannot possibly meet either its overall program cost or schedule goals if it becomes ensnarled in the technology and politics of man-rating. In any event, the Shuttle system can carry into space and back all the Americans who can possibly be useful there during the next two decades — if it is used with very special priority for personnel and man-in-the-loop payloads, as it manifestly should be.

The basic technical tasking of the program office should be to develop and flight-demonstrate a heavy-lift vehicle with at least twice the payload-orbiting capacity of which America is currently capable --- the 48,000 pounds for which the Shuttle is currently max-rated --- and to do so with an unstressed vehicle, one which isn't running close-to-the-edge in any crucial parameter.

In addition to meeting the President's schedule for the enabling technology-demonstrating first phase of the Space Exploration Initiative, a basic reason for requiring at least a two-fold performance gain is to at once inspire and enable a new generation of spacecraft and space mission designers in a manner inaccessible to incrementalists. This will also serve to liberate all such workers from the cramping physical constraints which bedevil many of them today and which drive the costs of large National-interest spacecraft to excessive levels, just as fiscal constraints are becoming much more severe. Such a 100,000 pound payload-to-orbit goal will also bring the United States back to only two-fold less than the National high-water-mark of space launch capability, the 220,000 pound capacity of our now-lost Saturn V --- and of the Soviet *Energiya*.

Given the requirements of minimum expenditures of time and money, the engineering solutions for the interim heavy-lift booster must be comprised in large part of existing hardware, albeit in innovative forms. Clusters of existing boosters, mixes of hardware from different boosters and brute-force scale-up of existing structures with multiple motors all have significant merit. The most important consideration is that, with relaxed performance margins and judicious use of advanced materials, compositions of such existing hardware can exhibit significant cost-per-pound reductions, simply from economies-of-scale.

It is imperative to move in the opposite direction from that pursued recently by man-rated vehicles. Small expenditures on short time-scales aimed at reliable heavy-lift space launch accomplishment must focus on low-pressure liquid engines, and should evolve toward the use of liquid strap-on boosters, which, prior to propellant-loading, lend themselves much more readily to horizontal launch system integration than do much more massive solids. Conversely, either an all-solid launch vehicle or liquid strap-ons mated to a solid core may lend themselves more readily to horizontal integration than does our current practice of tying enormously heavy solid motors onto fragile liquid cores. Non-reuseable stages can be highly advantageous, if economies-of-scale-enhanced prices are right, and relatively low stress levels in key components permit the use of more economical materials, fabrication methods and integration times.

Following initial feasibility demonstration, the interim heavy-lift launch vehicle can attain high launch rates if it has been composed of sub-systems which don't require extraordinary care in manufacture and integration and if it is supportive of system integration which can be performed off the launch pad, in parallel facilities, as the Soviets routinely do. A single American "pad empress," the space-age analog of a "hanger queen," routinely ties up a billion-dollar launch complex for as long as a year, a practice which cannot be continued.

Few things can abort any launch vehicle development faster in the current political climate than environmental problems. In this context, the Government must be able and willing to clearly state its case that the interim heavy-lift capability is indeed vital to the National interest, and that its environmental issues are not only localized ones but are also quantitatively dwarfed by many other anthropogenic sources offering smaller benefits to the Nation's future. These arguments must be backed with Presidential waivers, if required. At the same time, growth versions of the interim heavy-lift launcher should be maximally environmentally responsive as well as technically sound, featuring, for instance, hydrogen fuels and chloride-free solid rocket motor propellants.

A natural choice for the first payload of the interim heavy-lifter, the one flown on its demonstration flight, would be an International Space Shelter. Equipped with stores of oxygen, food, water and a highly reliable life-support system, a large airlock and and some form of emergency escape capsule — perhaps even an old Apollo Command Module — it could serve as a ground-commanded rescue vehicle for distressed spacemen. With 100,000 pounds of total mass budget, it could carry an orbital maneuvering system with serious plane- and altitude-change capabilities. Placed mid-way between 28 and 55 degrees orbital plane inclination at 500 km altitude, it could serve spacefarers of all nations for a decade or more as their rescue vehicle, emergency shelter and Earth-return capability. Its potential use in supporting operations at Space Station *Freedom* — and at *Mir* — is obvious.

Summary and Conclusions.

If there is a single lesson from the National space launch posture after the Challenger loss, it is to cherish diversity. This consideration alone impels the creation of an interim capability to lift large payloads into space, while the Shuttle-C and ALS programs do their necessarily higher-risk and longer-range work — even if the broad National interest and the President's schedule for the technology-demonstrating first phase of the Space Exploration Initiative both didn't cry out for large payloads to be lofted during the next dozen years.

There are many ways in which this capability may be realized, but getting it as rapidly and inexpensively as reasonably possible, so that it is a true interim capability, narrows the field considerably and stimulates close looks at innovative integrations of already-existing components and sub-systems.

We have sketched some of the first-level considerations and recommendations for a highly focussed, goal-oriented program to create and demonstrate a National heavy-lift space launcher for interim use throughout the second half of the '90s and perhaps even the first years of the next century, in the interval before more ambitious National launch options will become available under realistic assumptions.

We suggest that the 5 year, $1 B program sketched in the foregoing is quite adequate to create and initially demonstrate such an interim heavy-lift space launcher under prevailing, non-crisis conditions. It therefore merits the serious consideration of all those concerned with re-acquiring and then securing America's large-scale access to space in this century, as well as those committed to the President's Space Exploration Initiative.

As central as interim heavy-lift capability may be to American access to space in the '90s, national attention should <u>also</u> be effectively directed to other space-launch technologies which can offer high leverage along other axes in the foreseeable future. Indeed, near-term success in this central endeavor may restore National self-confidence in the space launch enterprise sufficiently to generate the funding required to seriously explore these other approaches to space access.

Notable among these are completely reusable rocket-based means for carrying reasonable-sized payloads to orbit — means whose development may well be synergic with NASP, and technologies which can deliver payloads — possibly ones quite modest in size or mass — to orbit at high sustained repetition rates. Laser-energized propulsion and both magnetic and chemical cannons are especially promising examples of the latter, as each of them presently appear capable of being demonstrated on useful scales in half-decade time-frames for costs under a billion dollars. Any reasonably well-balanced program directed toward assuring near-term American access to space will vigorously compete all credible proposals of these types for a few years, and then provide the one or two most successful of these competitors with technology-limited funding to demonstrate useful capability at the end of the next couple of years.

As with the creation of the interim heavy-lifter, ***the essential features*** of this aspect of the overall National program ***are tight focus, maximal dispatch, technology-limited resources, serious Government management --- and a "perform to specs by date certain" mandate from the outset.*** This combination was the key to winning the Second World War and the race to the Moon. It will serve America equally well in our enduring leap into space — and nothing less is likely to do the job.