 ADB165824

Launch on Demand

INDUSTRIAL COLL OF THE ARMED FORCES WASHINGTON DC

APR 1991

UNCLASSIFIED / LIMITED

Atch

UNCLASSIFIED / LIMITED

1991
Executive Research Project
RS2e

Launch on Demand

Captain
(b)(2),(b)(6) [redacted]
U.S. Navy

Faculty Research Advisor
Captain (b)(6) [redacted] USN

The Industrial College of the Armed Forces
National Defense University
Fort McNair, Washington, D.C. 20319-6000

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED

1b. RESTRICTIVE MARKINGS: Administrative or Operational Use — 6 AUG 1992

2a. SECURITY CLASSIFICATION AUTHORITY: N/A

2b. DECLASSIFICATION / DOWNGRADING SCHEDULE: N/A

3. DISTRIBUTION / AVAILABILITY OF REPORT: Distribution [illegible] to Department of Defense. All other requests should be forwarded through the National Defense University, ATTN: NDU-LD-SCH, Washington, D.C. 20319-6000. Contractor's requests must be signed by their DoD contract monitor to verify "need-to-know"

4. PERFORMING ORGANIZATION REPORT NUMBER(S): NDU-ICAF-91-RS2e

5. MONITORING ORGANIZATION REPORT NUMBER(S): N/A

6a. NAME OF PERFORMING ORGANIZATION: Industrial College of the Armed Forces

6b. OFFICE SYMBOL *(If applicable)*: ICAF-AR

7a. NAME OF MONITORING ORGANIZATION: National Defense University

6c. ADDRESS *(City, State, and ZIP Code)*: Fort McNair, Washington, D.C. 20319-6000

7b. ADDRESS *(City, State, and ZIP Code)*: NDU-LD-SCH, Ft. McNair, Washington, D.C. 20319-6000

8a. NAME OF FUNDING / SPONSORING ORGANIZATION: N/A

8b. OFFICE SYMBOL *(If applicable)*:

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER: N/A

8c. ADDRESS *(City, State, and ZIP Code)*:

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.

11. TITLE *(Include Security Classification)*: Launch on Demand

12. PERSONAL AUTHOR(S): Captain (b)(2),(b)(6)

13a. TYPE OF REPORT: Research

13b. TIME COVERED: FROM Aug 90 TO Apr 91

14. DATE OF REPORT *(Year, Month, Day)*: 1991 April

15. PAGE COUNT: 37

16. SUPPLEMENTARY NOTATION:

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*:

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

See Attached

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT: ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION: UNCLASSIFIED

22a. NAME OF RESPONSIBLE INDIVIDUAL: (b)(6)

22b. TELEPHONE *(Include Area Code)*: (b)(6)

22c. OFFICE SYMBOL: NDU-LD-SCH

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

LAUNCH ON DEMAND

There is a new space race: who can get there the quickest and the cheapest. In the 45 years since the V2 rockets, we have progressed dramatically in both our ability to exit the immediate boundaries of our planet and actually find a use for the "high ground" above us. We have marked our maturation in the space age by larger boosters, steadily increasinq satellite capability, vastly improved earth observation sciences, and a roundtrip to the moon. Yet, we continue to measure responsiveness—the time to launch—in days rather than hours, component assembly times in months, and mission scheduling in years. Each satellite we put in space is the output of highly skilled and extensive labor. We have access to space, but we can't routinely place a payload in orbit on short notice.

Access to space is a complex process of manufacture, launch support, and operations focusing on highly specialized spacecraft. Large production runs are uncommon; consequently, standardization of the interfaces from booster to bus to payload are unique—a time consuming and expensive combination. Despite over three decades of space operations, we still find ourselves, as General Piotrowski phrased it, in "white smocks" and countdowns: spacebased systems remain predominately in the hands of scientists not operators. This mindset restrains our quick access to space, a capability we will need in the near future.

Launch on-demand isn't a new idea; its the realization of missions needing a quick reaction capability (QRC) for launch. Our historical model of launch on-schedule (LOS) and store in-orbit to maintain robustness of our constellations fails to fully satisfy assured access to space: in the nineties and beyond we must be able to rapidly reconstitute our spacebased systems. While we may have an unproven capability to surge launch, it is unlikely we could sustain routine and quick access. New launch concepts enabling QRC and the emergence of Tactical Satellite Systems (TSS) may provide the means. This new component of our space infrastruture, QRC and TSS, defines launch on-demand: it is the means to complement our launch on-schedule model of heavier and long-life spacecraft with lighter, easily reconstituted assets.

The question arises, do we need a responsive launch on-demand capability? It is my intent to show we do. In support of my view I will discuss three components: factors that inhibit a policy to broaden our launch base; constraints in our current launch infrastructure; and, new innovations supporting launch on-demand. Throughout, my discussion includes both the military and the commercial application of launch on-demand. This satisfies an underlying tenet in any future U.S. industry: it must be world class.

1991

Executive Research Project

RS2e

Launch on Demand

Captain

(b)(2),(b)(6) [redacted]

U.S. Navy

Faculty Research Advisor

Captain (b)(6) [redacted] USN

The Industrial College of the Armed Forces

National Defense University

Fort McNair, Washington, D.C. 20319-6000

DISCLAIMER - ABSTAINER

Table of Contents

I. Introduction..1

II. Factors that shape policy......................................2

1. The environment...3

2. Assured and responsive access...................................4

a. A launch crisis...5

b. A growing need for QRC..6

c. The tactical satellite system (TSS).............................6

3. The money issue...7

4. The cost to orbit...8

a. Significance of support costs...................................8

b. The direct cost of launch.......................................9

c. True launch costs...9

d. Could we reduce the costs?......................................10

5. Spacecraft costs..11

6. Policy..14

III. Responsiveness..15

a. What constitutes a quick response?..............................17

b. Current launch rate...17

2. Quick response..19

a. On-pad alert..19

b. More launch pads..21

c. Alternative launching schemes...................................22

d. A final note on responsiveness..................................24

IV. New Thoughts, New Missions.....................................25

1. Improved Spacecraft...26

2. The distributed system..27

a. Increasing satellite autonomy...................................27

b. Artificial intelligence...28

3. The Iridium project...29

a. Launch service issues...30

V. Summary...31

LAUNCH ON DEMAND

There is a new space race: who can get there the quickest and the cheapest. In the 45 years since the V2 rockets, we have progressed dramatically in both our ability to exit the immediate boundaries of our planet and actually find a use for the "high ground" above us. We have marked our maturation in the space age by larger boosters, steadily increasing satellite capability, vastly improved earth observation sciences, and a roundtrip to the moon. Yet, we continue to measure responsiveness—the time to launch—in days rather than hours, component assembly times in months, and mission scheduling in years. Each satellite we put in space is the output of highly skilled and extensive labor. We have access to space, but we can't routinely place a payload in orbit on short notice.

Access to space is a complex process of manufacture, launch support, and operations focusing on highly specialized spacecraft. Large production runs are uncommon; consequently, standardization of the interfaces from booster to bus to payload are unique—a time consuming and expensive combination. Despite over three decades of space operations, we still find ourselves, as General Piotrowski phrased it, in "white smocks" and countdowns: spacebased systems remain predominately in the hands of scientists not operators. This mindset restrains our quick access to space, a capability we will need in the near future.

Launch on-demand isn't a new idea; its the realization of missions needing a quick reaction capability (QRC) for launch. Our historical model of launch on-schedule (LOS) and store in-orbit to maintain robustness of our constellations fails to fully satisfy assured access to space: in the nineties and beyond we must be able to rapidly reconstitute our spacebased systems. While we may have an unproven capability to surge launch, it is unlikely we could sustain routine and quick access. New launch concepts enabling QRC and the emergence of Tactical Satellite Systems (TSS) may provide the means. This new component of our space infrastruture, QRC and TSS, defines launch on-demand: it is the means to complement our launch on-schedule model of heavier and might, also, give the U.S. a competitive advantage in the international space industry. Cost and benefit are the crucible of policy: what does launch on-demand offer beyond our current launch on-schedule capability?

Access to space is literally like nothing on Earth. Analogies such as "highways to the stars" imply a misleading simplicity in spacebased operations. Likewise, the notions of pervasiveness, presence, and the "high ground of space" have few Earth bound equivalents. Most notably, cost is truly "astronomical": annual operating costs for the space shuttle alone could pay for one and one-half new aircraft carriers! Launch on-demand aims at:

- o improving access time to space
- o broadening the entry points to space
- o miminizing dependence on small satellite constellations
- o reducing overall cost throught reduced infrastructure

Let us begin with a review of the space environment...

<u>The environment</u>

The Earth, in a chemical sense, is a multiphase system consisting of solid, liquid, and gas. An added phase is the "non-molecular"[3] area of space. While the laws of physics are applicable in any phase, obviously some laws are more or less important in each. For example, Archimedes principle—fundamental to ships at sea—has little relevance on land. Likewise, orbital mechanics dictate an entirely different operational approach from our concept of aerodynamic lift: satellites don't fly, they orbit.

Satellites are hyperaccelerated masses orbiting from 90 to 22,300 miles from the surface and in planes centered through the Earths' mass. How do they get there? This is the inelegant part. Unlike science fiction, rocket boosters catapult them into space through the gross release of chemical energy. The initial vertical portion of the trajectory allows the booster to pass quickly through the dense lower atmosphere; then the trajectory flattens—pitches over—allowing the booster to accelerate the payload to its orbital velocity (about

18,000 miles per hour in low orbit). Throughout the ascent parts of the booster fall back to Earth.

There are no highways in space; rather, orbital ephemeris describes the path of the satellite—a mathematical conic section. Ephemeris is the name of the collective parameters such as the eccentricity of the orbit, apogee, azimuth, perigee, nodal intersections, and inclination from the equatorial plane. The latitude of the launch site and the direction of the launch initially determine the orbital inclination. Changes to the orbit require the expenditure of energy—fuel.

The dictatorial physics of launch constrain where and when we can launch. And the known launch points negate an ability to covertly place new systems in space. Lastly, the external effects on a satellite play an important role...

Satellites don't stay in a fixed conical orbit, they experience perturbation effects undermining their position and operational life. Other bodies such as the Sun or Moon cause gravitational deviations. Also, the Earth's irregular shape disturbs orbits. And at lower altitudes, 300 miles and below, the Earth's atmosphere imposes drag on the satellite. In all instances the satellite must use maneuvering fuel. In low Earth orbit (LEO), fuel not only maintains the satellite's position it keeps the satellite from reentering the Earth's atmosphere.[4] The point is satellites lead finite lives.

What is space? It is a <u>region</u> above the Earth, and it is a complex endeavor to reach it and to return. But is a it region we should continue to expand in? Or are our spacebased needs and capabilities in balance?

<u>Assured and responsive access</u>

Our space systems are of growing vital national importance—both militarily and commercially—in their roles of communications, surveillance, navigation, and environmental monitoring. Historically, the Cuban Missile Crisis illustrates their criticallity: "[satellites] confirmed for [President] John F. Kennedy that the Soviets lacked a nation killing ballistic missile force in 1962; the

President knew that he held the better hand in the showdown over Cuba."[5] Today, the lessons from Operation Just Cause demonstrate a new integration and a growing reliance on spacebased systems:

> "Just Cause was a showcase for just about all types of space resources. A remote-sensing satellite provided US commanders with the picture. GPS [Global Positioning System] made it possible, among other things, for aircrews to zero in on air evacuation points and airdrop and pickup zones. Soldiers toted GPS terminals in backpacks"..."Communication satellites made everything work. As space buffs like to point out, the single most important military function of space systems, as constituted today, may be to provide satellite links for battlefield and combat-zone communications..."[6]

A launch crisis. The Ch...enger mishap on January 28, 1986, grounded the shuttle fleet and exposed a flaw in our launch strategy threatening our national security--we had virtually no alternative access to space. General Bernard P. Randolph in his 1986 Congressional testimony commented while "our constellations are robust there is no room for unprogrammed failures."[7] How did we get to this crisis point of both non-responsiveness and low launch capacity? In 1972, President Nixon approved NASA's plan to create a reusable launch vehicle and "directed it become the Nation's primary launch vehicle." In 1982, the shuttle became operational and began its checkered history. In 1984, the Air Force concerned about the vulnerablility of a single launch system successfully gained approval to procure a "complementry" expendable launch vehicle (ELV). Had the Air Force not made these purchases, the U.S. wouldn't have had any capability. As it was, the deteriorating condition of the launch complexes and the low number of ELV's constrained both our responsiveness and launch capacity.[8] What was the impact? Our successes in the Persian Gulf War were not without some very intensive backroom work...

Behind the scenes operators had to shift assets to cover operating areas at the expense of orbit life. In the case of the Defense Satellite Communications System (DSCS) overage systems were kept on line because of the backlog of launches stemming from the Challenger mishap. The chokepoint was a launch infrastructure requiring a minimum of 120 days to get a payload into orbit and in some cases a five year lead time for a scheduled mission. The impact was a diminished responsiveness to support spacebased needs.

A growing need for QRC. Unplanned losses and overage satellites—satellites operating beyond their planned life—are factors calling for a more robust launch capability. Another is an ability to place in orbit, on short notice, one or more satellites for intelligence. In the post cold war era, arms control verification can potentially have life or death consequences for the security of our nation. Launched unannounced, a group of satellites—a constellation—would temporarily neither be as predictable as those in a known orbit (ephemeris) nor as vulnerable. Vice Admiral Ramsey believes we should develop "less expensive satellites and launch systems which can be quickly deployed to augment or reconstitute existing capability." In this context, he also suggests we "exploit evolving sensor technologies to introduce new tactically useful space capabilities."[9]

The tactical satellite system (TSS) is becoming a new pull on space technology. In the world of space based systems exists a bureaucracy governing the direction of information and operational control of the systems. In communications, the DoD controls who has priority over a limited number of transponders. Surveillance operations include similar protocols. The Center for Strategic Studies leveled this criticism: "The problems are not a lack of technological capability, but frequently ones of distribution, classification, and a lack of confidence." The take by a CIA and DoD bureaucracy undermines the flow to the tactical forces. One egregious example is the flow of target imagery to the field during the Libyan raids: handcarried from the US to the Mediterranean, the trip took three days. Tactical commanders have a real need for reliable, dedicated systems.[10]

In the commercial world, communication satellites are the prime driver. A new concept is a space based cellular network which Motorola is fielding under the name of Iridium. It consists of 77 satellite constellation in low Earth orbit

(430 miles). Due to its altitude, it appears Motorola may need to replace up to 12 satellites per year. Why a firm would lock itself into such a seemingly costly proposition is the subject of a subsequent discussion.

Do we have the ability to sustain and augment our space based systems? Are there technologies that can help? Yes, we do have the technical means to gain launch flexibility and responsiveness. The issue is one of priorities: our allocation of finite resources.

The money issue

Money in the pure textbook approach is a unit of exchange for goods and services. It is a means to match needs with resources, and it is the standard of measurement for national effort. It is easy to state we need to be in space either commercially or as a foundation of national security, but we must recognize the costs. And from this recognition, we must decide and form policy.

Vice President Quayle quite accurately states in his outline of national space priorities: "First we will develop our space infrastructure—the equivalent of the roads and bridges program of the 20th Century to get us to space in the 21st."[11] This statement brings forth the cost of refurbishing our existing highway infrastructure and compare that against the space infrastructure.

Secretary of Transportation Samuel Skinner wrote, "No industry in the nation is more important to U.S. economic growth and international competitiveness than transportation." His truism, equally applicable to space, was a lead-in to his description of increasing monetary needs. His estimate: We will need annual investments of over $50 billion to maintain our existing network of national highways and bridges.[12] Others estimate the total cost could reach $3 trillion by the year 2000.

Let us examine the total cost to orbit. In 1989 the totals for all government space programs exceeded $26 billon.[13] We must measure these costs not only in the context of a DoD or a NASA (Civil Space) budget but as competitors for limited national resources. Although we have a surplus lift capacity for our near launch needs (we can place over 900,000 pounds per year in LEO), if we hope to construct the space station we will need a greatly expanded lift capability gained through bigger boosters and improved launch facilities. These future cost factors could create a dilemma pitting responsiveness against capacity. Do we control these new costs through the boosters, facilities, or spacecraft? Could we alleviate them by developing an off-pad launch capability? Our national concern must be to isolate costs and determine strategies to control or reduce them.[14]

The cost to orbit

Support costs play a significant role. We spend nearly a third of the space budget on support—in 1989 over $9 billion. These expenditures don't cover capital improvements which is a critical deficiency: the support infrastructure is showing its age and must also compete for money. The consequence of our reliance on the space shuttle is overdue repairs and modernization of older expendable launch vehicle (ELV) facilities. At the Kennedy Space Center the repair cost alone could reach as high as $1 billion over the next decade.[15] Vandenberg AFB, the only other major US launch complex, is facing similar woes. Captain Robert Martin, USAF, writes:

> "A first building block is infrastructure. While the systems coming on line are excellent, some of the groundbased space infrastructure is decades old. Some emergency generators supporting west coast operations were cast in 1918! We cannot continue to allow the quality of the aerospace system we support to outstrip the quality of the infrastructure."[16]

Martin encapsulates this problem when he later states a projected launch increase of "fivefold in 20 years." He concludes, "[we] must help create new launch systems to handle the projected demand. The entire launch infrastructure must be modernized ..[and be made] affordable. We must make launch operations as routine as air operations today."[17]

I pose this question: can we economically improve our launch capacity and responsiveness without an off-pad capability?

<u>The direct cost of the launch.</u> The nature of space operations is larger satellites. Compare our first Vanguard launched satellite weighing 27 pounds to systems such as the KH-12 satellite weighing in at 32,000 pounds. Why the increase? Simply, it is from expanded capability and increased orbit life—more fuel. This increase mandates larger lift capacity and greater cost as we can see in Table 1. Long duration systems are, in part, a consequence of constrained launch rates—limited responsiveness.

Vehicle	Total cost	Payload lbs	Cost/lb
Shuttle	$375 million	55 K	$6,818
Titan IV	$178 million	39.1 K	$4,552
Titan 34D	$135 million	33.8 K	$4,012
Delta	$33 million	7.8 K	$4,256
Atlas	$59 million	12.3 K	$4,797
Scout	$10 million	0.57 K	$17,544

Table 1 NASA's Estimated Costs for Current Boosters [18]

An important impact on launch cost is the orbit the satellite will operate in. Geosynchronous (GEO) communication satellites, for example, can only use an equatorial orbit. This need restricts all U.S. GEO launches to the East Coast launch complex-Kennedy—which by virtue of its latitude and more so by its eastern launch direction is the only capable site in the continental United States.[19] By comparison, from Table 2 we can see the cost differential between GEO and low Earth orbit (LEO) is significant: for example, Titan is $22,000 versus $3718 per pound. These two factors, restriction and higher cost for geosynchronous orbits, are drivers for alternative space systems. A third is the recurring costs of the launch infrastructure.

<u>What are the true launch costs?</u> Table 2 factors in <u>all</u> costs for one launch.

All costs include the assembly, transport, preparation, and launch of the vehicle. For example, consider the direct cost for a Delta rocket: $33 million, in Table 1, compared to a total cost of $46.3 million in Table 2. Another check point is the shuttle launch costs. Recently both NASA and the Space Council placed annual shuttle operations costs at or above $4 Billion per year with or without launches. Assuming a best case launch rate of 10 per year the shuttle cost per flight is $400 Million to $500 Million. Or with no launches...

We can ameliorate infrastructure costs but we can't eliminate them.

Launcher	Orbit	Capacity	Cost/lb	Flt Cost
Delta	LEO Polar	8,200	$5,854	$46.3 M
	LEO Equ.	11,110	$4,320	
Atlas/	LEO Polar	13,700	$6,861	$94.0 M
Centaur	LEO Equ.	19,000	$4,947	
Titan/Centaur	GEO	10,000	$22,000	$220 M
Titan/NUS	LEO Equ.	39,000	$3,718	$145 M
	LEO Polar	31,000	$7,097	
Shuttle/IUS	GEO	5,000	$102,690	$534.0 M
Shuttle/NUS	LEO Equ.	48,000	$10,803	$484.0 M

Table 2 Costs for Selected Launch Systems [20]

notes: LEO = Low Earth Orbit, circular, 100 nm

GEO = Geosynchronous Orbit

Equ. = equatorial @ 28.5 deg inclination

NUS = No Upper Stage IUS = Inertial Upper Stage

Polar inclination 80 deg and elliptical (80X270 nm)

Flt cost assume $3.0 M insurance

Could we reduce the costs? General Piotrowski says "the United States is limited in terms of its ability to lower the costs of access to space, accommodate substantial increases in total mass to orbit, or provide major improvements in the launch responsiveness of the launch process."[21] We are using 60's technology in our launch systems. The Titan, Delta, and Atlas are conversions from ICBM/IRBM systems—"stretched technologies." Why haven't we changed?

Bruce Campbell, now on the National Space Council and formerly from Martin-Marietta, offers this insight. The market "pull" on the industry is not enough to encourage private development of newer—presumably cheaper—booster technology. He sums it up: "How much company profit could be invested to improve launch capability?" The answer is the cost is too much for the return-over 10 years for break even at today's rate.[22] The draw on industry for big boosters has come from the government.

In the final analysis, there is very little commercial incentive for firms to develop new launch technologies. Innovation in space has come from government programs. Orbital Science Corporation's Pegasus air launched vehicle, Fairchild's Lightsats, and the proposed joint venture National Aerospace Plane (NASP) owe their origins to DoD and NASA initiatives. Our leadership in space will likely continue from national priorities—policy—not from individual firms.

Our national compass, then, is to continue new courses in access to space: we should persist in altering a mindset of boosters from fixed sites are the only way to enter space. With this change we could reduce the overhead costs and constraints of launch facilities.

Spacecraft costs

Finally we must consider the cost of the payload. The Office of Technology and Assessment estimates reducing the direct cost of a launch from $3000 to $300 per pound would only reduce the overall system cost of spacecraft procurement and placement in orbit by less than 2 percent![23] In their study they found the bus—the supporting structure and subsystems—carrying the payloads ranged in cost from $130,000 to $520,000 per pound dry. The cost of the actual payload ranged from $200,000 to $800,000 per pound.

What are the factors driving the high costs of satellites? Principally they are mission, capability, and uniqueness. The general trend is the more capable a satellite the heavier it becomes. The heavier a satellite the greater the launch costs, and designers—working close to launch weight and volume margins-incur higher costs as they add last minute features. Conversely, a lighter satellite must give up fuel—time in orbit—or reduce its mission capabilities.

The mission of a satellite—what the user gets—is a fundamental cost impacting both the size and weight as well as the sophistication. In the case of the photoreconnaissance satellites the presumed nature of their equipment drives both the size and their complexity. In weight they have grown from 8000 pounds in the case of the KH-8 to 32,000 pounds for the KH-12. The Defense Satellite Communication System (DSCS), a communications satellite residing in Geosynchronous orbit [24], has experienced a growing user base and consequently a pull for greater capability.

Satellite growth is inevitable in the current scheme of operations. In the case of DSCS, compare the differences between DSCS II and DSCS III as shown is Table 3. The consequence of this growth is not only developmental costs but weight as well: 1,365 pounds for the DSCS II to 2,351 pounds for the DSCS III. Considering its operational altitude—geosynchronous—this weight growth is significant.

DSCS II	DCSC III
16 Spacecraft	14 Spacecraft
4 Channels	6 Channels
E-W Stations	E-W and N-S stations
No Hardening	Hardened
Limited ECCM	Good ECCM
SHF	SHF
4 Active	3 Active Single Channel Transponder

Table 3 Capability Comparison of DSCS [25]

Uniqueness is potentially the greatest cost. Satellite production is closer to research than manufacturing. And while the shared wishes among designers and end users are common bus structures and modularity, they remain only moderately achieved in industry. This failing impacts potential economies of scale gained from non-recurring costs and learning efficiencies. Table 4, the ratios of non-recurring to recurring costs, indexes potential cost savings with systems using common subsystems. As an example, substituting a previously designed spacecraft (without payload) could potentially reduce costs by 1 plus the ratio (2/1) or 3 fold. Fairchild (space division) estimated 60 percent of the spacecraft bus was potentially non-recurring in a production satellite.[26]

Subsystem	Ranges of Ratios
Structure	5/1 to 8/1
Propulsion (Apogee Kick)	2/1 to 6/1
Thermal Control	4/1 to 40/1
Attitude Control	1/1 to 2/1
Electrical Power	1/1 to 2/1
Telemetry, Tracking & Command	2/1 to 3/1
Spacecraft (less payload)	about 2/1
Communication mission payload	2/1 to 3/1

Table 4 Ratio of Nonrecurring Costs to Recurring of Spacecraft Subsystems [27]

The high cost of placing a capable system in orbit inhibits innovation. As we have seen, system growth has traditionally meant larger satellites and consequently higher launch costs. This weight growth ultimately restricts our launch freedom—our responsiveness—to bigger boosters operating from highly constrained launch sites. Because we are dependent on large satellites, there hasn't been the market "pull" as yet for smaller satellites—LIGHTSATS—and larger orbital networks. The net results are:

- Constrained launch rate: high capital cost to improve
- Long payoff for new boosters: high investment risk

- System reliance on few orbit assets: graceless degradation
- Unique system designs: few economies of scale

Policy

Should we develop new access strategies? Would a Single Stage To Orbit (SSTO) vehicle, as proposed under the National Aerospace Plane (NASP), keep our competitive advantage? And in the near future can we field a QRC launch system as both a means to increase our national security and gain an economic advantage?

It is my contention we can and should augment our heavy lift capability with a light load, on-demand ability. In terms of national security it isn't only reconstitution of forces, it is also increased presence when we choose. And we should avail ourselves of the increasing micro-miniturization of spacecraft components. Where we depend on a few satellites, we can distribute the system to many. Graceful degradation can be more than a hope; it could become reality. But these ideas aren't possible without routine and rapid access to space.

The notion of an untested or minimal QRC launch system flies in the face of logic—we need proven technology and a doctrine to support it. It is unlikely we could sustain TSS from fixed sites considering the current constraints: we must consider alternatives such as off pad launch systems. Coupled with the increased vulnerabilities of on-orbit spares, only an active short notice launch scheme can work—it must be routine.

A system to place assets in orbit quickly and cheaply has commercial appeal as well. The Iridium project and small earth observation satellites could benefit greatly from this capability. But what is happening? Ariane offers quick launch service for attractive prices. As one of the satellite manufacturer states, "I know I can get a launch in a few weeks for $5 million [through Ariane]."[28] While this comment merits attention, the long run benefit of a quick response might easily offset a nominal five percent increase in the total cost (vehicle and spacecraft). Do we have a competitive position? Perhaps. The European Space Agency recognizes the potential of Pegusus and has agreed with Orbital Science Corporation to help market it.

Launch on-demand systems are potentially a synergism offering an improved launch capability with little or minimal increase in the infrastructure. But it is of little use if the payload requires a year to produce or space support takes a month to bring the system on line. The improvement is attainable only if our national policy promotes these goals:

- augment launch capacity with a QRC
- promote industrial standards for satellites and subsystems
- develop off pad launch technologies
- create distributed networks through smaller satellites

I close this section with an observation from Mahan. Ever mindful of the need for a strong nation to have a strong maritime presence he offered this thought:

> "[When] excessive prudence or financial timidity becomes a national trait, it must tend to hamper the expansion of commerce and the nation's shipping."[29]

RESPONSIVENESS

> "Currently US [space] systems are a fragile, thin blue line--a thin blue line that is not sufficiently backed up by on-orbit spares or a rapid replenishment capability...In time of crisis or conflict these systems would not be sustainable."
>
> General John L. Piotrowski, USAF (Ret.)[30]

General Piotrowski posed a familiar question to all involved in National Defense: How do we reconstitute our space based systems? One of his former officers, Bruce Luna, recounts the General "pushed to speed up launch rate to the Soviet [presumed] rate" of pad to launch in 6 hours.[31] It was the familiar argument of launch responsiveness between the operators and the "techies": The operators' demand versus the reality of long mission lead times. Did we ever have a launch on demand ability? Luna recalled "at one point [20 years ago] we got them off in less than a month, but we've lost that ability now."

There are two goals we should aim for in our launch infrastructure: total mass to orbit and sustained rapid response. As I stated earlier, we have placed a premium on cost per pound and tonnage. I offer this thought: there are instances when time is the determinant. Consider these roles:

- Reconstitution: In hostilities, satellites are lost to an increasingly sophisticated ASAT threat. Immediate reconstitution becomes vital to national security.

- Broad based systems support: Increasing usage of interlinked, LEO satellite networks will require both scheduled and unscheduled replacements. Considering the revenue loss to a degraded network, the additional cost is offset through quicker online times.

- Unannounced reconnaissance: One or more satellites are directly injected into orbit thereby reducing the need to maneuver long duration systems. This capability could also substitute the need for extensive and costly on-orbit spares.

- Augmentation of Force Enhancers: "Bent-pipe" or "packet system" satellites launched, when needed, to augment existing communications systems. Examples of these are the Multiple Access Satellite (MACSAT) and the Global Low Orbit Message Relay (GLOMR).[32] Technologies from SDI also offer imaging and intelligence gathering LIGHTSATS that could augment larger systems.

What constitutes a quick response? The Air Force Space Command (AFSPACECOM) states "to perform its mission, primarily the operation of satellites, it would need the ability to schedule a launch [small and intermediate satellites] within 30 days, change out payloads on five days' notices, and launch seven satellites within five days."[33] What can we do? Typically lead times range from four months for a Delta to six months for a Titan IV. Table 5 gives an index of average launch times for existing and proposed systems.

Vehicle	Payload	Mission Lead (days)
Shuttle	50,000	30-60
Titan IV	50,000	147
Pegasus	500-900 (a)	2-7 (est. varies)
ALS (b)	100,000	?
Arianne V	22,000	40-50
NASP (c)	30,000	3-18

(a) Upper value of 1000 pounds is high dependent on orbit altitude and inclination.

(b) Advanced Launch System is under evaluation. Payloads may exceed 220,000 lbs.

(c) National Aeropace Plane is under evaluation. Payloads may be only 10,000 lbs.

Table 5 Index of Average Launch Times [34]

Current launch rate

What are the current constraints on our launch rates? As we shall see the critical flow points are receipt, processing, and on-pad check. To visualize this we will use a typical flow for a Delta launch at the Eastern Space and Missile Center (ESMC) at Cape Canaveral. Our scenario begins after an 18 month fabrication time. In place of time, I will use throughput per year.

Facility	Use	Number/yr
Delta Mission Checkout (DMCO)	*Offload, receive, inspect and store stages *Final, pre-erection preparations for interstage and PLF *Core system level checks	10
Horizonal Processing Facility (HPF)	*Final pre-erection preparation of the first stage	48
Area 55	*Second stage pressure checks	23
Area 57 Solid Rocket Motor Build-up area	*SRM receipt, inspection, buildup and storage (up to 18 SRM's)	10
Third Stage Processing	*Payload processing and third stage build-up and storage	12
Space Launch Complex (SLC)	SLC 17 A/B are the only two Delta capable pads at the (5/SLC) ESMC.	10

The critical point in this flow occurs on the pad. The constraint on the pad reflects on-pad processing, launch operations-including weather delays-and refurbishment of the SLC. In the case of a Titan II from Vandenberg AFB, the pad-time is a 14 week cycle (3 vehicles per year). Correspondingly, the pre-launch processing takes 12 weeks per vehicle (8 vehicles per year). Table 6 gives a quick breakdown of throughput times for various systems. [35]

System	Location	Throughput
Scout	Various	8 (a)
Atlas E	WSMC SLC 3	3
Delta II	ESMC SLC 17 A/B	5/5 (10)
Titan II	WSMC SLC 4W	3 (b)
Atlas II	ESMC SLC 36 A/B	4/4 (8) (c)
STS (Shuttle)	ESMC	9-13 (d)
Titan IV	ESMC SLC 40/41	3/3 (6) (e)
WSMC SLC 4E		2 (f)

Table 6 Typical Launch Throughputs

(a) Constrained by hardware

(b) Launch rate also constrained for safety due to proximity of SLC 4E

(c) 11 weeks on-pad processing + 2 weeks pad refurbishment

(d) Dependent on number of orbiters. With 4, max rate is 13. Normal turnaround is about 60 days.

(e) On pad processing time is 45 days

(f) Close proximity of SLC 4E seriously constrains launch rate.

Quick response

I have demonstrated what I consider a flaw in our launch structure— long response time. How can we remedy this situation? I offer three alternatives:

- o On-pad alert
- o More launch pads
- o Alternative launch schemes

On-pad alert. Twenty years ago this was one means to meet the demand. Unfortunately as we saw earlier, this capability-surplus launch capacity—languished in the 70's and resulted in our current dearth of launch facilities. As Bruce Luna, NASA, said: "If the Challenger accident had happened later, our ELV infrastructure would have been gone."[36]

As we can see on-pad response won't work. Even with an uninterrupted process of initial receipt to launch there are on-pad times of over 45 days. Combined with payload processing time, this isn't rapid response nor does it meet the Air Force's model for launch responsiveness—30 days. In fact, when we look at the total launch requirement for the next 7 years, nearly all pad time is devoted to scheduled launches.

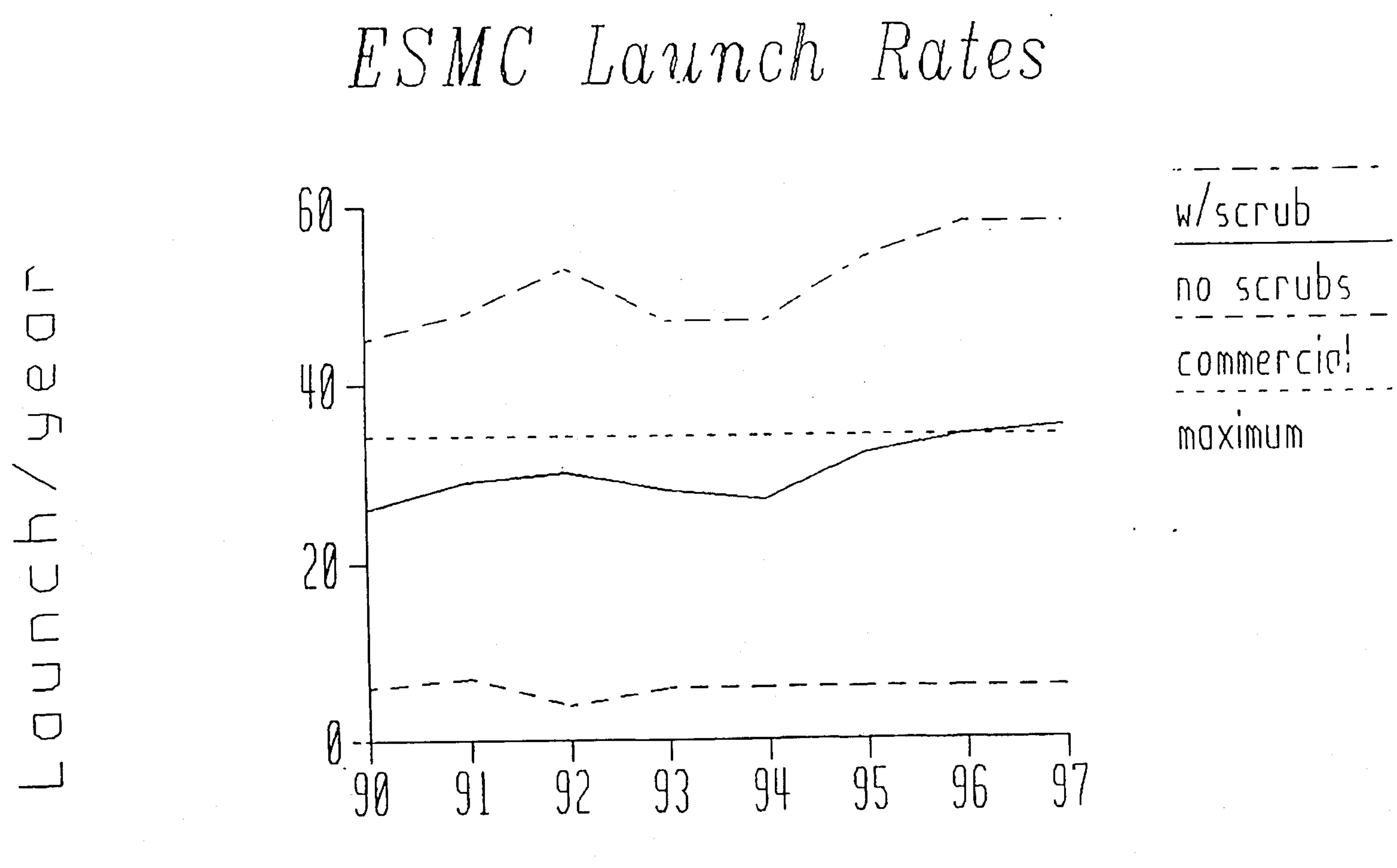
Chart 1 graphically plots proposed launch rates from the Eastern Space and Missile Complex through the FY97 outyear. The horizontal line represents the maximum launch rate using average throughput times. Please note the lowest line, our scheduled commercial launches: only six per year. Considering the saturation by civil and military launches, it is little wonder Ariane has 60 percent of the world market! [37]

It is highly unlikely we could surge to meet emergent requirements in the present state. Our launch on schedule infrastructure is strategically oriented not tactically. General Piotrowski offers this thought:

"Basically, the U.S. space launch infrastructure is a peacetime system operated by research and development (R&D) organizations in response to a program of planned and budgeted launches based on authorized on-orbit constellations and their scheduled replacement requirements."[38]

Perhaps this example cited by General Piotrowski will illustrate the problem. A few years ago a metrological satellite failed in orbit. Despite an emergency call-up preempting scheduled launches and moving the planned date ahead 73 days, it still took 14 weeks to replace the failed satellite. The General attributed this to a system steeped in launch on schedule—not demand. I previously cited the phrase "lab coats" and countdowns to reflect this problem.

As we saw earlier, the greatest constraint on launch responsiveness is on pad processing—45 days or more. Perhaps a strategy to take is a move to increased off-pad processing such as done with the shuttle and proposed under the Advanced Launch System(ALS). Both systems employ a Vertical Assembly Building to reduce on pad time. However, both are still launch on schedule systems. ALS offers an


ESMC Launch Rates
Launch/year
60
40
20
0
90
91
92
93
94
95
96
97
w/scrub
no scrubs
commercial
maximum
Fiscal Year
Chart 1

improved capability to meet the Air Force's 30 day surge model contrasted to the shuttle's best rate of 45 days. Perhaps the strongest point for the ALS is a design permitting greater payload weight and volume margins-an improvement over the shuttle.[39] This added flexibility supports a move to the common bus structures which in turn may result in faster payload processing—greater responsiveness. Undoubtedly, ALS or a derivative system will solve mass to orbit and even increase responsiveness, but launch pads and large facilities still dominate its overall throughput.

More launch pads. This is obvious. If we can't appreciably reduce the on-pad time, then we should increase the number of SLC's. In fact, this seems to be part of the Russian model as General Piotrowski notes, "the Soviets have about twice as many launch pads and put about five times the weight into orbit as the United States." [40] While the amount of weight placed in orbit is significant, more so is the time. For instance, during the Falkland War the Soviets conducted 29 launches in a 69 day period.

How do we stack up? We have reduced not increased our launch capacity. Daniel Goldin, executive director of the American Astronomical Society (AAS) states, "In the 1960's the United States had 537 successful space launches. In the 1970's that number dropped to 265, and in the 1980's we had only 132 space launches, less than 25 percent of the 1960's number "[41]

Should we build more launch pads? An underlying question is not only desirability but affordability. Interestingly some new thoughts have come out of the business sector. One company, Brown & Root, proposes using their heavy construction experience in offshore platforms to build improved, efficient launch pads—up to 50 percent savings in construction and operational costs. The facilities would be built off site then floated, by sea, to the launch complex. Among other thoughts on the design, Senior Vice President Henry proposes further cost savings through families of boosters enhancing turnaround time on the pad—more operability. As he puts it, "[every launch] is a research and development activity." Operability of the launch sites is fundamental to affordability.[42]

Location of new launch sites is another thorny issue. Environmental impacts, safety, and launch monitoring facilities are unavoidable overheads in the launch business. In my earlier discussion on the space environment, I mentioned two factors: boosters falling back to earth and "gross amounts of chemical energy." Both of these pose serious personnel hazards and constrain location of launch complexes. A third concern is the post launch support—down range tracking facilities. Undoubtedly, expanding their capability would offset concentration resulting from more pads in a launch complex; however, this need for post launch tracking imposes added costs on developement of new launch complexes.

One proposed complex, located in Australia, is an innovative attempt to exploit Soviet booster technology and put both countries in the commericial space business. Located at Cape York, a remote northeastern peninsula, it offers a clear range to launch into and a highly desirable launch latitude of 12 degrees south. Currently an environmental impact study is underway with construction scheduled to start in 1992 following final approval. The Cape York Space Agency (CYSA) estimates capital investment of $470 million dollars.[43]
While the Cape York complex may ease the needs for the commercial industry, it does nothing to improve U.S. competitiveness or responsiveness. Two concerns in both industry and government are dependency on foreign launches and possible unauthorized technology transfers. Alternatively, should more sites be built in the U.S.? Or should we push new launch technologies and reduce our need for more fixed launch sites?

<u>Alternative launch schemes.</u> I find myself in general agreement on this point: we must improve our launch facilities and payload to booster processing time. However, this doesn't resolve the issue of quick response. What is missing is a tactically oriented launch structure. I will describe a few new concepts.

The first thought is conversion of our mobile launch systems. On land, the Peacekeeper system is inherently attractive. Mobile, quick to erect it can place a 5000 pound payload into LEO.[44] The problem is lower reliability, acceptable to a military contingency, lacks appeal as an augmentation to routine launches. A spin-off from this concept is the Taurus system which I will discuss.

Convenience at the cost of efficiency is one thought behind Orbital Sciences' Pegasus vehicle. At $7.5 million a launch for payloads of 500 to 1000 pounds, the cost seems high particularly when measured against alteratives such as "hitchhiking" on scheduled launches such as an Ariane IV. However, "hitchhiking"—small payloads flown on a space available basis—has its drawbacks: The principle customers want assurance the load will not jeopardize the main load, and waiting for the right launch for the desired orbit may take time.[45]

What is Pegasus? It is a renewed concept in launch operations. Mounted on the wing of a B52, or any large bodied aircraft, it is taken to altitude and launched. Some of the key features are a large payload design margin (1.4), use of weight saving composites, and off the shelf technologies for its guidence—the computer from the M1A1 tank and the Inertial Measurement Unit (IMU) from a MK48 torpedo. Its entirely an off-pad, horizontal payload-to-vehicle process and has a greatly reduced infrastructure cost.[46] Operationally it offers:

- o launch into any orbital inclination
- o launch outside of normal range safety constraints
- o short notice launch
- o relative survivability through distributed basing
- o difficult to predict orbital characteristics [47]

A related system to the Pegasus is the Taurus. Taurus is a mobile launch system that incorporates an MX missile first stage the with second and third stage of a Pegasus. Like Pegasus, it also offers horizontal processing. It can deliver a greater payload than Pegasus.

SEALAR is a proposed system utilizing a unique approach. Rather than use a mobile or fixed launch site, the vehicle is placed offshore in the water and launched. A two stage system, each would parasail to earth for reprocessing aboard a mother ship.

Future access to space may be the National Aerospace Plane (NASP) or the British-Russian Horizontal Takeoff and Landing Vehicle (HoToL). Both use a combination engine design that initially uses ambient oxygen to oxidize the fuel--hydrogen. As the vehicle leaves the atmosphere, the engine switches from its scramjet to rocket mode. An appealing aspect is the use of the atmosphere to lift the vehicles to altitude before they begin their final acceleration.

The HoToL is actually a two phased approach. In the first stage of its life the HoToL will combine with the Russian An-225. Carried aloft-- a similar concept to Pegasus--it launches and then jets- rockets to orbit. One British Aerospace official places the payload delivered to an equatorial LEO of 15,432 pounds. The initial development cost for this vehicle is $4.6 billion and recurring costs are about $16 million. As one official says it " is a moving launch pad."[48] The second and long term phase is a vehicle that launches from a runway.

The NASP has no intermediate phase like the proposed HoTol, it will launch from a runway straight to orbit. General Moorman describes the NASP as "the ultimate responsiveness...beyond the ALS." What distinguishes it from others. It is still in its first stage of development; however, both NASA and DoD have set aside $130 million to continue development. Why? The mature design is a vehicle that can routinely transport up to 30,000 pounds to LEO and turnaround to launch in 3 to 18 days. This routine access opens up whole new concepts in access to space in both availability and cost--$50 to $400 per pound.[49]

<u>A final note on responsiveness.</u> I hope I have conveyed a need for a tactical capability in our launch systems. Our current fashion of launch pads and rockets is here to stay for the foreseeable future--it musc. But I don't believe it has the inherent flexibility to support quick response. While we must push new technologies such as NASP or HoTol we must also recognize they aren't here yet. We must wean ourselves from the launch pads with what we have. Pegasus, SEALAR, and mobile land launchers are technologies we have now and can use. However, they come with a price tag: they cost more per pound and carry smaller payloads. While responsiveness isn't free, it offers a peacetime utilization which is a competitive advantage we should gain and hold.

NEW THOUGHTS, NEW MISSIONS

What is changing to make responsiveness and tactical satellites more than a curiosity? The spinoff from SDI is a reduction in satellite components with an increased capability. General Moorman states "the next growth will be tactical applications." Cites one author:

"[The] shift toward smaller payloads is becoming particularly apparent in the growing popularity of small, cheap satellites. Conventional satellites, with their billion-dollar price tags, are the space-borne equivalent of mainframe computers." "Small satellites, typically weighing 50 to 1,000 pounds, are more like personal computers; they can be assembled quickly from inexpensive and accessible hardware and launched on short notice."[50]

We are in the information age, but it is two edged sword. It blesses us with increasingly quick and highly detailed information; on the other hand, we are becoming vitally dependent upon its flow. Maybe too much as one senior officer said, we get "more damn data than we know what to do with."

The crux of this section is our dependency on information. We are faced with a dilemma. Our space based systems offer a host of information support but their capacity limits them. A communication satellite has only so many channels it can dedicate to a user. A photoreconnaissance satellite can only work so much area. In normal usage this isn't a problem. But unexpected losses or surge requirements may leave some customers without service. Will a theatre commander or a CEO stake his or her livelihood on such an uncertain future?

Fortunately, as we shall see existing technology enables a new approach to our space systems. This new approach is the link in launch on-demand: the market pull for responsive launch system to support distributed space systems.

Improved spacecraft

Two concepts in spacecraft design are FATSATS and LIGHTSATS. Each has a specific approach to launch and an inverse relationship between size and needed technology.

The FATSAT optimizes cost versus weight constraints through improved total lift capacity of the launch vehicle. Obviously diminishing the costly process of close weight and volume tolerances for larger bodied satellites is an economical proposition. But do we gain a responsive launch capability? I have argued we wouldn't. One possibilty to improve time might be the promise of ALS—more permissive payload design margins. Coupled with a common bus, off-pad processing, and quicker on-pad to launch times FATSATS could achieve both cost savings and timeliness. However, fixed facilities still have fixed throughputs.

LIGHTSATS are a trade-off in size for timeliness. Earlier I discussed the costs of spacecraft and the dilemma of size—smaller is less ability; more ability is greater size. Andy Hartigan of DCA offers another dimension—total life of the satellite. In his argument, the annualized costs don't match the annualized returns. Attractiveness, then, should include both timeliness and increased benefits proportionate to added life cycle costs.

How could we reduce costs? One obvious means is economies of scale. Substituting several spacecraft in place of a few would spur a demand in production. Higher production would encourage not only spacecraft economies of scale but increase the derived demand for launch services; a demand, which, might also spur economies of scale in the booster industry. Two current means to reduce launch costs are "hitchhiking" LIGHTSATS aboard scheduled launches and placing several payloads on one big booster. Obviously, cost savings in the latter compromises timeliness as previously discussed.

The driving side of this equation is improvement of capabilities and changing mission concepts. The consequence is the need for both robustness and <u>responsiveness</u> in our launch systems.

The distributed system

One criticism levelled at current satellite systems is by virtue of their limited numbers the function they support (communications, imaging, etc.) is highly vulnerable to single satellite failures. An answer to this may lay in a distributed system. One concept is a phased array of spacecraft collectively providing the service of a larger cousin. Working in unison, they would pass their signals to another satellite or ground station for combination and decoding.[51] A phased or nodal network system would need cohesion in terms of accurate positioning and self-contained capabilities—autonomous operations.

Increasing satellite autonomy is a needed and achievable goal. We have come a long way since the Russian's launched Sputnik in October 1957. Satellite technology has increased tremendously from President Eisenhower's 1958 Christmas message, on an Air Force SCORE satellite; the Navy's multi-user Fleet Satellite Communications System (FltSatComm) launched in 1978; INTELSAT, Comsat's highly successful commercial system; to LandSat, the commercial imaging satellite. Unchanged, however, is the satellites strong dependency on a ground based communication and control network.

Tracking, Telemetry, and Command (TT&C) are fundamental to any satellite system. The TIROS weather satellite, launched over 25 years ago, illustrates the linkage. In the historical NASA scheme a support section, the then Office of Tracking and Data Acquisition, coordinates three elements: tracking to determine the exact position of the satellite; telemetry to monitor the satellite's health and to download accumulated data; Command and Control to give the satellite instructions. A central control center collates and interprets the information.[52]

What is now different from the TIROS TT&C network? The biggest item is the reduction, but not the requirement, of worldwide tracking sites. In today's scheme we centralize operations through increasingly automated Remote Tracking Sites and control centers such as the CSOC in Colorado. An important addition to the civil space program is the Tracking Data Relay Satellite System (TDRSS). Parked high in Geostationary orbit, it works in tandem with a sister TDRSS to relay information to multiple spacecraft. But control still resides at a ground based network subject to disruption and "electronic bureaucracy."

True launch on-demand to fulfil tactical or time critical needs suffers from this current centralization. Control crews may spend 30 to 45 days in preparation for a new satellite. Each satellite has its own signature (transmission protocol) to further complicate the problem. And finally, coaching the current large systems to come on line takes up to 30 days. Undoubtedly, we will need central control centers—fewer centers mean fewer crews and centralized expertise. What we must do to gain a benfit measured in reduced equipment and crews is reduce the satellite's dependence on them for navigation and basic housekeeping.[53] In the tactical application we will need distributed payload control.

Artificial Intelligence (AI) may offer a partial solution. AI technology is branching into two areas: expert systems and neural networks. Briefly, expert systems are a heuristic—rule of thumb— based approach to AI. Their chief advantage is an "expert", through a knowledge engineer, may program in operational parameters, common sense answers, and troubleshooting tips. Neural networks conversely learn to match answers through pattern recognition— "fuzzy" logic. Such recognition patterns may be installed or learned. Combining the two gives a computer an ability for both fixed and "fuzzy" logic.

How could we employ these complimentary abilities? One scenario is a mobile site that automatically receives information directly from the satellite system as it passes overhead. Both the satellite and the remote site use AI to screen information or redirect the satellite's attention. Another may be reduction of tasks in the satellite control centers through on-board housekeeping and navigation augmented by other space systems such as GPS. Both would reduce mission lead times, peculiar hardware-through signal standardization—and reduced training time for operators.[54]

Do we have such computer systems capable of this now? Perhaps. "Brilliant Pebbles," an SDI innovation, claims the technology to surveill, acquire, track, and target an incoming missile. Additionally, it has both imaging and sensor capability. The computer to support this must operate at extremely high speed and throughput comparable to a Cray II computer. How big is it? A single "pebble" measures just over three feet and weighs no more than 100 pounds fully fueled. The onboard computer is slightly larger than two packs of cigarettes. In all they are an autonomous system "independent in their performance of any other U.S. asset in space or on the ground."[55]

The net effect of an "intelligent" based system affords a truly tactical approach to space operations. Strategic systems such as long term surveillance or high volume communications could be left in place rather than diverted at a cost to mission fuel or disruption to other users. We might lessen the need to activate on-orbit spares and even reduce their number. And finally, the reduced weight and size of tactical systems without a proportionate loss in capability may make smaller launch vehicles affordable as well as timely in terms of total on-orbit costs.

The Iridium project

The Iridium project is a commercial venture headed by Motorola. What makes it unique is its service: cellular communications to a world market. It is also a potential market for small launch vehicles, such as Pegasus, used to augment ELV's such as the Delta II.

Why would a company begin a consortium whose initial outlay will likely exceed $2.1 billion and has a high risk associated with it? Iridium is a response to a need in satellite communications. Current systems such as INTELSAT (or DSCS) are anchored in Geosynchronous orbit. On the plus side three satellites, opposed to 77 satellites for Iridium, can provide world wide coverage. But the expense for this is the familiar echo (the quarter-second delay), higher required transmission energy, and a hypersensitivity to single satellite failure. What is a solution? Put the satellites in low earth orbit. The quarter second delay, a function of the speed of light, drops to milliseconds. Transmission energy drops by 30 decibels, a 1000 fold decrease. The large constellation allows for graceful degradation from satellite failures.

Why is the transmission delay so important? Apart from being very annoying it seriously disrupts computer-to-computer data transmission. In the business world its money. States the owner of one of the largest ticketing agencies, "every time I go to spacecraft I lose a quarter of a second" which results in an expensive ten percent increase in online computer time.

The reduced broadcast power offers the best reason through smaller antenna sizes. Current antennas can measure up to three feet in diameter for portable sets. This desire for smaller antennas places a hardship—reduced mission life—on the supporting satellite. To work its transponders must transmit higher energy in the Ku or Ka bands. Moving the satellite closer to the earth and the attendant decrease in range reduces both satellite and ground receiver output power requirements, enables lower frequencies, and allows use of smaller omnidirectional receiver antennas.[56]

When the project is a reality, cellular communications will be available on a world wide basis. Additionally, it may spur the market for QRC launch vehicles through the recurrent need to service the constellation. Will the market bear the cost for the service? Price estimates for the service range from $1 to $3 per minute compared to ground networks charging 40 cents per minute-its a good question. However, we shouldn't lose sight of this fact: Communications are growing so fast that cellular subscriptions exceed market expectations by four to five years. In areas like Eastern Europe, it transcends the need for telephone wires (twisted pair communications) for a communications network. However, we also shouldn't lose sight launch costs are still a driver in system development.

Launch service issues. The promise of flexibility given by Pegasus, $7.5 million per vehicle, compared to a payload piggybacked aboard an Arianne IV, nominally $5 million per satellite, may be too steep a price differential. This difference caused one satellite developer to deem the Pegasus a "pig commercially." As I suggested earlier, this $2.5 difference may only equate to a five percent increase in the total cost. Another twist is the use of a Delta rocket, for example, to launch two Lightsats versus a possible ten. Assuming the need to reach orbit quickly overrides the economy of launching several satellites and each Delta costs $33 million-the government assumes indirect infrastruture costs—the cost per satellite becomes $16.5 million! Availability of a launch site may well become a factor. In an indictment on the needed polar launch capability afforded only at Vandenberg, Motorola spokesman Hillis states, "It is questionable if we could ever rely on [Vandenberg] from a scheduling point of view."[57] Perhaps need or economies of scale will make Pegasus like vehicles or SEALAR more attractive.

The Iridium project captures both the promise of small, capable satellites and the need for a responsive launch structure. It represents innovation, also seen in such systems as GLOMAR and MACSAT. <u>It is a tangible pull on the market for affordable, responsive launch vehicles.</u> It may also preview a new competitive technology for the United States. Perhaps unlike the VCR's we can keep the lead or as the Texan said following the oil crash: "Lord give me another million and I promise not to lose it again."

SUMMARY

Launch on demand is an interplay of several factors. It can't be just a novelty, it must produce tangible benefits. It is more than just a unidimensional solution: we must recognize the environment it operates in, the needs it answers, and the systems it will support.

Is launch on-demand an all encompassing alternative to a known shortcoming in our nation's space infrastructure? No, it isn't. For the foreseeable future we can only satisfy the majority of our needs from scheduled operations and fixed launch site complexes. Whether such technologies as the NASP or HoToL will obviate this dependence is a moot point: they are technologies still in the design room.

What I have introduced is a need for a responsive system offering both military tactical application and commercial use. I suggest we have the technology and the innovativeness to augment our current space based architecture. Furthermore, I believe we must develop strategies reducing dependency on our strained launch facilities. We should measure every dollar spent on new launch facilities against the gains in developing vehicles operating independently of launch complexes.

We should continue developement of Tactical Satellite Systems (TSS) with an end-point being a nearly autonomous satellite. Large constellations comprised of small, interdependent satellites could offer a more survivable system aimed at the man in the field. And to support these systems we will need a flexible, responsive launch method: Launch On-Demand.

1. cited from "US Space Flight Ambitions Face New Ground Rules" <u>Congressional Quarterly</u> (July 22, 1989 vol 47, no. 29) p.1849

2. interview with Department of Commerce (Space) November 1990

3. Taken from Colonel (b)(6) [redacted], Industrial College of the Armed Forces. In his discussion he refers to the "medium of space" as a nonmolecular environment. I prefer the chemical concept of the phases of matter (considers density); however, the idea of a nonmolecular environment strikes me as on the mark.

4. Air Command and Staff College, <u>Space Handbook</u>, Maxwell Air Force Base, AL: AU,1985.

5. Sterner, Eric, "Space and Information for Decision Makers, " <u>Space.</u> Fall 1990, p67.

6. Canan, James W. "Space Gets Down to Earth" <u>Air Force Magazine</u>, Aug 1990 p32.

7. <u>Assured Access to Space: 1986</u> Hearings before the Committee on Science and Technology House of Representatives Feburary to August 1986. p 310.

8. Radzanowski, David P. and Smith, Marcia S. "Space Launch Options" <u>CRS Issue Brief</u> Updated February 27, 1991. p 2.

9. Ramsey, William F. "Shifting Military Space Needs" <u>Space Times,</u> Jul-Aug 90 (Vol 29, No.4) p. 4.

10. Op cit. "The Army and Navy in Space" p.38.

11. Prepared remarks of the Vice President to the American Institute of Aeronautics and Astronautics, May 1, 1990.

12. cited from Broder, David, "On America's Crumbling Roads..." <u>Washington</u>
footnote continues next page

continued footnote

Post Nov 3, 1990.

13. cited from "Space Business Indicators," Department of Commerce June 1990.

14. U.S. Congress, Office of Technology Assessment, Access to Space: The Future of U.S. Space Transportation Systems, OTA-ISC-415 (Washington, DC: U.S. Government Printing Office, April 1990) pp 5-7.

15. Kiernan, Vincent, "AF Launch Pad Work Needed in 1990's" Space Times, Nov 26, 1990.

16. Martin, Robert, "Building the Foundation for our Future" The Military Engineer, Sep-Oct 1990 p45.

17. Ibid. "Building the Foundation for our Future." p 45.

18. Hoeser, Steven, "The Cost Impacts of True Spaceships" The Journal of Practical Applications in Space, Summer 1990 p2.

19. Geosynchronous orbit is at 22,300 miles from the Earth's surface. A satellite maintains its relative position to the Earth through a period that equals the Earth's rotation (24 hours) and in an orbit close to the equatorial plane. To reach this orbit requires launching at a relatively low latitude a... in an easterly direction. As previously discussed, the downrange area from a launch must be clear of people and property to avoid damage from parts of the booster as they return to Earth. In the case of Polar launches, we normally use Vandenberg, the west coast complex, due to its southern launch corridor.

20. Ibid. p6.

21. Piotrwoski, John L., "Military Space Launch: the Path to a More Responsive System (Part II)", Aerospace & Defense Science (August, 1990) p29.

22. presentation by National Space Council to ICAF seminar, January 31, 1991.

23. U.S. Congress, Office of Technology Assessment, Affordable Spacecraft:

footnote continues next page

continued footnote

Design and Launch Alternatives-Background Paper, OTABPIPC-60 (Washington, DC: U.S. Government Printing Office, January, 1990) p1.

24. Zirkle, Robert, "Restoring U.S. Launch Capability," Space: National Programs and International Cooperation, Westview Press 1989 p6

25. presentation by [redacted], Defense Communication Systems

26. presentation by Fairchild Space Division to the Industrial College of the Armed Forces on April 4, 1991. Spacecraft production is essentially unique and, consequently, there are few economies of scale. A cited example is the GPS: 10 satellites in one run is largest production run to date. Mating to different launch vehicles is another cited reason for non-standard designs. Fairchild's strategy is a standard bus design for small satellites, Lightsats, capable of launch in a variety of vehicles ranging from the Pegusus to the Ariane. However, "standardization has a long way to go."

27. op. cit. Affordable Spacecraft p10.

28. interview with Mr. [redacted], Western Digital Lab Corporation, 18 January 1991.

29. Mahan, A.T., The Influence of Sea Power Upon History, New York: Dover Publications, 1987 p 54.

30. cited from the "The Army and Navy In Space" Air Force Magazine, August 1990, p38.

31. interview Mr. [redacted], NASA, Jan. 18, 1991.

32. op. cit., Affordable Spacecraft, p 19-20. The "bent-pipe" concept is essentially a radio repeater instantly retransmits information. The MACSAT is a store and forward satellite. Because of their weight, around 150 pounds, small capacity launchers are usable.

33. op. cit. Access to Space p 25.

34. Keyworth, George & Abell, Bruce "How to Make a Space Launch Routine" Technology Review (Oct 1990)

35. taken from presentation "Space Launch Infrastructure" prepared by Capt. (b)(6) [redacted] HQ AFSC/XRS

36. interview with Mr. (b)(6) [redacted], NASA, December 1990

37. op. cit. presentation notes from Alpert

38. Piotrowski, John, "Military Space Launch: The Path to a More Responsive System (Part I)," Aerospace & Defense Science, (July 1990) p43-44.

39. taken from presentation by Col. (b)(6) [redacted], "DoD Input to SDI."

40. Ibid. p46.

41. speech by Daniel Goldin, "Crossroads in the U.S. Space Program." AAS Space Times, (March-April 1990, vol 29, no. 2) p6.

42. Kolcum, Edward, "Brown & Root Attempts Move Into Space Launch Business," Aviation Week & Space Technology, (April 16, 1990) p60.

43. Asker, James, "Australians Pitch Cape York Complex as Best Way to Ease Soviets Into Launch Market," Aviation Week & Space Technology, (April 9,1990) p25.

44. op. cit. "Military Space Launch (Part III)," p 42.

45. Gump, David, Space Enterprise Beyond NASA, New York: Praeger 1990. p 36.

46. interview with Mr. (b)(6) [redacted] of OSC. January 1991.

47. op. cit. "Military Space Launch (Part III). p 42.

48. Shifrin, Carole, "British Aerospace, Soviets to Study Launching Hotol From An-225," Aviation Week & Space Technology (September 10, 1990)

49. op. cit. "How to Make Space Launch Routine." p26-28.

50. op. cit. "How to Make Space Launch Routine." p 27.

51. op. cit. Affordable Spacecraft p 20.

52. Truszynski, Gerald M. Space Communications Washington D.C.: Gov't Printing Office, 1963 pp 5-7

53. interview with Major [redacted] 16 January 1991

54. I have based my thoughts on this from notes taken during an ICAF elective, Expert Systems, and the suggestions of this cited article: "Expert Systems and National Security," Kunnesman, Robert, Aerospace and Defense Science, (October/November 1990).

55. Wood, Lowell, "From `Smart Rocks' come `Brilliant Pebbles'," Aerospace America, (April 1990). pp 18-19.

56. interview with Mr. [redacted], Western Digital Lab Corporation, 18 January 1991.

57. "Motorola Seeks High Ante from Partners," Space News (January 21 1991, vol 2, no 2).

[This page is intentionally left blank.]