Models of Transportation Development in America:

Lessons for Developing America's Space Transportation System

by

Patrick O'Neil
Carol Ebdon, Ph.D.

University of Nebraska at Omaha

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Contact

Patrick O'Neil
Aviation Institute
422 Allwine Hall
University of Nebraska at Omaha
Omaha, NE 68182-0508
poneil@mail.unomaha.edu

402-554-3424 (voice)
402-554-3781 (fax)

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Abstract: In 1994 Congress passed the National Space Transportation Policy (NTSP) that called on the National Aeronautics and Space Administration (NASA) to pursue the development of government and private sector partnerships, and to create private commercial spaceport and launch facilities capable of supporting affordable and sustainable space exploration. Since the passage of the NTSP, NASA has sought to develop collaborative public/private partnerships and foster new intergovernmental relationships for the development of technologically advanced space vehicles and the creation of a commercially based space transportation system. The loss of the Columbia and the lack of viable replacement in the near-term for the shuttle have emphasized the lack of a realistic long-term policy vision for America to create a viable and cost effective space transportation system. Given the current competition for space program funding with national security concerns, it is important that future space program policy possess a clear understanding of how sustainable transportation systems have traditionally evolved in America.

This paper examines public/private relationships and how past intergovernmental interdependencies have impacted the development of canal, railroad and aviation transportation systems within the United States. The goal of this paper is to identify transportation models that NASA may use in the development of a national space transportation system.

Growth of transportation systems can be best viewed as an incremental process fueled by economic demand and support of national security and shaped by both the geography of the United States and the advancement of transportation technology. The role of government and its relationship with private enterprise in development of American transportation systems has been varied and often complex. Study of canal, railroad and aviation systems reveals that development of individual transportation systems was most often undertaken by private enterprise and local and state governments. Sustainability of these systems has become increasingly dependent on federal government sponsorship, funding and regulation.

Financing methods for transportation systems has also been extremely varied. These strategies included public improvement bonds, loans, and issuance of stocks, barter arrangements, earmarked state revenues, debt, and tolls. States and federal government have also levied taxes on tickets, cargo, fuel, and on transportation companies. In times of emergency, transportation systems have also benefited from extensive federal financial assistance and protective legislative to safeguard national commerce and security.

Private ownership and operation of transportation modes, canals, railroads and airline companies, and/or operation of key transportation nodes, such as airports, by local governments are clearly preferred by both citizens and legislators. Each major system has relied on extensive involvement of both the public and private sectors. These respective roles have differed by system and have changed to some extent over time. Transportation systems typically developed in a fragmented, incremental manner. Thus, we have historically not had consistent national policies related to transportation. The federal government, however, almost exclusively developed space transportation. Because of this, widespread involvement by commercial actors,

states, and local governments in development and operation of space systems has been severely limited. As a result, a national space transportation infrastructure never evolved.

Market failures exist with space transportation systems. To the extent that such failures are for national defense and/or economic development with national benefits, a significant federal government involvement in space transportation system is not only justified but also necessary. If expansion of facilities and greater private sector participation is desired in the development of space transportation systems, then there is a need to more clearly identify the potential for economic development by state and local governments and the private sector.

Development of sub-orbital vehicles that can interface and operate in conjunction with the existing national transportation structure may be able to capitalize on existing transportation markets, moving people and goods at greater speeds in national as well as international markets. Space vehicles will have to readily connect and operate within existing transportation structure to gain access to markets. These vehicles should be capable of operating from commercial airports. Sponsorship by local and state governments is crucial for development of commercial and sustainable space operations. Not only must the federal government devise and sponsor a comprehensive plan for private commercial space transportation system development, but it must also actively support and fund development of technology to support this system. Government sponsorship of sub-orbital vehicle development may enable incremental technological advances that lead to new orbital craft capable of serving the Department of Defense’s need for sub-orbital and orbital craft in support of national defense. Support of a realistic and dedicated public/private partnership for development of incremental and cost effective space vehicles that meet both commercial and defense needs represents the best method to allocate limited and critical public dollars.

On 14 January 2004 President George W. Bush Jr. announced his vision for space exploration. The President's plan included completion of the International Space Station (ISS) by 2010 and creation of an exploratory vehicle capable of exploration beyond earth's orbit as well as providing transport and support to the ISS. This vision includes a return to the moon with the intention of developing a lunar-based facility capable of launching manned missions to Mars and beyond (Bush, 2004). In his address, the President stressed the importance of space exploration to the nation's prestige in addition to the gaining of new scientific knowledge and technologies while opening of new frontiers. President Bush's proposed program evokes many of the same expectations for future development of space by America that accompanied President John F. Kennedy's announcement of America's manned missions to the moon over 30 years ago (Kennedy, 1961). America's Apollo missions of the late 1960s and early 1970s were thought by many to be the space exploration catalyst that would lead to inhabited orbital platforms and lunar colonies served by regular commercial transports that would serve as bases for exploratory missions to Mars and beyond. Space enthusiasts and experts of that era envisioned a space transportation system, much like the commercial aviation industry, that would enable the average citizen affordable and safe passage into space (Heppenheimer, 1999).

However, dreams of space vehicles providing routine and affordable commercial transportation to orbiting hotels, moon colonies and manned missions to Mars and deep space have failed to materialize. The reason for this failure is that the current space transportation system (STS) lacked and still lacks a public/private sector partnership that can make space launch affordable and commercially viable. Transportation systems serving the diverse needs of Americans today evolved through on-going cooperation between public and private sectors. President Bush's newest space vision can only be achieved through the formation of the same public/private cooperative partnerships that helped foster and develop the other modes that currently make-up the American transportation system.

This essay will demonstrate how previous public/private partnerships have been responsible for building the current robust American transportation system and how understanding these partnerships will help develop a commercial space transportation mode that will meet both public and private needs. The paper is organized in the following manner. The first section provides an historical overview of successful public/private cooperative efforts used for the creation of American canal, railway and aviation modes. The second section chronicles how the development of the current American space transportation system (STS) lacked sufficient private sector participation to make it economically sustainable. The final section provides a summary and lists recommendations for creating a public/private partnership that is capable of building a viable and sustainable commercial space transportation system.

I. Historical foundations of Public-Private Cooperation in U.S. Transportation Systems.

Growth of transportation systems can be best viewed as an incremental process fueled by two needs, economic demand and support of national security. The creation of transportation modes to support the nation's growing commerce and defense needs has always been a product of collaborative partnerships formed between private interests and local, state and federal levels of government (O'Neil & Ebdon, 2003).

Canals: The first public support for the construction of canal systems within the United States was provided by Presidents Washington (Goodrich, 1960), Madison (Madison, 1961) and Jefferson (Hull and Hull, 1967), but the support was generally verbal not financial. Their support stemmed from the belief that canals would link the previously geographically and economically isolated colonies, greatly improving communication and cooperation within the young nation. Initial construction of the first canals in the late 1700s and early 1800s was strictly private, built with no public aid. Although a few of these private ventures enterprises were successful, others failed and work on many of the others was not completed. This was due to factors such as the lack of professional engineers on many of the projects and insufficient funding on others (Goodrich, 1960).

The most significant canal undertaking was the Erie Canal, begun by the New York State government in 1825. New York preferred development of canals by a public agency believing canal construction and ownership by private interests would further encourage disruptive "land speculation, already rife in western New York State" (Vance, 1986, p. 123). The Erie Canal was funded by 3 sources: earmarked state revenues, debt, and tolls. The construction of the Erie Canal resulted in immediate financial benefits for New York State. The canal had a substantial impact on New York's economic development, stimulating the commerce of New York City, the growth of cities along the canal route, and the spectacular development of the old Northwest. It also provided the conduit for the great channel of westward migration. It has often been noted that the opening of the Erie Canal "may be regarded as the most decisive single event in the history of American transportation" (Goodrich, 1960, p. 55). However, while canals initially did well financially, Erie Canal operations eventually fell victim to railroad competition. Tolls were eliminated in 1882 to encourage more usage, but by then railroads were carrying much more freight in the state than the canals.

Federal involvement in canal construction was limited. The federal government did provide a "national plan" in the early 1800s, but did not follow through, and ended up playing only a minor role in building canals. The government did sponsor a survey in 1820 of the Mississippi and Ohio Rivers and their tributaries as well as conducting general survey of canal and road routes in 1824 (Hull and Hull, 1967). However, significant and sustained funding for construction of canals never materialized. This was partly due to issues of constitutionality and states rights, and partly because some felt that the states had the ability to make the improvements themselves. Goodrich (1960) argues that the major reason for limited federal involvement was because of continuing conflicts between states and regions. Some states had done work on their own, and resented the idea of having to financially aid states that had not. As states pursued their own interests and developed internal improvement programs, the federal government found that obtaining consensus for the development of a comprehensive national transportation policy became increasingly difficult (Hull and Hull, 1967).

The federal government did become more heavily involved in waterway improvements in the latter part of the 19th century in reaction to public and political backlash against perceived predatory pricing by railroads. Congress appropriated limited funds for river and harbor improvements hoping to improve competition with privately owned railroads (Hull and Hull, 1967). The federal government again aided canals financially in World War I citing national security, purchasing the Cape Cod, the Chesapeake and the Delaware canals from private

ownership by the federal government. These canals, as well as the intracostal canals, have continued to be maintained by national treasury funds (Vance, 1986, p. 121).

A comparison of early canal development to future transportation mode development reveals importance of public/private cooperation. Private interests support transportation modes that link population centers and enable commerce. Public interests support both the development of commerce and provision of national security. Though private interests are willing to invest in transportation development, the initial construction and startup costs are often too high to be supported by the private sector alone. As in the case of New York, public financial support enables construction of viable transportation modes, fulfilling the needs of both private and public sectors. Importantly, private support of spending public dollars for transportation is gained when the private sector sees that business needs and public welfare needs are met.

Railways: Rail systems offered many advantages over canals, offering substantial improvements over horse-drawn transportation and canal structures, possessing greater speeds, capacity and comfort. They could be constructed much more easily than canals and were not as constrained by geography (Smerk, 1992). Rail systems often began conveniently at or near canal systems linking goods and passengers to locations water could not reach. Perhaps most significantly, rail systems could be operated by private enterprise at a profit. In the early 1800s, the private railroads enjoyed an era of unrestrained growth. In the thirty years prior to the civil war, railroad companies expanded lines without interference or regulation from state and federal governments. Railroad service promised significant economic opportunities for companies, towns and states. Railway companies seeking to expand and connect communities received enthusiastic support from the general public, from state governments and from the federal government (Leary, 1985). The Eastern seaboard was particularly supportive of rail systems that enabled the movement of relatively large numbers of people in densely populated areas. Railroads in the territories moved large numbers of people and goods to what had been relatively isolated areas. Costs of goods went down, towns grew and commerce links expanded (Smerk, 1992).

By the 1850s, railroad expansion was in a great up swing. However, at the beginning of the Civil War the American rail system was anything but an integrated and uniform transportation system. In the early 1860s, disparities among railway track gauges used by different companies necessitated changing cars eight times when traveling from Charleston to Philadelphia (Stover, 1997, p. 45). While the rail systems proved to be of critical importance to both the Northern and Southern forces during the Civil War, standardization of track and engines would not occur until after the war. Though still largely unregulated, railway operation and expansion following the Civil War experienced increased public and legislative concern regarding the railroads' safety, economic influence and national security impact (Stover, 1997).

Financing methods for railroads included public improvement bonds, loans, selling of stocks for individual companies and foreign investment and barter arrangements as well as federal issuance of land grants and subsidies. Private banking funded railroads by using bond strategies that had originally been developed for the development of canals. Public improvement bonds were originally sold by state agencies, and then purchased by private individuals or firms for resell to individual or institutional investors. Public assistance is estimated to have been about 25-30% of the total investment in railroads in the period before the Civil War; governments made much

larger investments after the war, but their share was a smaller proportion of the total investment in this period because private investment increased so much at this point (Goodrich, 1960). Private railroad companies also sold corporate shares. Barter arrangements that involved stocks to be issued in return for land and labor were also used, as wells as loans from private investors and banks (Greenburg, 1980).

On the federal level, issuance of land grants proved to be an important provision for the development of railroad systems. Land grants were used as a form of aid in the initial development of railroads because provision of federal funds to directly assist in internal improvements within the United States during the early 19th century was considered unconstitutional (Mercer, 1982). These land grants enabled the construction of the first transcontinental railroad. Grants proved to be an important source of revenue for railroads because they involved millions of acres of potentially valuable land, which could be sold by railroads to raise capital (Holbrook, 1947). After 1860, in addition to land grants of over 100 million acres, the first transcontinental railroad companies received federal loans of $65 million. Local and state governments also continued the sponsorship and financing of rail development within their jurisdictions. From 1861-1890, local aid to railroads was estimated to be have been about $175 million while state contributed aid was estimated to be somewhat smaller (Goodrich, 1960).

Following the Civil War, the federal government assumed an increasingly greater role in regulation of railways due to public criticism of private railroad companies' involvement in speculative and negligent building projects, financial misdealing, unfair rate practices, destructive competition and unfair labor practices. Individual states initiated legislation attempting to regulate railroad conduct, with little success (Kolko, 1965). The central agricultural states, in particular, revolted against what was perceived to be excessively high rates charged for grains, passing harsh legislation to control or fix fares charged by railroads (Cunningham, 1922). Congress responded to public and state pressure in 1887 by passing the Act to Regulate Commerce. This act created the Interstate Commerce Commission (ICC) (Kolko, 1965), empowering commission members to oversee rates, services and railroad financial management (Cunningham, 1922).

The national importance of railway transportation to defense was again evidenced by the government's nationalization of railroad companies during World War I. But public ownership of railways, regardless of importance to national transportation has not been popular. Congress considered leaving the railroads under a nationalized system but ultimately chose to relinquish control in 1920, acquiescing to a popular demand based on the belief that resumption of private rail ownership and management would produce the greatest benefit to the public. Although the federal government would maintain a substantial regulatory role in the operation of rail systems, ownership and operation of rail companies would be private (Crumbaker, 1940).

The evolution of railway systems in the United States demonstrates the following lessons for future transportation mode development. First, the successful development and successful continued operation of the railway mode required a public/private partnership that supported both commerce and national defense. Private sector participation in the construction and operation of transportation modes appears to be crucial for sustained development. Secondly, though private sector support of mode development may be enthusiastic, support of local, state

and federal governments is also critical. Initial construction costs for modes are too enormous to be supported by private industry alone and require local, state and federal support. Transportation mode development also requires state and federal regulation to ensure fair financial practices and safe operation, but the ownership and operation of transportation systems by the federal government is not popularly supported. Studying railways also demonstrates that the more important a transportation mode becomes to national commerce and security, the larger the fiscal and regulatory role the federal government will undertake. The government's growing fiscal and regulatory influence governing the development of new transportation modes is clearly evident in the evolution of American commercial aviation.

Air Transport Systems: In the two decades following the Wright brother's first aircraft flight, there was little demand for aircraft or airfields. By the middle 1920s, America depended upon wheels for transportation, not wings (Komons, 1884). As the primary private sector transportation mode, rail was being challenged by improvements in automobile technology. Motor vehicles traveling along an expanding highway network began to provide much greater flexibility for passenger travel and goods transport. By the end of the 1920s, the automobile was capable of moving America's 115 million people. Aviation during this period was considered a poor competitor for rail and auto, often considered to be more as entertainment for adventurers (Smith, 1991) than as a tool for commerce, falling "somewhere between a sport and a sideshow" (Komons, 1984, p. 11). Despite this view, there were airline pioneers who attempted commercial operations as early as 1913, merely ten years after the Wright Brother's historical flight. However, these early aircraft were incapable of competing with faster and more reliable express trains. None of these early private airline companies would survive past 1923 (Leary, 1989).

Though lacking private economic applications, aviation operations in the early 1900s were desired to a limited extent by the military. Frail aircraft used for aerial observation in 1914 were replaced by faster, more maneuverable and more reliable vehicles in 1918 by aircraft manufacturers. During WWI, the U.S. War Department built a number of airfields throughout the country to support military training (Bednarek, 2001). Government support kept early aircraft development alive when the National Advisory Committee for Aeronautics (NACA), the Post Office began to explore using air carriers for transporting mail (Leary, 1985), expending a total of $700,000 in 1918 and 1919. Federal support of aviation became increasingly important. Under the Waltres Act of 1930, the Post Master General of the United States had the ability to set and consolidate airway routes, form and dissolve carrier contracts and set rates. Under federal direction, a fare strategy that provided a strong financial incentive for airlines to establish passenger services was instituted (Leary, 1989). These incentives spurred a three-fold increase in airline passengers in just three years in the early 1930s (Leary, 1985). As the airborne postal service and commercial passenger market expanded, so did commercial ground facilities. The growing demand for airborne transport of mail to growing population centers stimulated demand for airfield development. Federal government sponsorship of early commercial and cargo aviation helped create commercial demand and the subsequent active participation of private businesses and local city and state governments in aviation system development (Bednarek, 2001).

Commercial aviation, like commercial rail systems has greatly benefited from national security concerns. Airport development was greatly aided by the War Department for WW II. In 1938

Congress enacted the Civil Aeronautics Act which removed a previous ban of federal aid to airports and also ordered the drafting of a comprehensive national airport plan to more orderly develop airports as part of the national transportation system. By 1939 National defense interests provided a program for improvement of commercial airports, under War Readiness, even though the airports remained primarily owned and operated by local governments. In 1940, Congress appropriated $40 million for airport work at 250 facilities, in addition to other federally funded work projects. Other cities gained from the War Department and Air Service development of airfields when some localities gained possession of fields following national emergencies. This act marked a distinct shift in airport improvement focus, moving from commercial development to national defense. The United States Army Air Force (USAAF) directed defense funds to many strategic municipal airports across the country. The USAAF typically entered into relationships with municipalities using one of three methods: (1) a lease agreement for military purposes, (2) the lease of the entire air facility (often also assuming the responsibility for airport operations) and (3) total militarization of all or part of the facility with the expressed intention of returning control of the airport to localities at the end of the war (Bednarek, 2001).

Following WWII, the federal government initiated the Federal Airport Act in 1946, beginning an aid to municipal airports program that would remain in effect for almost 25 years. The government heavily regulated and controlled the rapidly growing American domestic and international airline industry. The government carefully supervised and established safety and operational requirements for both airline companies and airports while supplying supplementary funding for airport construction and improvements. The partnership, formed between airport localities, local and state governments and the federal government, produced the steady expansion of American commercial aviation, producing the most commercially lucrative aviation market in the world (Owen, 1997; Wilson, 1996).

Commercial aviation's importance to America's economy would continue to be nurtured and safeguarded by the federal legislature. In 1970, Congress passed the Airport and Airway Development and Revenue Acts that enabled the establishment of a trust fund to sustain airport and aviation improvement supported by taxes on airline tickets, air cargo, fuel, and on the airlines themselves.

One of the most significant changes in the public/private relationship between airline industry, its airports and the government occurred in 1978 when the federal government relinquished federal regulation of economic control and scheduling of airlines. While the federal government still paid for air traffic control and regulated safety and certification of airlines and pilots, it no longer controlled the airline's operational routes and frequencies. Deregulation enabled companies to compete and grow rapidly. Airlines employed hub and spoke strategies in key city locations forming more intense commercial relationships with municipal airport owners (Reynolds-Feighan, 1992). A period of tremendous competition followed deregulation, fares decreased, and passenger travel increased dramatically. As aviation's importance to commerce and security has steadily increased, so has substantial federal aid and support to airlines and airports.

Although deregulation of the American commercial airline system was intended to make the industry self sufficient, this does not mean airlines and airports do not continue to receive substantial governmental financial support. From 1999 through 2001, approximately $12 billion

was provided for airport-planned capital development. The funding of bonds accounted for almost $7B, federal grants provided $2.4 billion and passenger facility charges produced $1.6 billion (GAO, 2003). Following the terrorist attacks of September 11, 2001, the federal government took several actions to protect airports and the airline industry. To offset the airlines' financial losses and civil liability claims as a result of terrorism, Congress passed the Air Transportation Safety and System Stabilization Act, *Public Law 107-42-Sept 22, 2001*. This act provided immediate fiscal and tax relief for airlines as well as limiting potential civil liability resulting from the use of commercial aircraft in the attacks. To strengthen aviation security, the Aviation and Transportation Security Act, *Public Law 107-71 [S. 1447] of Nov.19, 2001*, established the Transportation Security Administration, paid for by public dollars. In addition, the Terrorism Risk Insurance Act of 2002, *Public law 107-297, Nov 26, 2002*, was passed to protect American companies' future insurance losses and liability stemming from terrorist acts.

Commercial aviation in America today is the result of a complex and supportive collaboration between private companies and local, state and federal governments. It is also the result of an evolving model of transportation system development, one where the federal government plays an increasing financial supportive and regulatory role in development and operation in partnership with many private industries and local and state governments.

II. Development of Space Systems

Table I shows how initial demand that motivated construction of canal, railroad and aviation transportation systems has always been substantially based on commerce (the movement of goods and people) and national defense.

Table I. Initial Demand for Transportation Modes

	Canals	Railroads	Airports
Time Period	• **early-mid 1800s**	• **1800s**	• **early-mid 1900s**
Initial Demand	• **communication** • **national cohesion & defense** • **movement of goods & people** • **development**	• **movement of goods & people** • **national security** • **development**	• **military training** • **postal service** • **national defense** • **movement of goods & people**

Given this historical model, it would seem logical to assume that the American development of space transportation should proceed along a similar course. But this is not the case. The following review of space transportation history demonstrates that space transportation has evolved in a significantly different way. Space system development from almost its very beginning has been dominated by national defense concerns. Because of this domination, the public/private relationships that had been developed to form other transportation modes were not formed. The failure to form these traditional and vital public/private partnerships resulted in the absence of incremental development of space vehicle technology and integration into the American transportation system that connects population centers, isolating space from for local and national commercial markets that are needed to support space transportation system growth.

Space Launch Origins: World War II produced many significant aviation technological advances in aviation that directly lead to the development of space transportation systems. The Germans alone developed and deployed the first winged rocket interceptor capable of transonic speeds. They also developed the V-2 rocket capable of carrying a 2,000 pound payload nearly 120 miles at a speed of nearly 3500 miles per hour (Bergman, 1960). Though rocket technology would be developed too late in the conflict to help Germany, their rapidly emerging missile technology became very important to American and Russian governments post WW II. Immediately following Germany's capitulation, American and Russia actively sought out German scientists who had participated in V-2 rocket development. Both countries imported these scientists for work in missile development. Americans used a team of relocated German scientists headed by Werhner von Braun to test and improve the V-2 that was then capable of lifting 2,000 pounds of cargo. During the same period, the Russians actively pursued two programs that alarmed western defense agencies. In August of 1949, the Soviet Union detonated its first nuclear weapon. In addition to Russia becoming a nuclear power, there were reports that the Russians were pursuing an extremely aggressive and advanced missile program that was producing missiles capable of carrying significant payloads at increasing ranges. The belief that Europe was vulnerable to attack from Russian missiles potentially armed with nuclear warheads motivated Americans to aggressively pursue their own missile programs. The Huntsville and Redstone Alabama facilities were selected for missile research and development; Cape Canaveral Florida was selected to serve as a launch site (Bruerer, 1993).

Following WW II, America proceeded with what it considered to be a superior technological missile development program. However, funding problems and conflicts over what missiles should be developed and what service should develop and control the effort severely limited American missile advancement. The delays and problems inhibiting missile program caused by internal debate within American defense and political communities was brought into focus on October of 1957 with the startling report that the Soviet Union had successfully launched a satellite into earth's orbit. *Sputnik* satellite was 23 inches in diameter, weighed approximately 30 pounds and orbited the globe every one hour and 35 minutes at an altitude of 560 miles. On November 3, the Russians launched *Sputnik II*, a vehicle carrying a much heavier payload, including a dog named Laika. America hurriedly attempted a launch of a Vanguard test vehicle in December of that same year. However, the Vanguard rose three feet from its launch pad and burst into an inferno of flames (Bilstein, 1989). America's reaction was one of both humiliation and fear. Americans had been extremely proud of both its defense and aerospace programs, programs that then appeared to be clearly second rate to their Cold-War adversary.

In January of 1958, American achieved a limited amount of success by launching a small *Explorer I*, it was quickly eclipsed by the Soviet Union's launch of *Sputnik III*. *Sputnik III* was a real scientific and technological accomplishment. It weighed nearly 3000 pounds and presented grave military ramifications for the west. The Russians were not only ahead in development of missiles that represented a clear strategic nuclear threat, but they were also believed to be rapidly building a program that would allow them to conduct manned orbital flights as well as flights to the moon (Bruerer, 1993). The Russians were perceived to be pursuing domination of the ultimate military high ground, space.

America's response would be two-fold. It would enter a crash program of intercontinental ballistic missile (ICBM) development and it would seek to gain superiority in space by sending men to the moon. America's strategy to accomplish both of these goals was through the test and development of vertically launched rockets that would be capable of providing the needed heavy lift for both programs (Heppenheimer, 1999). The Atlas missile series served as an ICBM and also as a vehicle for four manned orbital flights in the Mercury program. ICBM development produced an operational Minuteman missile in 1961. The success of the Minuteman was quickly followed by the development of the versatile Titan series that included many variants including the Titan I (ICBM only), the Titan II (ICBM & Gemini) and the Titan III launch vehicle capable of lifting 33,000 pounds of cargo into orbit. America was successful in regaining its military footing against Russia with ICBMs and over-taking Russia in space by sending men to the moon, but this success came at an enormous economic cost and significantly slowed the development of future space transportation. Vertically launched rockets, not space planes with potential for linking with existing commercial airports were the chosen vehicles for American space flight.

The Demise of Commercial Winged Space Vehicle Development: The space race to the moon and crash ICBM development programs had significant impact on future space development economics. Since the basic motivation for both programs was national defense, funding was almost exclusively public. Commercial applications that might help off set program developmental and operational costs were extremely limited. In particular, the immense cost of involved with seeking manned space flight would have crucial implications for future space flight development.

. The NASA-directed program was expressively chartered to land men on the moon and return them safely to earth (Breuer, 1993). The NASA run Apollo program, though extremely successful, would cause extensive problems for follow-on space efforts. The immense cost of the moon race took a toll on programs deemed not crucial and directly related to the Apollo program. Originally estimated to cost $12 billion in 1963, the cost of the Apollo program had increased to over $21 billion at the time of the first moon landing in 1969 (Heppenheimer, 1993). Early winged space vehicle development was perceived as showing little potential to supply the heavy lift needed to support orbital missions. Winged vehicle funding was diverted to heavy lift and expendable lift vehicle (ELV) programs.

Following WWII, America pursued the testing and development of a string of extremely successful experimental (X-series) aircraft. These included the famous X-1 as well as the X-2, X-3, X-4 and X-5 variants that were designed to explore various aspects of high speed and high altitude flight. Probably the most success X series aircraft was the X-15, which underwent testing during the same time that Mercury, Gemini and Apollo craft were being flown and developed. For a decade starting in the late 1950s until 1968, the X-15 flew 199 flights, achieving a maximum speed of 6.7 Mach and a maximum altitude of 354, 200 feet (Thompson, 1992). X-15 tests of flight controls and instruments, alloys, aerodynamic configurations, life support and hypersonic flight regimes were documented in over 765 research papers and reports and a significant body of lessons learned for future hypersonic test programs. Of the twelve pilots that flew the X-15, five received astronaut wings (Jenkins, 2000). Even though productive beyond initial expectations, the X-15 was cancelled, a budgetary victim. Previous budget constraints for space vehicle development under the Eisenhower administration had replaced with an aggressive

multi-billion dollar government program. The NASA-directed program was expressively chartered to land men on the moon and return them safely to earth (Breuer, 1993). Winged hypersonic craft, like the X15 were incapable of providing the heavy lift needed to achieve desired orbital altitudes to support the moon program. Expendable vertical launch rocket systems could lift the needed heavy vehicles and components. But costs of the manned programs soared. Originally estimated to cost $12 billion in 1963, the cost of the Apollo program had increased to over $21 billion at the time of the first moon landing in 1969 (Heppenheimer, 1993). The immense cost of the moon race took a toll on programs deemed not crucial and directly related to the Apollo program.

The demise of the X-15 series effectively terminated winged vehicle hypersonic development. This was done despite the fact that the X-15 test series demonstrated that winged reusable launch vehicles (RLV) were capable of rudimentary space flight as early as 1959. Significantly, these vehicles clearly showed potential for future interface with existing airport systems as well as representing a developmental program that could eventually produce vehicles that would be capable of flying not only sub-orbital profiles but orbital profiles as well. The cessation of winged spacecraft that may have become capable of interfacing with commercial aviation markets prevented the creation of private sector partnerships that had been so crucial in past transportation mode development.

The NASA run Apollo program, though extremely successful, dictated how America would pursue future space efforts. Since early winged space vehicle development was perceived as showing little potential to supply the heavy lift needed to support orbital missions, America would become solely dependent on vertically launched rocket vehicles. The decision to only develop vehicles incapable of interfacing with existing air transportation would preclude incremental development of passenger and cargo markets in space transportation. Because of this, American space “transportation” was destined to remain principally funded and controlled by the federal government, to the exclusion of private markets that could aid in off-setting system operational costs.

The Birth of America’s Space Transportation System (STS): In March of 1958, the administration decided that America needed a national space program spearheaded by an agency capable of channeling technology, science, and military security requirements to meet the Soviet challenge. In October of 1958, the administration commissioned the National Aeronautics and Space Administration to meet the space race challenge (Bilstein, 1989 pp. 44-48). The NASA-directed program was expressively chartered to land men on the moon and return them safely to earth (Breuer, 1993).

NASA accomplished its mission. However, the American aerospace industry that emerged after Apollo was a “government-dominated” organization where cost containment was not considered an “important criteria for success.” Despite initiatives to correct this practice, NASA’s inability to control costs still plagues the agency today (Hoban, 1997, pp xiii-xvi).

As Apollo neared its first landing on the moon, NASA was looking ahead to the next phase of space exploration. NASA considered a space station as the critical next step, absolutely crucial to the future establishment of a lunar base or Mars manned missions. But the tremendous costs that

incurred in the Apollo program resulted in significant budget reductions during the economic downturn of 1970s. In reaction to the cutbacks, NASA abandoned plans for a space station, lunar colony and manned Mars mission. NASA sought an alternative to the reliable but expensive system of expendable launch vehicles that had been used in the past. NASA proposed a system combining a RLV with vertical rocket launch technology. Under pressure from the Office of Management and Budget, NASA commissioned studies that would be used to economically justify the construction and use of the proposed shuttle fleet. The NASA-commissioned studies claimed that flight costs of the shuttle would be less than using conventional ELVs. In the wake of the successful but enormously expensive Apollo moon missions, American space policy debate suddenly changed from a strategy of "beating the Russians" to one of program "cost-effectiveness" (Pace, 1990). The problem was how to impose efficiency onto an American space launch system that had been constructed, dominated and operated by the government primarily for defense with little cost constraint.

In response to efficiency concerns, the shuttle was marketed based on cost effectiveness by projecting an exceptionally robust operational schedule that would meet both NASA and DOD (USAF) mission requirements, thereby eliminating the need for the use of ELVs. The shuttle model construct proposed the use of five shuttles each flying once a month, every month, to achieve a yearly total of 60 flights. However, even relatively simple simulated reliability analysis by the Rand Corporation of the proposed shuttle schedule model produced serious doubts as to the sustainability of such an ambitious schedule (Leinweber, 1984). Critical analysis specifically cited concerns regarding the longevity of orbiters (aging and loss), vehicle turnaround and relaunch time requirements and the consequence of mishaps (stand-down periods following incidents). Prophetically, the studies recommended supplementing the fleet with additional orbiters or with "an alternative launch system" as a means to ensure adequate space launch capability (p. vi). Other agencies appeared to question original promises made by early shuttle advocates.

The Air Force was extremely uncomfortable with the prospect of relying solely on the shuttle to support critical DOD missions. When faced with ultimately having to phase out the Titan series, the USAF undertook two strategies. The first was to encourage Titan contractors to develop a Titan commercial variant for launch of commercial satellites. The second was to seek authority to purchase complementary ELVs based on the shuttle solid rocket booster design (Pace, 1990). The loss of the Challenger in 1986 validated the concerns about deficiencies in the shuttle program as originally forecast in the original Rand shuttle operational model reliability analysis. It also enabled the USAF to once again actively procure ELVs to meet its operational requirements. Of significance, even though a replacement shuttle orbiter was built and the shuttle fleet returned to service, the STS fleet would only carry shuttle-unique payloads. In its 20-year history, to this date, the shuttle has flown only 113 missions. Projects delayed by repeated shuttle groundings and long turnaround times became a priority well before the loss of the Columbia. By the 1990s, commercial missions were no longer part of the shuttle launch plan and were launched by ELVs. This action clearly signaled the end to any pretense to "justify the shuttle on cost-effectiveness grounds" (p. 8). Importantly, the ELV launch system that was judged too expensive to operate is now being used in parallel to supplement and in some cases directly perform missions intended for the STS system. Titan 4 missile costs, that were projected to be approximately $100M, have actually cost about $500M plus the cost of the payload. Like the

shuttle, the Titan's reliability was also less than desired, achieving 30 successful launches out of 34. In the late 1990s, three Titan Air Force Mission failures cost the government $3 billion (Kelly, 2004). The Titan has been retired because of cost concerns, but the end result is that the American government now pays for two expensive launch systems, the shuttle that is currently grounded and ELVs. Neither can be realistically considered to be part of a viable and affordable transportation system.

Space Launch Sites: In addition to being expensive, space transportation is also not easily accessible. There have been a total of five potential operating launch locations developed by the United States; however, only the isolated coastal complexes located in Florida and California are extensively used. Florida and California complexes are capable of both vehicle launch and recovery, but California is used only for emergency or alternate shuttle landings. California and Florida complexes remain on government property. As demand for commercial satellites and other launch services evolved, individual states formed some limited collaborative partnerships comprised of both federal and state governments and private companies seeking economic development and educational opportunities for the individual states.

Currently, launch sites are built, operated and maintained in one of three ways: directly by the federal government, by the federal government in agreement with private companies or under an agreement between state agencies and private companies. The California Space Authority, a nonprofit corporation, and the Florida Space Authority, an established state government agency, are supporting facilities and equipment for the construction of payloads, space flight hardware, rockets and other launch vehicles, and for other spaceport facilities and related systems. Both California and Florida agencies actively seek and enter into private launch development and operational agreements with commercial enterprises. At the present time, the shuttle is the only operationally recoverable and relaunchable space transportation vehicle in the American inventory. It is used in a very limited and restricted capacity serving mostly government security and research functions and is controlled by NASA. Because of environmental and safety considerations associated with the launch of large rocket powered lift vehicles, remote coastal locations isolated from population centers are required for operational space facilities within the United States. All these sites employ ELVs, with the exception of Florida's Shuttle RLV and also are isolated from population centers due to environmental and safety constraints.

Space Transportation System Summary: America's space transportation system was not developed by any public/private partnership as witnessed in prior American transportation mode development. Space launch has been government dominated, funded and operated by public tax dollars. Private sector participation has been extremely limited. Cost for current vertical launch is so prohibitively expensive that it is economically incapable of sustaining President Bush's proposed vision of future space exploration. If future space programs are to be achieved, then it is necessary to form the same public/private relationships that have been responsible for the development and evolution of America's other transportation modes.

Recommendations

Market failures do exist within the American space transportation system. To the extent that such failures are for national defense and/or economic development with national benefits, a significant federal government involvement in the space transportation system is not only

justified but also necessary. Because defense is a public good and is such an important factor in space systems, it is critical that a balance of public and private ownership and operations within the space transportation mode be shaped. Past models of transportation mode development provide a roadmap for future transportation mode development to follow. Table II displays how the American space program, unlike its transportation predecessors has lacked private commercial demand and has been primarily reliant on public dollars. For a space transportation mode to develop, the same public/private relations as experienced in the creation of prior transportation modes must be formed. Both private sector demand for services and private sector funding must be dramatically increased.

Table II. Demand and Financing for Transportation Mode System Development

	Canals	Railroads	Airports	Spaceports
Time Period	• early-mid 1800s	• 1800s	• early-mid 1900s	• mid-late 1900s
Initial Demand	• communication • national cohesion & defense • movement of goods & people • development	• movement of goods & people • national security • development	• military training • postal service • national defense • movement of goods & people	• scientific exploration • national security • national pride • commercial satellites
Primary Financing:				
Vehicles	• private	(same as infra.)	• private	• federal government
Infrastructure	• states • private (populated areas) • minor federal role	• private • local governments • states • federal (land grants & loans)	• local governments • federal government • some private	• federal government

To be sustainable, it is critical for space transport to establish working connectivity with the existing transportation structures. Space vehicles capable of interfacing with existing aviation and ground transportation modes must be developed. The establishment of connectivity and overlap with existing transportation systems is vital for space transportation growth. Development of sub-orbital vehicles that can interface and operate in conjunction with the existing national transportation structure may be able to expand existing transportation markets, capitalizing on the potential to move people and goods at greater speeds in national as well as international markets.

As in the past, private sector and local government involvement is necessary for future transportation modes to grow. If greater private sector participation is desired in the development

of space transportation systems, then there is a need for the federal government to more clearly identify the potential economic gain for state and local governments and the private sector as well as providing the economic incentives for localities and states to pursue space transportation expansion.

Vehicle development is expensive, but serves a public good. Government funding is not only appropriate, but also necessary for new vehicles to emerge. The federal government must more actively support the development of sub-orbital vehicle development by private companies. Provision of incentives for private companies currently developing and testing sub-orbital experimental vehicles would be a very positive step in developing a more sustainable and robust space transportation with many different vehicles competing in an expanding commercial market. As commercial markets and demand evolves and improves, so will vehicles. Steady and incremental improvement of sub orbital vehicles will lead to variants capable of servicing both medium and high orbital markets. These markets will make travel to and development of earth's orbit more affordable. Space transportation will enable the same incremental expansion of population and business centers into earth's orbit and on the moon, just as rail and water systems enabled expansion and colonization of early American territories.

Private sector markets are critical for viability, sustainability and growth of transportation systems. However, because of the enormous initial costs, government financial and legislative assistance will be needed for sub-orbital vehicle development and establishment of commercial markets. Government support of private vehicle development can ensure there are vehicles with dual commercial and defense capabilities, as well as gaining the support and participation of localities and states. Space-related costs of defense, commercial and scientific ventures will be reduced because of private commercial involvement and competition. Incremental development of space markets and the building of commercial space transportation into earth's orbit and to the moon will ultimately reduce mission costs of exploratory ventures to Mars and beyond because such missions will be launched and supported from locations in space, not on earth. Public/private partnerships will enable cost containment and cost sharing will ultimately improve the sustainability of American space transportation system development far into the future.

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Authors

Patrick O'Neil is a doctoral candidate in Public Administration participating in the NASA space Grant College and Fellowship program for the University of Nebraska at Omaha Aviation Institute. Mr. O'Neil earned his Masters of Security Management and Strategic Studies from the Naval War College in Newport, Rhode Island. In addition, he has a Bachelor's degree in Psychology from Washington State University. His research interests include the Small Aircraft Transportation System, Spaceport development, Advanced Air-Ground Traffic Management Systems, and Transportation Security management. He is a retired senior naval officer and Designated Naval Aviator with 6,000 hours of flight experience, holding a Private Pilot Certificate and pursuing additional civilian ratings. Mr. O'Neil is a member of Alpha Eta Rho and the American Society for Public Administrators.

Carol Ebdon is an Associate Professor in the School of Public Administration at the University of Nebraska at Omaha. Her research interests are in the areas of public budgeting and finance.