The Aero/Space Economy in North Carolina

A Preliminary Assessment of Current Performance and Future Prospects

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Executive Summary

The original edition of this white paper was created for "The Aero/Space Economy in NC: An Innovation Workshop," held on May 10, 2005, on the Centennial Campus of North Carolina State University. The workshop began the process of determining how North Carolina can contribute to and benefit from the existing and emerging Aero/Space Economy. Discussions during the workshop indicated that a more fundamental question to be addressed first is whether North Carolina should invest its resources in developing an Aero/Space Economy. To begin answering this complex question, this second, expanded edition of the white paper contains:

- A more detailed discussion of how to define "Aero/Space Economy."
- Snapshot statistics of the state's current aerospace industry and an aerospace-related industry cluster.
- A high-level summary of the distribution of aerospace-related economic activity throughout the U.S. economy.

Statistics indicate that North Carolina has a modest presence in the narrowly prescribed core aerospace industry but a more significant presence, and potential for growth, in the broadly inclusive aerospace-related cluster, the latter comprising the "Aero/Space" economy as defined in this paper. These findings, while not comprehensive, suggest that North Carolina's role in the Aero/Space Economy will be multi-faceted and possibly more indirect, coming via one or more aerospace-related clusters rather than via a significant role in the core aerospace industries. Moreover, North Carolina's activity in the broader Aero/Space Economy could have widely

distributed impacts throughout virtually all major industry sectors and geographic regions.

Based on these preliminary findings, the authors recommend that North Carolina develop a strategic plan for how best to contribute to and benefit from the Aero/Space Economy. To do so, the North Carolina Space Initiative should collaborate with a highly-regarded economic development consultant or consulting firm to produce an in-depth, aerospace-related cluster analysis specific to North Carolina.

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Introduction

North Carolina's commercial Aero/Space cluster, broadly defined, has the potential to be a significant state and national economic engine in the future, much as biotechnology and information technology are today. A strategy for realizing this promise is vital, and we must begin by answering these questions:

- How well is North Carolina positioned to contribute to and benefit from the emerging commercial Aero/Space Economy?
- What non-Aero/Space sectors will influence and benefit from this new economy, and how?
- What assets do we have in place in our state government, commercial, academic, and R&D sectors?
- What key pieces are missing from the state's portfolio?

Answers to these questions will lay the foundation for a comprehensive strategic assessment of the Aero/Space cluster in North Carolina and its role in the economy of our state. This will permit an informed investment of precious resources in what has potential to be an important economic driver for North Carolina's 21st century economy.

Why now? Why here? With respect to the first question, the answer is that Aero/Space activities are increasingly important to the nation's economy. Consider, for example, these significant events of 2004:

January	President Bush announces a new vision for the U.S. civil space program.
March	The House of Representatives passes the Commercial Space Launch Amendments Act, "To promote the development of the emerging commercial human space flight industry."
April	The Federal Aviation Administration's Office of Commercial Space Transportation issues the world's first license for a manned sub-orbital rocket flight to Scaled Composites, Inc.
May	"The President has accepted the notion that eventually humans will incorporate accessible space into their economic zone," says John Marburger (Science Advisor to the President) in *Space News*.
June	The Report of the President's Commission on Implementation of United States Space Exploration Policy is released, and it emphasizes the importance of entrepreneurs and the research and education communities.
October	Scaled Composites' *SpaceShipOne* becomes the first private manned spacecraft to exceed an altitude of sixty-two miles twice within a fourteen-day period, winning the Ansari X Prize and demonstrating the capacity and the will of the private sector to succeed in space utilization.

October	Virgin Airways CEO Sir Richard Branson announces plan to purchase five spacecraft for commercial sub-orbital passenger flights beginning in 2007.
December	The Senate passes the Commercial Space Launch Amendments Act.
December	Robert Bigelow, owner of Budget Suites of America and Bigelow Aerospace, announces America's Space Prize, a $50 million space launch contest. The objective is to spur development of a low-cost commercial manned orbital vehicle to carry passengers to Bigelow inflatable modules by 2010.

With respect to the second question — Why here? — the answer is that North Carolina has in place many of the critical pieces necessary for building a robust Aero/Space economy. We excel as a state in terms of inputs to innovation process, i.e., research and development activity, intellectual capital, entrepreneurial activity, and small business funding — all of which continue to increase over time. Moreover, our technology-intensive economy continues to grow, as does our generation of intellectual property. Indeed, despite the unfavorable national trends that ultimately affected the economies of all states early in this decade, North Carolina continues to have one of the fastest-growing technology economies in the U.S. Most importantly, North Carolina is known around the world for the farsighted investments that it has made in the past in support of its high-technology future.

Clearly, the stage is set for the development of a vibrant Aero/Space Economy in North Carolina.

Context

In 1902, Wilbur Wright wrote to a friend explaining his and Orville's plans for the following year. "We are thinking about a machine next year with a 500 ft^2 surface. This will give us opportunity to work out problems connected with the management of large machines both in the air and on the ground. If all goes well the next step will be to apply a motor" (Kandebo 2002). All went well, and in 1903 North Carolina became *the* launch pad for American aviation. Between 1959 and 1975, many Mercury, Gemini, Apollo, Skylab, and Apollo-Soyuz astronauts trained at Morehead Planetarium in Chapel Hill. Whether through entrepreneurs or government programs, North Carolina has demonstrated its value as a significant contributor to America's aerospace endeavors.

Fast-forward one hundred years — the Commission on the Future of the United States Aerospace Industry presented its report regarding the status of the industry (Walker 2002). North Carolina ranked 20th among the states, with approximately 38,000 jobs reflecting an average wage of $41,000 and over $1.6 billion in payroll. These jobs reflect an 8% growth in North Carolina's aerospace and aviation employment from 1996 to 2001. This report shows that California, Texas, Washington, and Florida lead the aerospace employment rankings. Alabama, Arizona, Georgia, and Kansas also have

strong aerospace industry clusters. These states will not sit still as traditional, primarily government-funded aerospace transforms into primarily commercial Aero/Space. In the face of competition, how can North Carolina's growth be sustained? Can it be increased with strategic investments?

> *All major industry sectors are affected by the activities of the commercial space transportation and enabled industries. Although some of these industry types seem unrelated to commercial space transportation, they provide goods and services, directly or indirectly, to the commercial space industry, or they benefit from the re-spending of money on consumer goods.*
>
> *(FAA 2004)*

Clearly, North Carolina has the foundation for an Aero/Space economic cluster, such as air transportation and aircraft and parts manufacturing, which in turn provides business to the state's traditional and emerging industries. This cluster offers a vital mechanism for a transition of the state's economy in which traditional industries are retooled, new industries are born at the confluence of old and new, and each new firm increases the attractive force of the cluster.

A case in point — illustrating the spillover economic effects of Aero/Space — is the Health and Medical Services industry cluster. As one of the largest and fastest-growing clusters in the state (Feser and Renski 2000), it is significantly affected by the Aero/Space Economy. In 2002, for example, the U.S. health services industry derived over $2.8 billion in economic activity and more than $1.3 billion in earnings and created over 34,000 jobs as a result of activities of commercial space transportation and enabled industries (FAA 2004).

Another example is the textile industry. This has been a mainstay in the North Carolina economy for decades, but has seen a steady decline in recent years. As noted below, the textiles industry appears in both *High-Tech Clusters in North Carolina* (Feser and Renski 2000) and *The Economic Impact of Commercial Space Transportation on the U.S. Economy: 2002 Results and Outlook for 2010* (FAA 2004). While not an Aero/Space industry *per se,* it is a North Carolina industry and, as seen in the second report just listed, it benefits from other non-Aero/Space industries supported by commercial space transportation.

These are just two examples of how Aero/Space permeates the entire economy. They demonstrate how a vibrant Aero/Space cluster in North Carolina could benefit other sectors as well in both urban and rural regions.

Although North Carolina currently ranks 11th among all states in the air transportation sector (Walker 2002), the state is active in other sectors. It has multi-sector activity within the commercial Aero/Space industry, much of which is not tracked or catalogued. This activity needs to be clearly and explicitly identified so that

complementary resources from strong university, industry, and government partnerships can foster the development of the Aero/Space industry's high-growth and high-value sectors within North Carolina.

Historically, space activity has been predominantly government-funded. Now, however, with the nation's reinvigorated space exploration policy, we are poised to embrace Earth-orbit as a full-fledged economic development zone. States like California, Colorado, Florida, Oklahoma, Texas, and Virginia recognize that future high-wage jobs will be generated by the emerging commercial Aero/Space Economy. They understand the commitment required to attract the companies and institutions that will create these jobs and provide a growing portion of their tax revenues.

> *We must challenge and rely heavily upon the private sector — major corporations, small business, and entrepreneurs — beyond anything that has ever been attempted in a major government-run program. The government must execute only those activities that are too risky for private sector involvement. The government must change its focus to provide incentives for the commercialization of space, and to create, nurture, and sustain a robust space-based industry.*
>
> *It's time to connect chambers of commerce, labor unions, school boards, and other civic organizations to take advantage of the educational and commercial benefits of space exploration. The marketing and communication involved in keeping people informed about and engaged in space exploration cannot be a part-time effort nor a stop-and-start endeavor.*
>
> *[We must] work together with state and local political leaders to infuse the excitement associated with exploring space into science, math, and technology education programs across the country.*
>
> *(Aldridge 2004)*

The Potential for North Carolina

Defining the Aero/Space Economy: Industry vs. Clusters vs. Economy

The first step toward understanding the state's potential for developing an Aero/Space Economy is to understand the distinction between three important economic levels. These levels set the stage for determining North Carolina's current performance throughout the entire Aero/Space Economy.

Figure 1 illustrates these levels and the dynamic transition across levels from narrow aerospace industry to aerospace-related clusters to broad Aero/SpaceEconomy.[1] It also summarizes the specific measures discussed and used in the following sections of the paper.

[1] The various reports and presentations cited in this white paper, and the insights drawn from them, also demonstrate this transition.

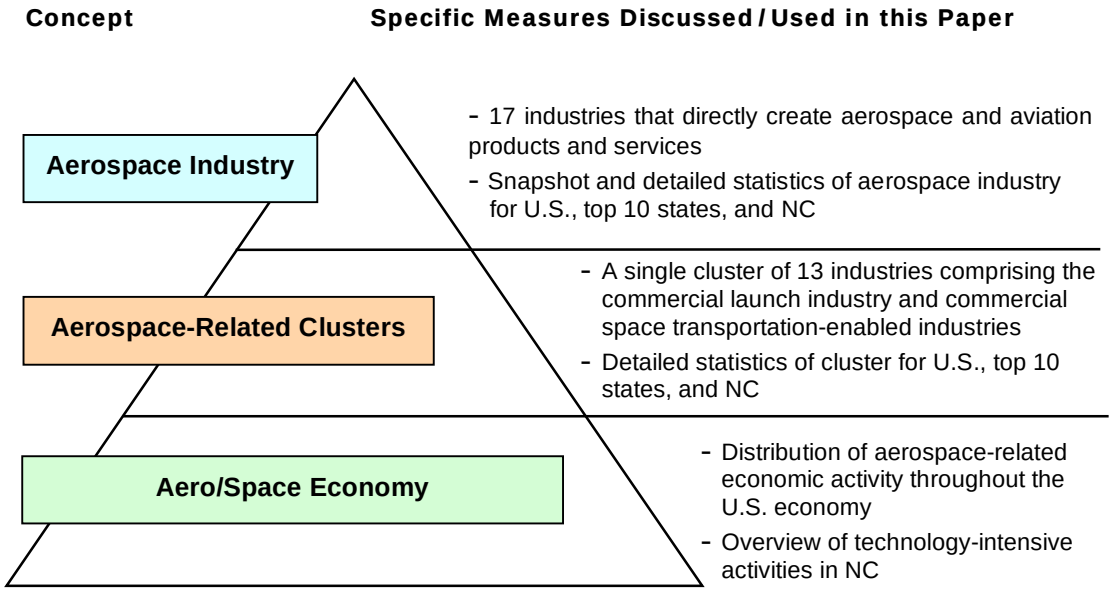

Figure 1. Defining Aero/Space Economy: Industry, Clusters, and Economy

The first level is the ***aerospace industry***. Currently, there is no consensus on the definition of the aerospace industry, and most definitions depend on the needs of the particular study being conducted. For example, the Aerospace Industries Association exclusively examines the manufacturing segments of the aerospace industry, while the Air Transportation Association focuses only on the air transportation industry. For the purposes of this white paper, we use the following definition, provided by the Commission on the Future of the United States Aerospace Industry (Walker 2002):

> **Aerospace Industry**: Representing a narrowly defined core of the larger civilian and commercial aerospace and aviation cluster in the United States, the aerospace industry includes only those industries that directly create aerospace and aviation products and services and excludes those components of the military that are engaged in aerospace and aviation-related activities. It is defined by the following 17 codes in the North American Industry Classification System[2]:
>
> **MANUFACTURING**
>
> **Aerospace Products and Parts**
>
336411	Aircraft manufacturing
336412	Aircraft engine and engine parts manufacturing
336413	Other aircraft parts and auxiliary equipment
336414	Guided missile and space vehicle manufacturing
336415	Space vehicle propulsion units and parts manufacturing
336419	Other guided missiles and space vehicles and auxiliary equipment

[2] Some researchers have classified this group of North American Industry Classification System (NAICS) codes as an aerospace cluster rather than the aerospace industry. As discussed in the paragraph above, the line distinguishing an "industry" from a "cluster" is not clear.

Search, Detection, Navigation, and Guidance

334511 Search, detection, and navigation instruments

SERVICES

Air Transportation

481111 Scheduled passenger air transportation

481112 Scheduled freight air transportation

481211 Nonscheduled chartered passenger air transportation

481212 Nonscheduled chartered freight air transportation

481219 Other nonscheduled air transportation

Support Activities for Air Transportation

488111 Air traffic control

488119 Other airport operations

488190 Other support activities for air transportation

Satellite Communications

517410 Satellite communications

Flight Training Schools

611512 Flight training

The next level entails ***aerospace-related clusters***. Broader than single industries, clusters are groups of businesses that are related through presence in a common product chain, dependence on similar labor skills, or utilization of similar or complementary technology. Whereas an industry is a group of businesses that produce a similar product, a cluster includes final market producers, suppliers, related producer services, and other linked enterprises. While this definition appears straightforward, the term "cluster" means different things to different people. Moreover, the appropriateness of any definition, as well as any subsequent method of cluster identification, depends on the reasons for defining the cluster (Feser and Bergman 2000).

Given the preliminary scope of this white paper, a formal cluster analysis is not conducted here.[3] However, building on existing research conducted by the Federal Aviation Administration, this paper presents preliminary findings regarding North Carolina's level of activity in a single pre-defined aerospace-related cluster: Commercial Launch Industry and Commercial Space Transportation-Enabled Industries. The purpose of presenting these findings is to illustrate how an alternative (and broader) definition of aerospace-related activities provides additional insight into North Carolina's potential for developing an Aero/Space Economy.

[3] As noted in the Recommendations section below, the key recommendation of this white paper is that such an analysis be conducted.

For the purposes of this white paper, we use the following aerospace-related cluster definition (FAA 2004):

> **Commercial Space Transportation Cluster:** This represents a narrowly defined core of the larger civilian and commercial space transportation industry and launch-enabled industries cluster in the United States. It includes only those industries that directly comprise the commercial launch industry and the industries that commercial space-enabled transportation enables. It excludes those components of the military that are engaged in space transportation or launch-enabled activities, as well as the 17 industries that constitute the aerospace industry discussed above. It is defined by the following 13 codes in the NAICS[4]:
>
> **Launch Vehicle Manufacturing and Services**
>
> 541710 Physical, engineering and biological research
>
> **Satellite Manufacturing**
>
> 334220 Broadcast and wireless communications equipment
>
> 334418 Printed circuit assembly manufacturing
>
> 334419 Other electronic component manufacturing
>
> **Ground Equipment Manufacturing**
>
> 334290 Other communications equipment manufacturing
>
> 334310 Audio and video equipment manufacturing
>
> **Satellite Services**
>
> 517211 Paging
>
> 517510 Cable and other program distribution
>
> 515210 Cable and other subscription programming
>
> 517212 Cellular and other wireless carriers
>
> 517910 Other telecommunications
>
> **Remote Sensing**
>
> 541360 Geophysical surveying and mapping services
>
> 541370 Other surveying and mapping services

The final and most extensive level is the ***Aero/Space Economy***, which is far more encompassing than "industry" or "cluster." For example, North Carolina (as well as the nation and the entire world) was once primarily an agrarian economy, where input to and output from agriculture permeated and influenced all (or most) other economic (and social) activities. The agrarian economy was replaced by an industrial economy, which now is transitioning to the knowledge economy. As outlined above, the stage is set for federally driven aerospace activities to become increasingly commercial, thus creating the foundation for an emerging Aero/Space Economy.

[4] This is just one of several possible aerospace-related clusters. Another possible aerospace-related cluster, composed of enabling technologies for space exploration, is suggested in the Appendix.

Determining North Carolina's performance in the Aero/Space Economy is beyond the scope of this white paper. However, the paper does provide a brief discussion below of key economic impacts within the U.S. Aero/Space Economy. In addition, the findings below regarding North Carolina's performance in the aerospace industry and in a particular aerospace-related cluster provide a starting point for a broader analysis of North Carolina's performance in the Aero/Space Economy.

Measuring North Carolina's Performance in the Aero/Space Economy: Industry vs. Clusters vs. Economy

Aerospace Industry

North Carolina ranks 20th in the nation in terms of aerospace/aviation employment. Table 1 provides a snapshot view of North Carolina's current performance in the aerospace industry, as compared with the performance of the U.S. overall and of the top 10 states.

As Table 1 indicates, nationwide in 2001, the aerospace/aviation industry had over 21,000 establishments, employing over two million workers and accounting for 16 jobs per 1,000 jobs nationally. The average industry wage was $47,673, which was 35% higher than the U.S. average wage for all industries. This activity created $98 billion in payroll. The top 10 states combined accounted for over half of the total employment, establishments, and payroll in the industry.

North Carolina's overall rank of 20th in employment in the aerospace industry accounts for approximately 2% of the U.S. aerospace/aviation workforce. Ten of every 1,000 jobs in North Carolina, or 1%, are in the aerospace/aviation industry, ranking it 34th in the nation on this measure, and the state's 410 aerospace/aviation establishments comprise 2% of all such establishments nationwide. North Carolina's average wage for the aerospace/aviation industry is $41,035, ranking it below the top 10 states on this measure and ranking it 32nd in the nation. However, that wage is 32% higher than the state's average wage for all its industries. With a total payroll of $1.6 billion, North Carolina's aerospace/aviation industry accounts for 2% of the total U.S. payroll for the industry.

Together, these statistics suggest that North Carolina, while not a leader in the aerospace/aviation industry, has considerable activity in this sphere that can spur activities in related spheres. The state's top three aerospace/aviation sectors are *air transportation* (34,900 jobs), *aircraft and parts manufacturing* (2,300 jobs), and *search, detection, and navigation instruments* (600 jobs). North Carolina's employment in this industry increased by 2,700 jobs between 1996 and 2001, an 8% increase. This is slightly higher than the 7% rate of increase for the U.S. overall.

Table 1. Snapshot Statistics for the Aerospace and Aviation Industry

U.S., Top 10 States (ranked by total aerospace/aviation employment), and NC, 2001

Statistic	U.S.	CA	TX	WA	FL	NY	IL	GA	AZ	PA	OH	NC
Employment	**2,034,587**	293,701	184,175	117,629	114,274	97,066	88,709	83,006	68,987	66,185	62,475	**37,971**
Employment rank	**NA**	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	**20th**
% of U.S. total	**100%**	14%	9%	6%	6%	5%	4%	4%	3%	3%	3%	**2%**
Jobs per 1,000 workers	**16**	19	20	44	16	11	15	21	31	12	11	**10**
Jobs per capita rank	**NA**	12th	10th	1st	16th	28th	18th	8th	4th	27th	29th	**34th**
Establishments	**21,852**	2,843	1,679	666	1,620	1,223	608	530	571	636	613	**410**
% of U.S. total	**100%**	13%	8%	3%	7%	6%	3%	2%	3%	3%	3%	**2%**
Avg. industry wage	**$47,673**	$53,909	$48,332	$57,098	$41,383	$44,647	$41,285	$52,413	$49,556	$46,649	$47,082	**$41,035**
Wage rank	**NA**	5th	12th	3rd	30th	21st	31st	7th	9th	16th	15th	**32nd**
U.S./state average wage	**$35,296**	$41,194	$34,948	$37,059	$30,549	$44,942	$38,044	$34,182	$32,606	$33,999	$32,510	**$31,077**
Wage differential	**35%**	31%	38%	54%	35%	-1%	9%	53%	52%	37%	0%	**32%**
Payroll	**$98b**	$16.1b	$9.0b	$6.7b	$4.8b	$4.4b	$3.5b	$4.4b	$3.4b	$3.0b	$3.0b	**$1.6b**
% of U.S. total	**100%**	16%	9%	7%	5%	4%	4%	4%	4%	3%	3%	**2%**

Source: Walker 2002

To put this in context, an examination of 2001 employment data for the six sectors comprising the aerospace/aviation industry shows that the vast majority of the nation's two million jobs were concentrated in the *air transportation* industry. In that year, 1.3 million people were employed by this sector, comprising nearly two-thirds of all aerospace industry employees. *Aircraft and parts manufacturing* was the second largest aerospace sector by jobs, employing over 460,000 workers in 2001. The *search, detection, and navigation manufacturing* sector employed more than 150,000 workers in 2001, earning $65,100 on average. The other three sectors employed fewer than 100,000 industry workers each (Commission on the Future of the United States Aerospace Industry 2002).

A more detailed look at employment patterns in the aerospace/aviation industry across the U.S., the top 10 states in terms of employment, and North Carolina is shown in Table 2. The industry is broken down according to the six segments that comprise the core of the industry: *aerospace products and parts; search detection, navigation, and guidance; air transportation; support activities for air transportation; satellite communications;* and *fight training schools*[5].

Although a significant number of the data for specific segments are not disclosable or not calculable, two instructive patterns still appear. First, in terms of the largest segment, *air transportation,* North Carolina is holding its own with 13,166 employees, or 2.5% of all U.S. air transportation employees. This is just slightly below the share that North Carolina's total population represents of the total U.S. population (2.8%). Second, North Carolina fares comparatively worse for the second and third largest segments, *aerospace products and parts* and *search, detection, and navigation instruments,* respectively. Here, North Carolina's 1,754 and 576 employees, respectively, represent only 0.4% of all the employees in the segments.

Further insight into these employment specialization patterns is provided in Table 3. The table presents location quotients for each state in each of the industry segments. Location quotients are a standard measure for comparing the degree of specialization across industries or clusters (see box). States having a location quotient of at least 1.0 — indicating the state's share of employment in that segment matches the comparable share for the U.S. — are shaded in gray.

A Summary Measure of Relative Size

To evaluate the relative size of a cluster, we use a simple descriptive measure called a location quotient. It is calculated as

$$\frac{Employment, cluster\ i, NC}{Total\ employment, NC} \div \frac{Employment, cluster\ i, US}{Total\ employment, US}$$

A location quotient of 1.0 indicates that the share of employment in the cluster in North Carolina matches the comparable share for the U.S. Location quotients significantly above 1.0 suggest the state is specialized in the given cluster, i.e., it has a larger share of activity in the cluster than would be expected based on national trends.

[5] The totals presented in Table 2 are lower than the totals presented in Table 1 because data for several industry segments in Table 2 were not disclosable or not calculable. The U.S. Bureau of Labor Statistics withholds publication of employment and wage data for any industry level when necessary to protect the identity of cooperating employers.

Table 2. Employment in the Aerospace and Aviation Industry

U.S., Top 10 states (ranked by total Aerospace/Aviation employment) and NC, 2003

Industry	U.S. Total	CA	TX	WA	FL	NY	IL	GA	AZ	PA	OH	NC
MANUFACTURING												
Aerospace Products & Parts (total)	**438,100**	57,431	43,632	6,823	16,699	3,270	1,642	15,976	15,441	2,508	10,358	**1,754**
Aircraft manufacturing	**207,195**	28,525	30,538	ND	3,956	ND	ND	13,437	5,312	ND	ND	**ND**
Aircraft engine & engine parts mfg.	**80,861**	4,764	4,374	180	3,650	1,209	1,642	2,051	6,523	1,394	10,358	**1,341**
Other aircraft parts & auxiliary equip.	**80,230**	22,000	8,720	6,643	2,352	2,061	ND	488	3,606	1,114	ND	**413**
Guided missile & space vehicle mfg.	**50,778**	ND	ND	NC	6,741	NC	NC	ND	ND	NC	NC	**NC**
Space vehicle propulsion units & parts mfg.	**12,410**	2,142	ND	ND	ND	ND	NC	ND	ND	NC	NC	**ND**
Other guided missiles & space vehicles & auxiliary equip.	**6,626**	ND	NC	ND	ND	ND	ND	NC	ND	ND	NC	**NC**
Search, Detection, Navigation & Guidance (total)	**145,667**	47,302	5,351	1,764	8,082	10,688	2,179	390	8,143	1,439	733	**576**
Search, detection & navigation instruments	**145,667**	47,302	5,351	1,764	8,082	10,688	2,179	390	8,143	1,439	733	**576**
SERVICES												
Air Transportation (total)	**527,022**	53,824	67,209	12,689	33,528	29,387	39,254	38,671	14,376	20,117	12,291	**13,116**
Scheduled passenger air transp.	**472,247**	48,691	60,442	11,978	29,051	25,550	37,718	37,728	13,511	18,613	7,962	**12,163**
Scheduled freight air transp.	**11,815**	884	733	160	1,563	1,562	570	302	264	101	518	**188**
Nonscheduled chartered passenger air transp.	**32,585**	3,011	4,185	292	2,024	2,087	676	550	509	881	3,618	**667**
Nonscheduled chartered freight air transp.	**7,585**	1,088	1,770	125	503	140	186	83	83	109	162	**35**
Other nonscheduled air transp.	**2,790**	150	79	134	387	48	104	8	9	413	31	**63**
Support Activities for Air Transportation (total)	**131,656**	14,470	16,490	1,082	13,347	2,943	2,888	2,264	3,877	3,674	3,038	**3,721**
Air traffic control	**3,037**	742	44	ND	358	ND	ND	ND	53	193	211	**47**
Other airport operations	**56,647**	8,079	5,279	ND	7,140	ND	ND	ND	1,168	2,507	937	**1,952**
Other support activities for air transp.	**71,972**	5,649	11,167	1,082	5,849	2,943	2,888	2,264	2,656	974	1,890	**1,722**
Satellite Communications (total)	**17,190**	11,899	361	31	531	390	211	ND	150	157	110	**22**
Satellite communications	**17,190**	11,899	361	31	531	390	211	ND	150	157	110	**22**
Flight Training Schools (total)	**17,228**	2,029	2,255	703	2,950	370	269	652	898	604	214	**170**
Flight training	**17,228**	2,029	2,255	703	2,950	370	269	652	898	604	214	**170**
Total	**1,276,863**	186,955	135,298	23,092	75,137	47,048	46,443	57,953	42,885	28,499	26,744	**19,359**

Source: U.S. Department of Labor, Bureau of Labor Statistics, 2003.

Note: WA employment is significantly underrepresented in this table because of missing or nondisclosable data.

Note: ND signifies not disclosable, and NC signifies not calculable.

Table 3. Location Quotients for the Aerospace and Aviation Industry
U.S., Top 10 states (ranked by total aerospace/aviation employment), and NC, 2003

Industry	U.S.	CA	TX	WA	FL	NY	IL	GA	AZ	PA	OH	NC
MANUFACTURING												
Aerospace Products & Parts												
Aircraft manufacturing	1.00	1.18	2.08	ND	0.33	ND	ND	2.20	1.44	ND	ND	**ND**
Aircraft engine & engine parts mfg.	1.00	0.51	0.76	0.11	0.78	0.24	0.44	0.86	4.54	0.39	3.03	**0.57**
Other aircraft parts & auxiliary equipment	1.00	2.36	1.53	4.11	0.51	0.40	ND	0.21	2.53	0.31	ND	**0.18**
Guided missile & space vehicle mfg.	1.00	ND	ND	NC	2.29	NC	NC	ND	ND	NC	NC	**NC**
Space vehicle propulsion units & parts mfg.	1.00	1.48	ND	ND	ND	ND	NC	ND	ND	NC	NC	**ND**
Other guided missiles & space vehicles & auxiliary equip.	1.00	ND	NC	ND	ND	ND	ND	NC	ND	ND	NC	**NC**
Search, Detection, Navigation & Guidance												
Search, detection & navigation instruments	1.00	2.79	0.52	0.60	0.96	1.15	0.33	0.09	3.15	0.22	0.12	**0.14**
SERVICES												
Air Transportation												
Scheduled passenger air transp.	1.00	0.89	1.81	1.26	1.06	0.85	1.75	2.71	1.61	0.89	0.40	**0.89**
Scheduled freight air transp.	1.00	0.64	0.88	0.67	2.28	2.08	1.06	0.87	1.26	0.19	1.04	**0.55**
Nonscheduled chartered passenger air transp.	1.00	0.79	1.81	0.44	1.07	1.01	0.45	0.57	0.88	0.61	2.63	**0.71**
Nonscheduled chartered freight air transp.	1.00	1.23	3.29	0.82	1.14	0.29	0.54	0.37	0.62	0.32	0.51	**0.16**
Other nonscheduled air transp.	1.00	0.46	0.40	2.38	2.39	0.27	0.82	0.10	0.18	3.33	0.26	**0.78**
Support Activities for Air Transportation												
Air traffic control	1.00	2.10	0.20	ND	2.03	ND	ND	ND	0.98	1.43	1.64	**0.54**
Other airport operations	1.00	1.18	1.27	ND	2.10	ND	ND	ND	1.12	0.96	0.38	**1.15**
Other support activities for air transp.	1.00	0.68	2.19	0.75	1.40	0.64	0.88	1.07	2.08	0.30	0.62	**0.83**
Satellite Communications												
Satellite communications	1.00	5.95	0.30	0.09	0.53	0.36	0.27	ND	0.49	0.21	0.15	**0.04**
Flight Training Schools												
Flight training	1.00	1.01	1.85	2.02	2.95	0.34	0.34	1.28	2.93	0.79	0.29	**0.34**
Average	**1.00**	**1.26**	**1.50**	**0.90**	**1.01**	**0.58**	**0.80**	**1.54**	**1.89**	**0.50**	**0.50**	**0.52**

Source: U.S. Department of Labor, Bureau of Labor Statistics, 2003.

Note: A location quotient significantly above 1.0 signifies state specialization, i.e., the state has a larger share of activity in the industry segment than would be expected based on national trends.

Note: ND signifiies not disclosable, and NC signifies not calculable.

What is clear from the pattern of gray boxes is that North Carolina has a relatively high degree of specialization in only one segment — *other airport operations.* The only other segments in which it is approaching a critical mass of specialization are *scheduled passenger air transportation, nonscheduled chartered passenger air transportation,* and *other support activities for air transportation.* Each of the other 10 states has at least two segments with a location quotient greater than 1, and four states have eight or more segments with location quotients higher than 1. Similarly, looking at the location quotient totals at the bottom on the table, it is clear that North Carolina has one of the lowest degrees of specialization in the industry. Does this pattern hold true for broader aerospace-related clusters?

Aerospace-Related Clusters

While ascertaining whether North Carolina's low degree of specialization would hold true for broader aerospace-related clusters is beyond the scope of this white paper, an examination of North Carolina's performance in a single aerospace-related cluster — the commercial launch industry and commercial space transportation-enabled industries — is instructive. Table 4 compares North Carolina's performance with that of the U.S. overall and of the top 10 states in terms of aerospace/aviation employment. The cluster is broken down according to the five segments that comprise its core industries: *launch vehicle manufacturing and services, satellite manufacturing, ground equipment manufacturing, satellite services,* and *remote sensing.*

Three patterns emerge from Table 4. First, in terms of the largest segment, *launch vehicle manufacturing and services,* North Carolina is holding its own with 9,707 employees, or 2.1% of all U.S. launch vehicle and manufacturing service employees. This is slightly below North Carolina's share of the total U.S. population (2.8%). Second, North Carolina fares comparatively better for the second and third largest segments, *satellite services* and *satellite manufacturing,* respectively. Here North Carolina's 9,561 and 6,592 employees, respectively, represent 2.3% and 3.5% of all the employees in the segments. Third, compared with North Carolina's aerospace/aviation industry in Table 2, North Carolina's aerospace-related cluster in has 10,868, or 33%, more jobs and represents a relatively larger share of the U.S. total.

Table 5 sheds additional light on these favorable patterns, showing location quotients for each state in each of the industry segments; states having a location quotient of at least 1.0 — indicating the state's share of employment in that segment matches the comparable share for the U.S. — are shaded in gray. From Table 5, it is clear that North Carolina has a higher degree of specialization in this particular aerospace-related cluster than in the broader aerospace/avation industry shown in Table 3 (0.86 vs. 0.52). In four of the cluster's segments, North Carolina has a location quotient greater than 1.0, and in two others — *other communications equipment manufacturing* and *cellular and other wireless carriers* — it is approaching a critical mass of specialization.

Table 4. Employment in the Commercial Space Transportation Industry and Launch-Enabled Industries
U.S., Top 10 States (ranked by total Aerospace/Aviation employment) and NC, 2003

Industry	U.S.	CA	TX	WA	FL	NY	IL	GA	AZ	PA	OH	NC
Launch Vehicle Mfg. & Services (total)	**467,460**	**86,840**	**15,893**	**16,432**	**9,847**	**33,210**	**30,296**	**3,157**	**2,260**	**19,845**	**11,867**	**9,707**
Physical, engineering & biological research	467,460	86,840	15,893	16,432	9,847	33,210	30,296	3,157	2,260	19,845	11,867	**9,707**
Satellite Manufacturing (total)	**191,906**	**35,912**	**18,210**	**3,673**	**11,746**	**11,955**	**11,426**	**3,519**	**1,983**	**8,057**	**4,464**	**6,592**
Broadcast and wireless communications equip.	77,263	15,603	8,148	1,058	6,899	5,189	5,007	2,508	1,154	2,531	1,400	**1,547**
Printed circuit assembly mfg.	48,705	5,467	2,103	818	2,886	3,671	1,636	626	290	1,887	1,485	**4,170**
Other electronic component mfg.	65,938	14,842	7,959	1,797	1,961	3,095	4,783	385	539	3,639	1,579	**875**
Ground Equipment Mfg. (total)	**64,588**	**14,266**	**3,106**	**1,228**	**4,162**	**3,228**	**4,738**	**1,462**	**456**	**3,666**	**583**	**1,069**
Other communications equipment mfg.	26,869	4,524	2,170	370	3,174	2,446	2,403	237	ND	962	439	**714**
Audio & video equip. mfg.	37,719	9,742	936	858	988	782	2,335	1,225	456	2,704	144	**355**
Satellite Services (total)	**416,037**	**49,717**	**42,131**	**17,118**	**27,834**	**27,001**	**13,313**	**18,873**	**3,485**	**18,117**	**11,347**	**9,561**
Paging	22,929	8,348	2,248	57	568	450	1,544	335	ND	318	1,504	**237**
Cable & other program distribution	132,528	8,171	7,299	3,942	8,633	8,431	5,540	3,513	2,871	8,612	6,536	**1,205**
Cable & other subscription programming	85,541	16,855	7,972	207	4,524	13,856	2,034	5,437	592	2,804	579	**3,810**
Cellular & other wireless carriers	166,482	15,566	23,509	12,636	13,893	3,817	4,120	9,588	ND	6,251	2,443	**4,248**
Other telecommunications	8,557	777	1,103	276	216	447	75	ND	22	132	285	**61**
Remote Sensing (total)	**71,476**	**3,333**	**10,777**	**1,169**	**7,981**	**2,458**	**1,915**	**2,750**	**863**	**1,645**	**2,051**	**3,298**
Geophysical surveying & mapping services	13,196	448	4,202	118	1,172	399	320	308	115	278	433	**517**
Other surveying & mapping services	58,280	2,885	6,575	1,051	6,809	2,059	1,595	2,442	748	1,367	1,618	**2,781**
Total	**1,211,467**	**190,068**	**90,117**	**39,620**	**61,570**	**77,852**	**61,688**	**29,761**	**9,047**	**51,330**	**30,312**	**30,227**

Source: U.S. Department of Labor, Bureau of Labor Statistics, 2003.

Note: ND signifies not disclosable, and NC signifies not calculable.

Table 5. Location Quotients for the Commercial Space Transportation Industry and Launch-Enabled Industries
U.S., Top 10 States (ranked by total Aerospace/Aviation employment) and NC, 2003

	U.S.	CA	TX	WA	FL	NY	IL	GA	AZ	PA	OH	NC
Launch Vehicle Manufacturing & Services												
Physical, engineering & biological research	1.00	1.60	0.48	1.74	0.36	1.12	1.42	0.23	0.27	0.96	0.60	**0.72**
Satellite Manufacturing												
Broadcast & wireless communications equip.	1.00	1.74	1.49	0.68	1.54	1.06	1.42	1.10	0.84	0.74	0.43	**0.69**
Printed circuit assembly mfg.	1.00	0.97	0.61	0.83	1.02	1.19	0.74	0.44	0.33	0.87	0.72	**2.96**
Other electronic component mfg.	1.00	1.94	1.70	1.35	0.51	0.74	1.59	0.20	0.46	1.24	0.57	**0.46**
Ground Equipment Manufacturing												
Other communications equipment mfg.	1.00	1.45	1.14	0.68	2.04	1.43	1.96	0.30	ND	0.81	0.39	**0.92**
Audio & video equipment mfg.	1.00	2.22	0.35	1.13	0.45	0.33	1.36	1.10	0.68	1.61	0.09	**0.33**
Satellite services												
Paging	1.00	3.13	1.38	0.12	0.43	0.31	1.48	0.50	ND	0.31	1.55	**0.36**
Cable & other program distribution	1.00	0.53	0.78	1.48	1.12	1.00	0.92	0.90	1.22	1.46	1.17	**0.31**
Cable & other subscription programming	1.00	1.69	1.32	0.12	0.91	2.55	0.52	2.16	0.39	0.74	0.16	**1.54**
Cellular & other wireless carriers	1.00	0.80	1.99	3.77	1.44	0.36	0.54	1.95	ND	0.85	0.35	**0.88**
Other telecommunications	1.00	0.78	1.82	1.60	0.43	0.82	0.19	ND	0.14	0.35	0.79	**0.25**
Remote sensing												
Geophysical surveying & mapping services	1.00	0.29	4.49	0.44	1.53	0.48	0.53	0.79	0.49	0.47	0.78	**1.36**
Other surveying & mapping services	1.00	0.43	1.59	0.89	2.01	0.56	0.60	1.42	0.72	0.53	0.66	**1.65**
Average	1.00	1.35	1.05	1.62	0.88	1.01	1.12	0.83	0.42	0.95	0.59	**0.86**

Source: U.S. Department of Labor, Bureau of Labor Statistics, 2003.
Note: A location quotient significantly above 1.0 signifies state specialization, i.e., the state has a larger share of activity in the industry segment than would be expected based on national trends.
Note: ND signifies not disclosable, and NC signifies not calculable.

Together, the findings in Tables 1 through 5 indicate that North Carolina has a modest presence in the core aerospace industries but a more significant presence in the one aerospace-related, broader-range cluster examined in this paper, i.e. the commercial launch industry and commercial space transportation-enabled industries. These findings, while not comprehensive, suggest that North Carolina's role in the Aero/Space Economy will be multi-faceted and possibly more indirect, coming via one or more aerospace-related clusters rather than via a significant role in the core aerospace industries. Additional analysis is required to confirm this hypothesis. Regardless of the accuracy of the hypothesis, the emerging aerospace industry will have widely distributed impacts throughout the economy. The next section discusses how.

Aero/Space Economy

In any economy, the input-output linkages and impacts between firms in different industries are complex and multidimensional. The Aero/Space Economy is no exception. As shown in Figure 2, the impact of the Aero/Space Economy is on three primary components:

- **Direct impacts** are the expenditures on inputs and labor involved in the provision of any final good or service relating to the industries analyzed therein.
- **Indirect impacts** involve the purchases (e.g., silicon, copper wire) made by and labor supplied by the industries that provide inputs to the launch and enabled industries. This impact quantifies the inter-industry trading and production necessary to provide the final goods and services.
- **Induced impacts** are the successive rounds of increased household spending that result from the direct and indirect impacts (e.g., a launch vehicle engineer's increased spending on household goods and services)

Using this model as a basis for statistical measurement, the Federal Aviation Administration found that, to some extent, all major U.S. industry sectors are influenced by the activities of the commercial space transportation and enabled industries (the cluster examined in the previous section of this paper). Table 6 shows how each of the industry sectors was impacted.

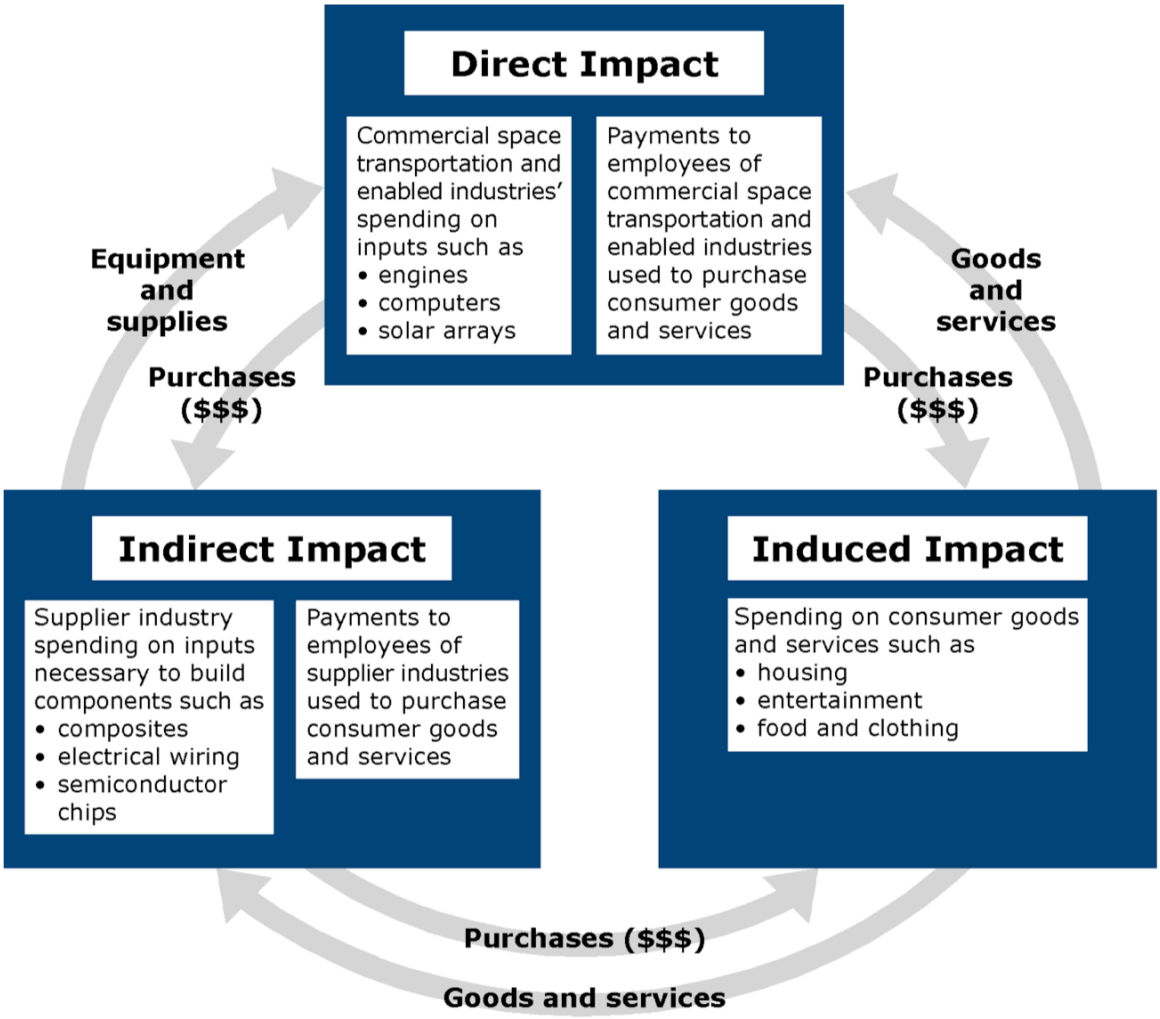

Figure 2. The Impact of the Aerospace Economy (Source: FAA 2004)

Of the various sectors in Table 6, *communications* and *electronic and other electric equipment* were the two largest in terms of additional economic activity, earnings, and jobs. Together, they generated over $43 billion in economic activity and more than $8 billion in earnings and created nearly 135,000 jobs.

How do the technologies in Table 6 relate to North Carolina companies? Preliminary findings are in Table 7, which outlines North Carolina's major industry clusters, many of which parallel one or more of the industries in Table 6, as indicated by gray shading in both tables.

Table 6. Distribution of Economic Activity, Earnings, and Jobs throughout Major U.S. Industry Sectors Generated by Commercial Space Transportation and Enabled Industries, 2002

Industry Group	Economic Activity ($Million)	Earnings ($Million)	Jobs
Communications	23,904.3	3,587.6	55,465
Electronic & other electric equipment	19,407.9	4,739.4	79,487
Business services	6,352.9	2,811.2	73,522
Real estate	5,722.5	236.3	9,692
Wholesale trade	3,999.5	1,304.1	26,986
Hotels & other lodging places, amusement & recreation services & motion pictures	3,506.2	1,251.6	38,285
Depository & nondepository institutions & security & commodity brokers	3,013.8	1,027.4	19,238
Health services	2,847.0	1,330.5	34,061
Retail trade	2,780.2	1,003.0	47,091
Miscellaneous services	2,380.1	783.7	33,206
Transportation	2,204.8	789.8	21,571
Construction	2,004.4	677.8	18,104
Chemicals & allied products & petroleum & coal prod.	1,626.4	261.3	3,171
Food & kindred products & tobacco products	1,559.0	187.0	4,992
Fabricated metal products	1,416.3	438.3	11,611
Insurance	1,286.7	429.1	9,370
Electric, gas & sanitary services	1,252.6	205.3	2,510
Eating & drinking places	1,169.6	404.0	29,500
Printing & publishing	1,140.0	356.5	8,553
Primary metal industries	984.1	183.0	3,646
Industrial machinery & equipment	899.7	215.5	4,163
Rubber & miscellaneous plastic products & leather & leather products	789.5	178.8	4,882
Farm products & agricultural, forestry & fishing svcs.	746.1	195.1	9,906
Paper & allied products	636.5	122.6	2,601
Motor vehicles & equipment	574.4	77.5	1,236
Personal services	492.7	212.2	11,373
Other transportation equipment	409.8	94.3	1,551
Lumber & wood products & furniture & fixtures	388.6	83.7	2,712
Oil & gas extraction	338.8	47.4	535
Instruments & related products	308.5	83.8	1,292
Apparel & other textile products	205.9	47.5	1,937
Stone, clay & glass products	187.4	46.3	1,040
Textile & mill products	176.9	32.7	1,039
Miscellaneous manufacturing industries	153.5	47.6	1,514
Coal mining	75.2	19.6	235
Metal mining & nonmetallic minerals except fuels	54.2	13.6	273
Forestry & fishing products	29.9	3.3	98
TOTAL	95,025.9	23,528.4	576,448

Source: FAA 2004.

Table 7. North Carolina Industry Clusters

Clusters	Employment 1998	Annual % Change '89–'98	Location Quotient 1998	Average Wage ($)
Existing General Industry Clusters				
Apparel	207,698	-3.3	4.46	25,057
Fabricated textiles	128,893	-3.8	2.70	23,538
Wood products (incl. furniture)	77,549	0.0	2.15	26,445
Pharmaceuticals	17,783	3.0	1.82	48,538
Tobacco products	16,151	-3.8	10.84	47,151
Stone & clay products	13,838	5.8	1.26	40,161
Emerging General Industry Clusters				
Printing & publishing	279,849	4.9	0.87	35,621
Hospitals, labs, specialized medical svcs.	226,117	6.1	0.94	34,657
Transportation, shipping and logistics	118,989	2.6	1.06	32,918
Construction materials	118,390	2.2	1.00	31,990
Information technology & instruments	105,796	4.4	0.74	47,378
Chemicals & plastics	104,367	3.9	1.04	36,070
Banking & advertising	95,259	5.3	0.79	40,978
U.S. Technology Clusters, Presence in the State				
Information technology & instruments	104,420	4.5	0.86	47,363
Communications services & software	63,660	10.0	0.66	48,241
Chemicals & plastics	53,923	4.1	1.12	38,106
Motor vehicle manufacturing	44,277	4.1	0.82	35,169
Pharmaceuticals & medical technologies	34,629	1.7	1.01	41,915
Industrial machinery	21,464	1.3	1.06	35,870
Aerospace	5,545	5.8	0.19	41,168
Household appliances	1,139	NA	0.36	23,492

Source: Feser and Bergman 2000. NA = not available.

The Aldridge Commission (2004) found that successful development of 17 space exploration enabling technologies (listed in the Appendix) will be critical to attainment of exploration objectives within reasonable schedules and affordable costs. As such, the industries developing and producing the technologies are potential candidates for an Aero/Space cluster analysis.

By matching North Carolina's industry clusters in Table 7 with the Aldridge Commission's space exploration enabling technologies, we begin to see how North Carolina companies are positioned to create an Aero/Space Economy in our state (see Table 8). As recommended below, further research along these lines is needed to determine the best prospects for that economy.

Table 8. Comparison of NC Technology Clusters with Enabling Technologies for Space Exploration

Technology Clusters in NC	—matches with—	Space Enabling Technologies
Chemicals/plastics	—	Advanced structures
Pharm./medical technology	—	Biomedical risk mitigation
Industrial machinery	—	Planetary *in situ* resource use
Information tech./instruments	—	Autonomous systems and robotics
Information tech./instruments	—	Scientific data collection/analysis
Communication services/software	—	High-bandwidth communications
Aerospace	—	All 17 identified technologies

Sources: Feser and Renski 2000, Aldridge 2004.

Clearly, an Aero/Space Economy is not defined solely by traditional aerospace companies. An Aero/Space Economy spreads its jobs across many other sectors, such as communications, electronics, chemicals, and textiles, to name just a few. The potential benefits include new high-wage jobs in existing, emerging, and potential high-tech sectors (clusters) in the state, thereby growing the state's treasury and expanding research and education opportunities at the state's universities. Furthermore, the state clusters mentioned above are heavily weighted toward innovation and knowledge-driven manufacturing jobs.

Michael Porter (2002) wrote that the Research Triangle can seize on under-realized opportunities by, among other methods, developing "…new opportunities at the intersection of clusters, including environmental sciences, biotechnology and information technology, telecommunications and medicine, and biotechnology and agribusiness." This applies across the entire state, and across an Aero/Space Economy.

> *Central to the state's continued economic prosperity is the development of leading industry clusters that seek competitive advantage through continued innovation, highly skilled and productive workers, and the utilization of advanced infrastructure and technology.*
>
> *(Feser and Renski 2000)*

Recommendations for Directing Future Expansion

To realize its goal of contributing to and benefiting from the Aero/Space Economy, North Carolina must develop a strategic plan. Building on the preliminary findings presented in this paper, **the North Carolina Space Initiative should collaborate with a highly regarded economic development consultant or consulting firm to produce an in-depth, aerospace-related cluster analysis specific to North Carolina**. At a minimum, the analysis should produce the following information:

- **A detailed analysis of existing aerospace-related clusters in North Carolina**. Tables 4 and 5 present initial examples of the types of analysis needed for a more comprehensive collection of clusters. Although these tables present only employment-based information, the follow-on analysis recommended here should also include information such as the number of establishments per cluster and industries within clusters, wages per cluster and industries within clusters, rate of growth (in establishments, employees, wages) in clusters and industries within clusters, and other information deemed relevant.
- **A detailed analysis of how the identified clusters impact the economy.** An example of this type of analysis is provided in *The Economic Impact of Commercial Space Transportation on the U.S. Economy: 2002 Results and Outlook for 2010* (FAA 2004). Although the report just cited focuses on only one aerospace-related cluster and its impact nationally, the follow-on analysis recommended here should focus on the clusters identified in recommendation 1 above (or a key subset of them) and their impact at multiple levels (e.g., state, regional, national), to the extent possible.
- **A detailed inventory of North Carolina's aerospace-related assets**. Examples of assets include aerospace-related university centers, institutes, and consortia; aerospace-related university faculty; aerospace-related companies; and aerospace-related government agencies or organizations. The inventory should contain, for each asset, a standardized set of information relevant to commercial activity (e.g., location, core area of expertise, and measures of activity intensity, such as funding, publications, employees).
- **Contextual information at the national, regional, or state level**. The information should be designed to assist with interpreting findings produced by the analyses above.
- **Recommendations regarding steps for how North Carolina can best contribute to and benefit from the emerging Aero/Space Economy.** The recommendations should be reasonable in number, assign implementation responsibility to specific groups and/or individuals, specify timelines for implementation, and specify expected outcomes.

Imagine the Future

It is clear that commercial aviation has been a significant economic growth engine, and commercial Aero/Space is poised to continue on this path. The events of 2004 permit us to imagine a very real scenario for North Carolina's Aero/Space future, beginning with these anticipated entrepreneurial Aero/Space accomplishments ***in other states***:

2005	Inaugural flights of new privately developed and operated launch vehicles.
2006–08	Prototype commercial habitats placed in orbit for testing.
2007	Richard Branson's Virgin Galactic company begins space flights at Mojave Airport (a typical commercial airport, *not* a government space complex).
2010	First occupants arrive at orbiting three-deck commercial habitat.

Now, imagine this possible scenario ***for our state***:

2007	RTP opens the (nation's first) corporate/academic Space Exploration Enabling Technologies R&D Institute.
2009	Honda's business aviation unit in Greensboro begins designing personal sub-orbital spacecraft, working closely with Triad-based aviation companies.
2010	Virgin Galactic begins East Coast space flights from North Carolina.
2011	DHL begins trans-Atlantic sub-orbital cargo flights to Global TransPark (renamed the North Carolina Inter-modal Transportation Complex).
2013	Durham's GE Transportation-Aircraft Engines facility begins manufacturing engines for small commercial hybrid air/space vehicles.
2014	Ft. Bragg/Pope Air Force Base complex ("Home of the Airborne and Special Forces") inaugurates space flight deployment.
2015	NC State opens a permanent North American International Space University campus.
2020	NC State, UNC, and Duke universities operate the first orbiting campus built with Bigelow Aerospace habitats.

Does this seem unreasonable? Recall that it took only 66 years to get from Kitty Hawk to the Moon. Did those watching the Wright Brothers' flight anticipate the rapid commercial and technical aviation advances that would take place in the next three-score years?

North Carolina is the birthplace of aviation, and the state played a significant role in the nation's manned space endeavors. Clearly, North Carolina has the vital skills and experience to contribute to and benefit from the creation of a global commercial Aero/Space Economy. Do we have the foresight — and the will?

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About the North Carolina Space Initiative

The North Carolina Space Initiative, as a program of the Kenan Institute for Engineering, Technology & Science, facilitates coordinated efforts among various educational, governmental, and commercial organizations to develop and promote space-related research education and commercial activities. The NCSI is also supported by the NCSU Vice Chancellor for Research and Graduate Studies and the UNC Office of the President.

Appendix

The Aldridge Commission (2004) found that successful development of the following 17 space exploration enabling technologies will be critical to attainment of exploration objectives within reasonable schedules and affordable costs. As such, the industries developing and producing the technologies are potential candidates for an Aero/Space cluster analysis.

1. *Affordable heavy lift capability* — technologies to allow robust affordable access of cargo, particularly to low-Earth orbit.
2. *Advanced structures* — extremely lightweight, multi-function structures with modular interfaces, the building-block technology for advanced spacecraft.
3. *High-acceleration, high-life-cycle, reusable in-space main engine* — for the crew exploration vehicle.
4. *Advanced power and propulsion* — primarily nuclear thermal and nuclear electric, to enable spacecraft and instrument operation and communications, particularly in the outer solar system, where sunlight can no longer be exploited by solar panels.
5. *Cryogenic fluid management* — cooling technologies for precision astronomical sensors and advanced spacecraft, as well as propellant storage and transfer in space.
6. *Large aperture systems* — for next-generation astronomical telescopes and detectors.
7. *Formation flying* — for free-space interferometric applications and near-surface reconnaissance of planetary bodies.
8. *High bandwidth communications* — optical and high-frequency microwave systems to enhance data transmission rates.
9. *Entry, descent, and landing* — precision targeting and landing on "high-g" and "low-g" planetary bodies.
10. *Closed-loop life support and habitability* — recycling of oxygen, carbon dioxide, and water for long-duration human presence in space.
11. *Extravehicular activity systems* — the spacesuit of the future, specifically for productive work on planetary surfaces.
12. *Autonomous systems and robotics* — to monitor, maintain, and, where possible, repair complex space systems.
13. *Scientific data collection/analysis* — lightweight, temperature-tolerant, radiation-hard sensors.

14. *Biomedical risk mitigation* — space medicine; remote monitoring, diagnosis and treatment.
15. *Transformational spaceport and range technologies* — launch site infrastructure and range capabilities for the crew exploration vehicle and advanced heavy lift vehicles.
16. *Automated rendezvous and docking* — for human exploration and robotic sample return missions.
17. *Planetary* in situ *resource utilization* — ultimately enabling us to "cut the cord" with Earth for space.