W. P. CAREY SCHOOL of BUSINESS

L. WILLIAM SEIDMAN RESEARCH INSTITUTE

# *Aerospace & Defense Industry in Arizona*

## *An Intellectual Roadmap for Economic Development*


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## Executive Summary

Arizona's Aerospace & Defense (A&D) industry faces several challenges to its continued growth thanks to an increasingly competitive economic landscape and the changing technological needs of the military.

This current report, commissioned by Science Foundation Arizona (SFAz):

- summarizes the current state of the A&D industry within Arizona;
- identifies key players and developments that could yield additional growth to the industry;
- provides an overview of best practice in other states;
- evaluates the threats, opportunities, weaknesses and strengths of Arizona's A&D industry;
- identifies a range of strategic choices open to the A&D industry within Arizona today; and
- recommends a plan to enable the industry to maximize its opportunities while simultaneously minimizing the impact of any weaknesses and protecting itself against threats.

Drawing from a literature review and in-depth interviews with five industry stakeholders, the report examines the business environment, the supply chain, research competitiveness, workforce, educational policies, and the case for an Aerospace Institute, leading to the development of seven key messages:

- Arizona needs small businesses and entrepreneurs to support the operations of medium and large manufacturers, and to drive the innovation of new technologies or new applications of existing technologies;
- The optimal strategy for promoting growth within the A&D industry is to focus upon established operations and competencies;
- Arizona's congressional delegation needs to take a more proactive role within industry caucuses, and more aggressively champion investment by the Department of Defense within the State;
- An Arizona Aerospace & Defense Institute (ADI) is needed to align research and development with commercial and military needs;
- The provision of STEM education within Arizona should be advanced;
- Gaps within Arizona's A&D industry should be acknowledged, but not all of them need to be necessarily addressed;

- The industry needs to leverage local strengths in research and geography, complemented by targeted tax incentives, to foster future growth.

A comparison with three competitor states (Alabama, Florida and Virginia) is also made to provide further insight into best practice, highlighting both the importance of federal contracts and collaboration between stakeholders.

Collating these preliminary analyses within a point of intersection framework, the report recommends the following roadmap as a springboard to the future success of the Arizona A&D industry:

- Arizona's A&D industry is currently quite disparate and will benefit from greater collaboration between industry, research and the military;
- This collaboration is ideally best served by the establishment of an Aerospace Institute, facilitating the exchange of ideas and needs between all stakeholders;
- Current core competencies in areas such as national defense, cyber warfare, intelligence and surveillance, special operations, counter terrorism and border security have to become the main focus of future development;
- The Department of Defense is receptive to working outside the confines of Washington, DC. However, to take advantage of this opportunity, Arizona needs much greater support from its congressional delegation;
- Arizona's universities must work hand-in-hand with the business development teams at very large manufacturers such as Boeing and Raytheon to maximize share of the research dollars available, and produce work of value both commercially and militarily;
- Closely aligning the efforts of research and industry around established themes in A&D and through collaborative efforts, guided by the likes of an Aerospace Institute, will enable Arizona to offer the Department of Defense beginning-to-end solutions based on existing and solid competitive advantages;
- Further analysis is required to account for the lack of Second-Tier Suppliers within the State, the impact this has upon the industry, and the optimum strategy to remedy the situation.

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## 1. Introduction

Arizona's Aerospace & Defense (A&D) industry currently contributes $8.8 billion in gross state product to the local economy and is responsible for 93,800 jobs. (Seidman Research Institute, 2010a) The major contractors in the State include Raytheon Missile Systems, The Boeing Company, Honeywell Aerospace and General Dynamics C-4 Systems. These four companies alone contribute approximately 83% of private A&D jobs in Arizona based on a recent survey (Seidman Research Institute, 2010a). However, the industry faces numerous challenges as the economic landscape becomes more competitive and the technological requirements of the military continue to evolve.

The purpose of this report, commissioned by Science Foundation Arizona, is to meet these challenges head-on by outlining the necessary steps for the establishment of an Aerospace Institute within the State. Building upon current local strengths, and with some financial support from the Department of Defense, this Institute would enjoy a competitive advantage by crucially fostering the commercial developments needed to solidify A&D as perhaps the most important base industry component of the Arizona economy.

The objectives of this current report are to:

- summarize the current state of the A&D industry within Arizona;
- identify key industries and suppliers that could yield additional growth to the industry;
- describe key activities and best practice in other states;
- evaluate the threats and opportunities of the external environment, plus weaknesses and strengths of the industry's internal environment via a TOWS analysis[1];
- utilize this TOWS analysis to enhance understanding of the strategic choices faced by the A&D industry; and
- recommend a plan to enable the industry to maximize its opportunities while simultaneously minimizing the impact of any weaknesses and protecting itself against threats.

To meet these objectives, Section 2 draws from a literature review and in-depth, semi-structured interviews with five key stakeholders to describe the current economic landscape. Section 3 provides an overview of activities and best practice at three competitor States. Section 4 examines the linkages

[1] A TOWS matrix is a variant of a SWOT analysis used to evaluate the threats, opportunities, weaknesses and strengths involved in a project, business venture, industry or any situation requiring a decision.

between key players within the industry, focusing upon their points of intersection. In Section 5, a TOWS matrix is applied to the Arizonan A&D industry to highlight the strategic choices that need to be made to maximize the industry's strengths, circumvent weaknesses, capitalize on opportunities and manage threats. Our conclusions and recommendations are outlined in Section 6.

## 2. Literature Review and Analysis

### 2.1 Literature Review

The Arizonan A&D industry continues to attract significant interest within military, government and academic circles, resulting in a broad collection of reports, plans and studies. Table 1 lists the key existing literature reviewed for this report, primarily based upon Science Foundation Arizona recommendations and Arizona Commerce Authority commissioned reports:

**Table 1: List of Literature Reviewed for This Report**

| AUTHOR | PUBLICATION |
|---|---|
| ANGLE Technology Group | • AZ Aerospace, Defense and Avionics Industries Study (2008) |
| Applied Economics | • Arizona Supply Chain Analysis (2005) |
| Arizona Aerospace & Defense Commission | • Progress Reports (2005) (2006) (2008) (2009)<br>• Strategic Plans (2008) (2009) (2010)<br>• Variety of Issue Forms submitted to the AADC |
| Arizona Arts, Sciences & Technology Academy | • Astronomy, Planetary Sciences, and Space Sciences Research Opportunities to Advance Arizona's Economic Growth (2007) |
| Arizona Commerce Authority | • Arizona Center of Excellence (2010) |
| Arizona Department of Commerce | • Arizona Military Regional Compatibility Project: Project Update #12 (2007) |
| Battelle Technology Partnership Practice | • Building from a Position of Strength: Arizona Advanced Communications and Information Technology Roadmap (2004) |
| The Gold Group | • Creating an Arizona Aerospace Institute (2008) |
| The Maguire Company | • Economic Impact of Arizona's Principal Military Operations (2008) |
| L William Seidman Research Institute (ASU) | • The Boeing Company – Economic Impact on Arizona (2006) (2010)<br>• Economic Impact of the Boeing Led Ground-Based Midcourse Defense Program: Arizona Operations 2007 (2008)<br>• Economic Impact of Raytheon Missile Systems (2009)<br>• Economic Impact of Aerospace & Defense Firms on the State of Arizona (2010) |

Several themes of relevance for the Arizonan A&D industry emerged from this literature review, namely:

a. The Business Environment
b. The Supply Chain
c. Research Competitiveness
d. Workforce/STEM Education
e. Aerospace Institute

The first four themes reflect the strategy adopted by the Arizona Aerospace & Defense Commission and outlined in their most recent annual report (Arizona Aerospace & Defense Commission, 2010).

### 2.1.1 The Business Environment

Improvements to the business environment are an essential pre-requisite for the development of a robust A&D industry within the State. This will initially require a clear and thorough understanding of both the scope and impact of A&D upon the Arizonan economy. In 2010, The Arizona Aerospace & Defense Commission (AADC) commissioned an economic impact study to quantify the direct, induced and indirect impacts of A&D firms within the State. This study estimated that the A&D industry in 2009 contributed $8.8 billion in gross state product and helped create 93,839 jobs (Seidman Research Institute, 2010a). It also concluded that Arizona was the eighth highest U.S. state in terms of A&D employment, with employees receiving salaries 52% higher than the average Arizonan wage (ANGLE Technology Group, 2008).

One important business environment factor often overlooked is the economic impact of the military installations upon the State. A recent study by The Maguire Company in collaboration with ESI, concluded that major military operations within Arizona created 96,328 jobs and generated $9.1 billion in economic output for the local economy (The Maguire Company, 2008). That's greater than the economic output of Arizona's largest private employers, Wal-Mart and Banner Health System.

The AADC has taken the lead in trying to improve the local business environment by collaborating with the Commerce Board's A&D Growth Sector Committee, and identifying key legislative incentives to help retain and foster growth within the industry (Arizona Aerospace & Defense Commission, 2010). Some of these programs include developing enterprise zones which incentivize investment through premium tax credits and property tax reductions, initiating a research and development tax credit, and reducing the corporate tax rate to below 5%.

### 2.1.2 The Supply Chain

In 2009, the direct impact of supplier purchases from A&D firms exceeded $1.4 billion, generating 17,059 jobs (Seidman Research Institute, 2010a). A recent report criticized the lack of interaction between large and medium manufacturers within the State and the host of suppliers that support their efforts (ANGLE Technology Group, 2008). Long-standing relationships with out-of-state suppliers, coupled with a lack of awareness about local ones, are highlighted as reasons for the lack of collaboration between suppliers and manufacturers; and this area is worthy of future study via a census or survey of A&D suppliers in Arizona.

Nevertheless, the AADC has taken steps to improve the linkage between manufacturers and suppliers via the formation of a subcommittee to actively engage with professional associations such as the ATC, NDIA, Arizona MEP, ACE, the Armed Forces Communications Electronics Association and the Southwest Defense Alliance. This subcommittee is also encouraging the creation of a Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR) Matching Fund Program similar to existing schemes in Kentucky, North Carolina, Oklahoma and Michigan (Arizona Aerospace & Defense Commission, 2010).

Local and regional tools are also being leveraged to enhance links between suppliers and buyers. For example, the City of Tucson operates AZBusinessLinc, an on-line supplier database that can be searched by potential buyers; and connectory.com, a Californian business-to-business, buyer-supplier marketing and communication tool providing a regional source for products, technologies and services (Applied Economics, 2005).

### 2.1.3 Research Competitiveness

The research output of Arizona's three major universities (ASU, University of Arizona and Northern Arizona University) plus the Embry Riddle Aeronautical University is also highlighted within the literature as a key competitive advantage. Collectively offering important technological research opportunities for the A&D industry, this topic will be discussed in more detail in Section 4.

### 2.1.4 Workforce/STEM Education

The literature review also highlighted the variety of technical schools within Arizona dedicated to the supply of skilled labor to large and medium sized A&D firms. Some reference was made to the lack of qualified graduate and post-graduate level workers in the areas of science, technology, engineering and

mathematics (STEM) - a national problem currently affecting a variety of industries (ACT, Inc., 2010). This has already prompted the State to invest in K-12 STEM education in accordance with the Governor's P20 Council recommendations and through merit-based scholarships. However, greater effort is required to raise STEM education to a level that allows Arizona to compete nationally and internationally.

**2.1.5 Aerospace Institute**

The literature also emphasizes the need for an Arizona Aerospace Institution, to serve as a focal point for meeting the critical needs of the industry. For example, a 2008 report produced by The Gold Group concluded that the establishment of an Aerospace Institute focusing on select high value services and meeting the needs of both in state and out of state aerospace industry stakeholders is essential to help protect and grow the A&D industry within Arizona. Positioning the Institute as a 'one stop shop' for industry expertise and knowledge, The Gold Group recommended a primary focus upon three core competencies:

1. Machine to machine and human to machine interactions and integration;
2. Information management and information assurance; and
3. Visioning, Simulation, and Modeling.

This report also suggested that an Institute could facilitate workforce development, accelerate the commercialization of advanced technologies and provide an environment for collaboration between business, government, the military and academia.

An advisory board, recruited by the Speaker of the Arizona House of Representatives, was also charged in 2009 with defining the mission of the Institute and securing a consortium of industry leaders committed to addressing the industry's most critical needs. Their initial vision is of a premier research and innovation center focusing on eight key areas:

1. Next Gen;
2. Human Performance Enhancement (Human-Interface Cognitive, Modeling, Simulation & Design);
3. Optical Imaging Sciences;
4. Aerospace Medicine;

5. Data & Information Intelligence/Security;
6. Sustainable Energies (Engines/Energy, Battery, Storage, etc);
7. UAV Development & Testing/Education & Training;
8. Space & Missile.

The advisory board argues that an Aerospace Institute is needed to not only maintain and grow existing A&D relationships within Arizona. It's needed to also aggressively pursue federal and private industry research and manufacturing opportunities.

The lack of progress within this area is probably due to a variety of reasons. Is the vision of sufficient appeal? Have the champions of an Aerospace Institute been bold enough in making this become a reality? Were the right people originally put in place? Nevertheless, the literature at least suggests that the desire for an Arizonan Institute exists.

**2.2 Industry Leader Interviews**

To build upon the 5 initial themes outlined in Section 2.1, and acquire further insight into the current state of the Arizonan A&D industry, five semi-structured, in-depth interviews were held with industry, government and research leaders, recommended by Science Foundation Arizona and ASU. The leaders interviewed were:

- Vicki Panhuise - Previous Vice President of Commercial & Military Helicopters at Honeywell and Chair of the Arizona Aerospace & Defense Commission;
- Werner Dahm – Director of the Security & Defense System Initiative (SDSI) at Arizona State University;
- Mitzi Montoya – Executive Dean of the College of Technology & Innovation at Arizona State University;
- Steven Kimmel – Senior Vice President, Corporate Development at Alion Science and Technology;
- Dee H. Andrews – Technical Director of the Warfighter Training Research Division of the Air Force Research Laboratory in Mesa, AZ.

Prior to interview commencement, a generic framework of twelve exploratory themes was prepared, illustrated in Table 2. However, a semi-structured approach was pursued to enable the interviewer to

tailor the order and expression of the questions to the interview context/situation, and ask additional questions in direct response to an interviewee's comments.

**Table 2: Industry Stakeholder In-depth Interview Exploratory Framework of Questions**

| | |
|---|---|
| 1 | What are the linkages in the aerospace & defense system in AZ? |
| 2 | What role should government take in the economic development of the A&D industry? |
| 3 | What are the major challenges/roadblocks in developing an aerospace institute in AZ? |
| 4 | What role should tax incentives play in economic development? |
| 5 | What role should industry play? |
| 6 | What role should research entities play? |
| 7 | What role should the military play? |
| 8 | Where is the breakdown in communication between the major players in the industry? |
| 9 | What challenges does AZ face in terms of workforce development? |
| 10 | Which states do you see as leaders in collaborative initiatives? |
| 11 | What are the challenges/opportunities in AZ for commercializing new technologies? |
| 12 | What is being done to develop small businesses in the State (SBIR/STTR)? |

Seven discernable, common themes emerged from these interviews:

1. **Small business support and entrepreneurial development**: Arizona needs small businesses and entrepreneurs to support the operations of medium and large manufacturers, and to drive the innovation of new technologies or new applications of those technologies. Too many businesses currently operate within small restrictive circles, and would therefore benefit from a forum in which they can engage and collaborate with research institutions, large manufacturers and military entities.

2. **Focus upon existing State competencies:** The optimal strategy for promoting growth within the A&D industry is to focus upon established operations and competencies. State industries are heavily influenced by decisions made at the federal level and can take many decades to evolve (e.g. industry growth around the Tennessee Valley Authority was established by FDR in support of "The New Deal"). Successful regional economic development strategies usually focus upon the core competencies of a State, encouraging an industry's key stakeholders to collaborate around those core competencies. Arizona's A&D industry will therefore benefit most from collaboration between research, industry and the military working within established operations and competencies.

3. **Secure congressional support:** All interviewees called for Arizona's congressional delegation to take a more proactive role within industry caucuses, and encourage greater levels of investment by the Department of Defense within the State.

4. **Align research and development:** An Arizona Aerospace & Defense Institute (ADI) is needed to engage with, and function as, a link between, all of the players in the industry, thereby enabling the flow of information and aligning research and development efforts with the requirements of the military.

5. **Nurture STEM education:** Consistent with the literature review, the interviewees argued that STEM education is a national problem that merits immediate attention. However, the ADI could play a key role by coordinating the efforts of government and private industry in the advancement of STEM education within Arizona.

6. **Acknowledge existing gaps:** Arizona's A&D industry currently suffers from a number of gaps, due in no small part to a lack of coordination and collaboration between research, industry and the military. These include:

    a. a lack of second-tier suppliers supporting large manufacturers in the State;
    b. lost opportunities within value engineering, directed energy and optics;
    c. IP ownership issues which undermine collaboration between industry and universities;
    d. a failure to correlate the development of new technologies with the needs of both military and civilian consumers.

    Some, but not all, of these gaps should be addressed.

7. **Leverage strengths to foster growth:** Arizona has several strengths that provide a solid foundation for future industry growth. For example, Arizona's research and education entities (echoing the literature review) and its geographic location as a border state collectively offer the Department of Homeland Security some of the U.S.'s best research and testing capabilities. The AADC's efforts to improve the business environment through targeted tax incentives and

economic development programs is also highlighted for positioning Arizona as a prime location for A&D operations.

## 3. Competitor Strategies

Building upon the literature review and the five in-depth interviews, an analysis of best practice in competitor states also provides pointers for the continued development of the A&D industry in Arizona. In particular, Science Foundation Arizona requested a review of collaborative programs and best practice in Alabama, Florida and Virginia. Table 3 summarizes the publications reviewed for each of these States.

**Table 3: Sources Consulted for Competitor States**

| STATE | PUBLICATIONS |
|---|---|
| Alabama | • The Alabama Development Guide (2010)<br>• Best Practices in State Science & Technology Policies (Collaborative Economics Inc., 2009)<br>• Aerospace & Defense White Paper (Alabama Aerospace & Defense Committee, 2009)<br>• White Paper on Commercialization (Alabama Commercialization Committee, 2009)<br>• Alabama Science & Technology Roadmap (Collaborative Economics, Inc., 2009) |
| Florida | • Modeling, Simulation & Training Overview (Metro Orlando Economic Development Commission, 2010)<br>• Florida Defense Industry Economic Impact Analysis (Haas Center for Business Research and Economic Development, 2008) |
| Virginia | • The State of Virginia, U.S.A. (Virginia Economic Development Office, 2008)<br>• National Institute of Aerospace 2009 Annual Report |

All three States appear to focus on unique competitive advantages, leveraged by intermediary entities, to set their respective A&D research and economic development agendas. Some commonalities are also visible, including the establishment of each institute as a public-private or a private not-for-profit entity, affiliation programs between universities and industry partners, and Federally Funded Research and Development Centers (FFRDCs). The key strengths and characteristics of each state can be summarized as follows.

### 3.1 Alabama

The history of the A&D industry in Alabama can be traced back to the 1950s when the federal government located Wernher von Braun's rocket science team at the Redstone Arsenal in Huntsville.

Since that time, over 200 aerospace firms have clustered around Huntsville, illustrating the profound, long-term effects of federal decisions pertaining to the location of specific installations, projects or initiatives. This is why states need to focus solely upon things they can control and make sustained, long-term investment in existing core competencies.

Alabama's A&D industry can be explained in part with reference to five core strengths:

a. substantial SBIR investment (20% per $1,000 GDP compared to a national average of 8%);
b. per capita R&D expenditures within the State are 24% higher than for the U.S (although per capita R&D investment is only $3 compared to a national average of $11)
c. the State is home to military and government installations such as Fort Rucker, Maxwell Air Force Base, Marshall Space Flight Center and Redstone Arsenal;
d. over 330 aerospace companies currently operate within Alabama;
e. Cummings Research Park is the second largest research park in the nation.

**3.2 Florida**

The genesis of the A&D industry in Florida dates back to the transfer of a U.S. Navy training facility from Virginia to Florida in 1969. By 1995, all four military services had relocated their training facilities to Florida; and the State today specializes in modeling, simulation & training (MS&T), hosting over 200 companies within that area collectively accounting for 25,000 jobs. This again demonstrates how the inception of an industry within a State can depend upon external decisions about the relocation of a major program.

To encourage the growth of a robust and stable MS&T industry, Florida has also implemented long-term sustained programs that promote collaboration between stakeholders. The strength of the A&D industry within Florida today is attributed to a large extent to the following:

a. the State is home to the Naval Air Warfare Center Training Systems Division, plus the Army's Program Executive Office, Simulation Training and Instrumentation facilities;
b. the University of Central Florida offers leading graduate and postgraduate programs in simulation and training systems, as well as founding the Institute for Simulation and Training – a major source of internships, scholarships and grants for the MS&T industry;

c. significant support is received from The National Center for Simulation, a non-profit organization that promotes simulation technology both within the region and nationally;
d. Florida's Center of Excellence for MS&T promotes modeling and simulation technologies across commercial and military applications;
e. Research Park promotes collaboration through mere geographic proximity;
f. Florida Department of Commerce supports Research Park through building grants;
g. Florida's congressional delegation has joined the MS&T Caucus.

**3.3 Virginia**

Virginia's A&D industry secured $38.8 billion in US Department of Defense Prime in 2009, positioning the State second in terms of the total value of contracts awarded (Virginia Economic Development Partnership, 2011b). This phenomenal success can be attributed, at least in part, to the following:

a. proximity to major government agencies;
b. housing of important military installations;
c. 6% corporate income tax for the last 30 years;
d. some of the lowest worker's compensation and unemployment insurance payroll expenses within the U.S.;
e. availability of undergraduate and graduate aerospace engineering programs at Virginia Tech, University of Virginia, Old Dominion University and the National Institute of Aerospace;
f. major Research and Development assets such as NASA's Langley Research Center, Virginia Space Grant Consortium, Mid-Atlantic Regional Spaceport and the Commonwealth Center for Aerospace Propulsion Systems
g. ongoing financial commitments from the State of Virginia

Virginia's National Institute of Aerospace (NIA) Research, Education and Outreach activities is also a prime example of best practice. Conducting a broad range of research sponsored by government agencies and the aerospace industry (from space exploration to material science), this is frequently pursued in collaboration with other institutions worldwide, courtesy of the NIA's partnerships with industry and university partners, and the Institute's willingness to share intellectual property to meet research objectives.

The successful development of an A&D industry within Alabama, Florida and Virginia illustrates how competitive advantage can be attained outside DC. The high value of DOD contracts secured, for example, by Virginia in 2009 suggests that the Department of Defense is receptive to decentralization. Arizona needs to be more aggressive in its pursuit of these opportunities. The estimated $8.8 billion dollars that the A&D industry brings to the State is based solely upon companies receiving federal dollars from Department of Defense contracts (Seidman Research Institute, 2010a). The importance of aggressively pursuing large federal contracts therefore cannot be overstated.

Furthermore, it should also be noted that while stakeholders often compete for similar or even the same contracts, collaboration with other stakeholders does not necessarily lead to everyone receiving a smaller piece of the pie. Having the resources of universities and other suppliers at their disposal increases the competitive effectiveness of contractors, illustrated by this comment from Thomas L. Baptiste, President of the National Center for Simulation in Florida:

> "Orlando and Central Florida are the epicenter for Modeling and Simulation--when you combine the power of the Research Park, close ties between a World Class University, Industry and Team Orlando you produce a synergy found nowhere else in the world. Companies who want to be serious players in the Modeling and Simulation Industry need to consider focusing their efforts on Orlando and Central Florida." (National Center for Simulation, 2009)

## 4. Economic Landscape & Key Players - Points of Intersection

This section will attempt to match the major players within Arizona's A&D industry to corresponding themes in the Aerospace & Defense landscape[2], highlighting the points of intersection across industry, research institutions and the military that can be leveraged to aggressively pursue large government contracts and maximize the economic impact on the State.

### 4.1 Identifying Clusters

The first step in this process is the segmentation of Arizona's A&D industry into 5 segments or clusters:

a. Very Large Manufacturers (VLMs)

[2] The Points of Intersection framework uses the themes identified by the Security and Defense Systems Initiative at Arizona State University to provide a comprehensive "Security Research Space."

b. Second-Tier Suppliers
c. Research Entities
d. Workforce
e. Military Assets[3]

These clusters collectively develop nascent technologies into commercial applications used by the military. A description of each cluster and their role in Arizona's A&D industry follows to provide a macro picture of the economic landscape.

### 4.1.1 Very Large Manufacturers (VLMs)

VLMs represent the last step in the commercialization process of new technologies. Primarily interested in technologies with a Technology Readiness Level (TRL)[4] of 7, 8 or 9, VLMs generally do not have the capacity or expertise to develop technologies below a TRL of 5 or 6. Arizona currently has nine A&D VLMs, employing 500 to 12,000 staff respectively, listed in Table 4. VLMs receive the majority of Department of Defense dollars and rely on a network of second-tier suppliers within the State.

**Table 4: Arizona's Aerospace & Defense VLMs**

| COMPANY | EMPLOYMENT |
|---|---|
| Raytheon Missile Systems | 11,835 |
| Honeywell Aerospace | 9,716 |
| The Boeing Company | 4,853 |
| General Dynamics C-4 System | 4,000 |
| Orbital Systems Corp. | 1,317 |
| L-3 Electro-Optical Systems | 753 |
| Goodrich Interiors | 630 |
| BAE Systems | 607 |
| Hamilton Sundstrand Aerospace | 520 |

*Source: Seidman Research Institute (2010a)*

### 4.1.2 Second-Tier Suppliers

Second-Tier Suppliers support VLMs and display the most variance of all the clusters in terms of technology, needs and strategy. Usually specializing in a few key competencies, these are combined

[3] Clusters were identified by literature review and verified through industry leader interviews.
[4] Technology Readiness Levels range from 1 to 9 and correspond to the stages new technology passes through, from Basic principles observed and reported to actual system 'flight proven' through successful mission operations (Source: DOD (2006), Defense Acquisition Guidebook).

with relatively lower operating costs to remain competitive. The smaller size of Second-Tier Suppliers also enables them to more readily adjust their strategies to meet the changing requirements of the Department of Defense or VLMs.

Table 5 lists some of Arizona's Second-Tier Suppliers. These companies stand to benefit most from external support in the areas of training, networking and collaboration with other entities. A report by the Seidman Research Institute (2010) suggests that Arizona has a relatively small number of Second-Tier A&D Suppliers in comparison with other States, thus highlighting a potential opportunity for growing the entrepreneurial base. Further research is required to determine the relationship between suppliers and manufacturers, and the effect it has on the economic impact of the Aerospace & Defense industry in Arizona.

**Table 5: Arizona's Second Tier Suppliers – Some Examples**

| COMPANY | EMPLOYMENT |
|---|---|
| Nammo Tally Inc. | 275 |
| Universal Avionics Systems Corp. | 275 |
| Alliant Techsystems Inc. | 226 |
| Paragon Space Development Corp. | 74 |
| Applied Energetics | 49 |
| Planetary Science Institute | 38 |
| Kutta Technologies | 19 |
| Qualtec Inc. | 17 |
| Engineering Science Analysis | 10 |

*Source: Seidman Research Institute (2010a)*

### 4.1.3 Research Entities

Research Entities are one of Arizona's greatest resources and represent a major core competency for the State. Table 6 lists the four key players within this cluster and their core competencies. Further detail about each institution is available in the Appendix.

**Table 6: Arizona's Four Lead Research Entities**

| INSTITUTION | CORE COMPETENCIES |
|---|---|
| Arizona State University (ASU) | • Aerodynamics and fluid mechanics,<br>• Helicopter Electromagnetics<br>• Nanofabrication<br>• Control Systems<br>• Combustion Dynamics<br>• Planetary Sciences<br>• Aeronautical Management Technology<br>• ADRC<br>• Security & Defense Systems Initiative (SDSI) |
| University of Arizona (UA) | • Optics<br>• Spacecraft Design<br>• Aerodynamics<br>• Aircraft structures<br>• Manufacturing<br>• Sensors & Actuator Design<br>• Propulsion Systems<br>• Signal Processing<br>• Telecommunications<br>• Modeling & Simulation |
| Northern Arizona University (NAU) | • Environmental<br>• Ecosystem<br>• Sustainable Energy |
| Embry Riddle Aeronautical University (ERAU) | • Flight Engineering<br>• Space Physics<br>• Global Environment & Management<br>• Global Security & Intelligence Studies<br>• Computer Science<br>• Aviation Business Administration<br>• Meteorology<br>• Safety Science<br>• UAV<br>• Autonomous Helicopters<br>• Computational Fluid Dynamics<br>• Airport Runways<br>• Fatigue Analysis of Aircraft Structures |

### 4.1.4 Workforce

The A&D industry requires a steady supply of Engineers and Scientists supplied by Arizona's four leading universities, alongside skilled technicians, machinists and other trades proficient in Science, Technology Engineering & Math (STEM) from Arizona's technical schools and community college system. Table 7 lists some of these institutions and the programs offered.

**Table 7: Arizona's Schools & Technical Colleges**

| INSTITUTION | PROGRAMS OFFERED |
|---|---|
| Anthem College | Business Management, Business Networking & Security, Computer Science, Computer Aided-Drafting, Electronics Technology, Information Systems, Management, Master of Business Administration |
| Argosy University | Information Systems, Information Systems Management |
| Arizona Automotive Institute | Advanced HVAC and Basic Refrigeration, Automotive Service Technology, Diesel - Heavy Truck, HVAC and Basic Refrigeration, Combination Welding |
| Brookline College(Phoenix, Tempe or Tucson) | Business Technology Specialist (Diploma) |
| Brown Mackie College | Information Technology |
| College America Phoenix | Computer Science (BS), Computer Programming (Associates), Computer Technology & Networking (Associates) |
| DeVry University (Glendale, Mesa or Phoenix) | Engineering & Information Sciences, Electronics and Computer Technology (Associates), Network Systems Administration (Associates), Biomedical Engineering Technology (BS), Computer Engineering Technology (BS), Computer Information Systems (BS), Electronics Engineering Technology (BS), Electrical Engineering (Masters), Information Systems Management (Masters) |
| East Valley Institute of Technology | Marketing, Management, and Entrepreneurship; Automotive Technology, Collision Repair Technology, Diesel/Heavy Equipment Technology, Computer Service Technician/Networking, Electronics, Aviation Flight Training, Aviation Maintenance Training, Engineering Technology |
| Everest University (Online) | Computer Information Science (Associates), Computer Information Science (BA) |
| Fortis College | Biotechnology (Associates) |
| ITT Technical Institute (Central Phoenix, Tempe, Tucson or West) | Information Systems Security (BS), Information Technology - Computer Network Systems (Associates), Electronics and Communications Engineering Technology (BS), Computer and Electronics Engineering Technology (Associates) |
| Keller Graduate School of Management | Information Systems Management (Masters), Network & Communications Management (Masters), Biomedical Engineering Technology (BA), Computer Engineering Technology (BA), Computer Information Systems (BA), Electronics & Computer Technology (BA), Electronics Engineering Technology (BA), Game & Simulation Programming (BA), Multimedia Design & Development (BA), Network Systems Administration (BA), Technical Management (BA) |
| TechSkills (Mesa and Phoenix) | Information Technology - Cisco Certification, CompTIA Certification, Database Administration, IT Security, Microsoft Certification, Networking, Oracle |
| The Refrigeration School, Inc. | Refrigeration, AC, Heating, Electronic Technologies, Electro-Mechanical Technologies, Mechanical Maintenance |
| Universal Technical Institute Phoenix | Automotive Technology Training Program (51 week program), Diesel & Industrial Technology Training Program (45 week program), |
| University of Advancing Technology | BS: Advancing Computer Science, Enterprise Software Development, Network Engineering, Network Security, Robotics & Embedded Systems, Strategic Technology Development, Technology Forensics, Technology Product Design, Open Source Technologies; MS Advancing Computer Science, Emerging Technologies |

| | |
|---|---|
| Arizona Western College | Air Conditioning and Refrigeration, Automotive Technology, Biology, Chemistry, Computer Graphics, CIS, Computer Security, Environmental Sciences, Industrial Graphics, Logistics, Mathematics, Networking |
| Central Arizona College | Fire Science Technology, Manufacturing Engineering, Microcomputer Business Applications, Operating Engineer, Plumbing Trades |
| Eastern Arizona College | Biological Science, Chemistry, CNC Machining, CAD & Drafting Technology, CIS, Database Support, Electrical and Instrumentation Technology, engineering, Environmental Technology, Graphic Design, IT, Machine Shop Technology, Mathematics, Physics, Renewable Sustainable Energy, Welding Technology |
| Maricopa Community Colleges | Aircraft Maintenance Technology, Airline Operations, Airway Science Technology (Flight Emphasis), Architectural CAD Technology, Associate in Science, Automation Technology, Biotechnology, Broadband Telecommunications, CAD Technology, Civil Engineering Technology, Networking, Graphic Design, CIS, Programming, Electrical Technology, Electro/Mechanical Drafting, Electronics Engineering, Hydrologic Studies, Information Security, Manufacturing Engineering Technology, Military Leadership, Power Plant Technology, Systems Analysis, Surveying Technology, Web Development, Welding |
| Pima Community College | Computer Aided Drafting, Computer Information Systems, Computer Software Applications, Digital Arts, Associate of Science, Biotechnology, Engineering, Astronomy, Biology, Chemistry, Geography, Geology, Mathematics, Physics |
| Mohave Community College | Electrical Technology, Industrial Electrical Maintenance, Welding Technology, Chemistry, Geology, Mathematics, Science, Computer Information Systems Administration, CIS Foundation, Computer Graphics & Web Design, Computer Support Services, Essential Computer Technology, Network Support & Security, Professional Applications, Programming & Gaming Development, Systems Administration |
| Yavapai College | Computer Networking Technology, Computing Systems and Applications, Electrical Instrumentation Technician, Graphic Design, Gunsmithing, Industrial Plant Technician, Professional Pilot – Helicopter |
| Cochise College | Geography, Mathematics, Chemistry, Computer Science, Engineering, Physics, Manufacturing Engineering, Professional Pilot Technology, Avionics Technology, Computer Applications, Computer Information Systems, Computer Programming, Electronics Technology, Game Design and Creation, Information Security, Intelligence Operations Studies, Counterintelligence, Electronic Intelligence analyst, General Intelligence Operations, Ground Surveillance Systems Operator, Human Intelligence Collector, Intelligence Analyst, Linguist, Military Intelligence Systems Maintainer, Morse Interceptor/Communications Interceptor, Multi-Sensor Operator, Signal Collector Analyst, Signals Collection/ID Analyst, Signals Intelligence Analyst, Interpretation and Translation, Logistics Supply Chain Management, Manufacturing Engineering, Network Technology, Unmanned Aerial Vehicle Flight Operator, Unmanned Aircraft Systems Technician, Welding Technology |

Arizona's public and private research institutions provide the industry with future technologies and usually operate at TRL 1-6. The biggest challenge facing this cluster is the alignment of ongoing research with the specified needs of commercial entities and more generally the larger A&D industry. This is due historically to a lack of intermediary entities interfacing between researchers, industry and the military. Efforts are already underway to correct this problem, but more assistance and guidance is needed.

#### 4.1.5 Military

Arizona's principal military installations exert a significant impact upon the local economy, creating 96,328 jobs and generating $9.1 billion in economic output. Table 8 lists Arizona's principal military operations facilities.

Enjoying a unique competitive advantage due to the variety of testing and training capabilities available, this cluster is the final consumer of A&D products. Arizona's A&D industry needs to take advantage of the presence of a large military community within the State by proactively engaging with them to ascertain needs and wants. This information can then be leveraged to obtain larger Department of Defense research grants and contracts in areas that are closely aligned with the future missions of local military facilities (The Maguire Company, 2008).

### 4.2 Key A&D Themes

The in-depth interview with Werner Dahm identified four key themes within the A&D landscape, emanating from ASU's Security and Defense Systems Initiative. The current section therefore lists and summarizes these themes, before utilizing them within a point of intersection framework for the clusters in Section 4.3.

Dahm's four themes are traditional, irregular, emerging and underlying. Traditional refers to established activities the military engages in as part of its normal operations. Irregular activities do not occur consistently over time. Emerging activities have historically not played a major role in military operations but are now growing in importance for security and defense. The underlying refers to potential future sources of conflict around the world that are not directly related with military operations. Each theme can be further sub-divided into five mini-themes.

**Table 8: Arizona's Principal Military Facilities**

| MILITARY BASE | PRIMARY MISSIONS |
|---|---|
| Davis-Monthan Air Force Base | Provide combat ready A/OA-10 aircraft to theater commanders worldwide and conduct initial qualification and reoccurring training for A/OA-1 pilots |
| Army Intelligence Center, Fort Huachuca | Military intelligence training, army network management, communications-electronics testing and training, and unmanned aerial systems training |
| Luke Air Force Base | Train the world's greatest F-16 pilots and maintainers while deploying mission ready war fighters |
| Marine Corps Air Station, Yuma | Provide aviation ranges, support facilities and services that enable the US Marine Corps and other military forces to enhance their mission capability and combat readiness |
| Army Proving Grounds, Yuma | Engineering, testing, developing, and supporting the development of military equipment including production testing of artillery, direct fire, automotive, aviation systems mines and countermines, unexploded ordnance, air delivery and soldier equipment |
| Air National Guard's 161st Air Refueling Wing | Provide trained combat forces to the USAF for the global war on terror and, under the command of the Governor of Arizona, work as a team to care for, serve and defend the citizens of local communities and the State |
| Air National Guard's 162nd Fighter Wing | Provide the finest fighter training programs in the world while partnering with the U.S. Air Force in the global war on terror and Air Sovereignty Alert |
| Army National Guard | Recruit, train, retain, sustain, and deploy the AZ ARNG forces |
| Western Army National Guard Aviation Training Site | Provide aviator, enlisted and specialty courses for the Army, and support regional simulation in the AH-64A, UH-60A, and AVCATT for US and allied pilots |

Source: (The Maguire Company, 2008)

An overview of the four themes and their constituent parts, as discussed by Dahm, are as follows:

**Theme A: Traditional**

1. ***National Defense*** – Defending the homeland and its interests abroad by focusing primarily on direct military engagement.
2. ***Cyber Warfare*** **–** This is defined by government security expert Richard A. Clarke (2010) as "actions by a nation-state to penetrate another nation's computers or networks for the purposes of causing damage or disruption."
3. ***Homeland Security*** – This refers to security efforts to protect the homeland from terrorism.
4. ***Intel & Surveillance*** – Linking several battlefield functions to assist a combat force's employment of sensors and managing the information that they gather.

5. ***Special Operations*** – Operations to achieve a political or military objective that are performed either independently or in conjunction with conventional military activity, in situations where a conventional force requirement does not exist or might affect the overall strategic outcome.

**Theme B: Irregular**

1. ***Counter-Terrorism*** –Operations taken to prevent, deter, preempt, and respond to terrorism.
2. ***International Piracy*** – War-like acts committed by private parties not affiliated with any government, including robbery and/or criminal violence at sea.
3. ***Weapons Trafficking*** – Illegal trafficking or smuggling of contraband weapons or ammunition.
4. ***Counterfeiting*** – Producing currency imitations without the legal sanction of the state or government.
5. ***Internal Security*** – Maintaining peace within the national borders by upholding the national law and defending against internal security threats.

**Theme C: Emerging**

1. ***Border Security*** – Methods used to prevent the smuggling of drugs, weapons, endangered species and other illegal or hazardous material.
2. ***Cargo Inspection*** – Efficient use of technologies to detect illegal materials and threats to national security in or among transported freight.
3. ***Immigration & Control*** – Technologies used for legal and illegal immigration, monitoring the movement of citizens across borders.
4. ***Narcotics Interdiction*** – Technologies used to discourage the production, distribution, and consumption of illegal drugs.
5. ***Cyber Crime*** –Any crime that involves a computer and a network, where the computers may or may not have played an instrumental part in the commission of that crime.

**Theme D: Underlying**

1. ***Energy and Security*** – Threats to energy security including the political instability of energy producing countries, manipulation of energy supplies, competition over energy sources, attacks on supply infrastructure, plus accidents and natural disasters.
2. ***Religious Extremism*** – Monitoring and responding to religious ideologies far outside the perceived political center of a society, which could potentially become a cause of conflict.

3. ***Legal & Policy Issues*** – Any issues faced during armed conflict that requires expert consultation to avoid violating treaties and other international agreements.
4. ***Global Disparities*** – Differences in culture and ideologies that lead to an innate mistrust of different nations or political views.
5. ***Root Social Causes*** – Broad political, economic and social issues which, if left unchecked, can lead to internal and external conflicts.

### 4.3 Points of Intersection

Building upon the clusters identified within Section 4.1 and the key themes outlined in Section 4.2, a point of intersection framework can be developed to provide a comprehensive 'Security Research Space', illustrated in Table 9. The color code represents the number of clusters affected by a theme.

**Table 9: Arizona's A&D Points of Intersection**

| Type | Themes | VLM | 2nd Tier Suppliers | Research Entities | Unique Facilities | Workforce | Military Bases |
|---|---|---|---|---|---|---|---|
| TRADITIONAL | National Defense | X | | X | X | X | X |
| | Cyber Warfare | X | | X | | X | X |
| | Homeland Security | | | X | X | X | X |
| | Intel & Surveillance | X | | X | X | X | X |
| | Special Operations | X | X | X | X | X | X |
| IRREGULAR | Counter Terrorism | | X | X | X | X | X |
| | International Piracy | X | | X | X | X | |
| | Weapons Trafficking | X | | X | X | X | |
| | Counterfeiting | | | X | X | X | |
| | Internal Security | | | X | X | X | X |
| EMERGING | Border Security | | X | X | X | X | X |
| | Cargo Inspection | | | X | X | X | |
| | Immigration & Control | | | X | X | X | |
| | Narcotics Interdiction | | | X | X | X | |
| | Cyber Crime | X | | X | X | X | |
| UNDERLYING | Energy and Security | | | X | | | |
| | Religious Extremism | | | X | | | |
| | Legal & Policy Issues | | | X | | | |
| | Global Disparities | | | X | | | |
| | Root Social Causes | | | X | | | |

| KEY | |
|---|---|
| Number of Clusters | Color Code |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |

Table 9 suggests that Special Operations affects every Arizona cluster. It also highlights six areas well represented within the State that can be leveraged as a competitive advantage. These are:

- national defense;
- cyber warfare;
- intelligence & surveillance;
- special operations;
- counter terrorism; and
- border security.

Representing Arizona's core competencies, these six areas should serve as a focal point around which collaboration between industry, research and the military entities is encouraged to maximize the economic impact of Aerospace & Defense statewide. This collaboration is ideally best served by the establishment of an Aerospace Institute, facilitating the exchange of ideas and needs between all stakeholders. If the Institute is to be effective, it must establish key links with the business development teams at VLMs such as Boeing or Raytheon. If the Institute fails to connect and interact with the 'big ideas' personnel and long term planners at VLMs, it will be unable to maximize its share of the research dollars available.

Table 9 also identifies several gaps or weaknesses in Arizona's A&D industry, such as counterfeiting, cargo inspection, immigration and control, and narcotics interdiction. Arizona could try to address or fix these areas to increase its competitiveness. However, the TOWS analysis presented in Section 5 concludes that the most effective strategy for the economic development of the A&D industry within the State is to focus all efforts around established clusters and core competencies.

## 5. TOWS Analysis

The implementation of a TOWS analysis provides a clear strategic direction for the economic development of the A&D industry within Arizona. Similar in its constituent parts to the more traditional SWOT analysis, TOWS initially focuses upon the threats (T) and opportunities (O) of the external environment to formulate a strategy for success within the applicable landscape, rather than starting from the weaknesses (W) and strengths (S) of the industry's internal environment.

Identifying a range of strategies from offensive to defensive, a TOWS matrix is therefore an effective framework for identifying the optimal strategy to manage threats, capitalize on opportunities, circumvent weaknesses and maximize strengths.

**5.1 The Four Strategies of a TOWS Matrix**

A TOWS Matrix offers four conceptually distinct alternative strategies, ranging from the offensive to the defensive. These are:

- The WT Strategy (Mini-Mini)
- The WO Strategy (Mini-Maxi)
- The ST Strategy (Maxi-Mini)
- The SO Strategy (Maxi-Maxi)

The general aim of the WT Strategy is to minimize both weaknesses and threats. It is, in effect, a mere survival position that a firm or industry would usually try to avoid. A WO Strategy attempts to minimize weaknesses and maximize opportunities. An ST Strategy recommends the use of strengths to meet and therefore minimize threats. The SO Strategy is one in which strengths are used to maximize opportunities. Weihrich (1982) argues:

> "Successful enterprises, even if they temporarily use one of the three previously mentioned strategies, will attempt to get into a situation where they can work from strengths to take advantage of opportunities. If they have weaknesses, they will strive to overcome them, making them strengths. If they face threats, they will cope with them so that they can focus on opportunities." (Weihrich, 1982, p. 62)

Although conceptually different, in reality overlap is possible between these strategies.

### 5.2 Developing a TOWS Matrix for Arizona's A&D Industry

The first stage in the development of a TOWS Matrix is to identify the threats and opportunities of the external environment, plus the weaknesses and strengths of the internal environment. Drawing from the literature review, in-depth interviews and best practice elsewhere, these can be listed as follows:

**(A) Threats**

1. Lack of communication between researchers, industry and the military.

   This could result in lost opportunities within value engineering or undermine an ability to win large federal contracts by offering the military a "cradle-to-grave" solution (ANGLE Technology Group, 2008).

2. Difficulty transitioning from TRL 6 to TRL 7.

   Without a statewide coordination of efforts by research and industry, it's difficult to advance from prototype to operational technologies.

3. Classified domain.

   Due to the unique nature of the A&D industry, the inability of some players to operate in the classified domain makes it difficult to coordinate statewide efforts.

4. Lack of integration between the Legal and Policy domain and other research.

   The legal and policy domain plays an important role in certain missions. The inability to integrate this expertise with current research may present a missed opportunity when coordinating the efforts of research and industry.

5. Competition from other states.

   The competitor states outlined in this report among others are structuring and positioning themselves well in order to compete for scarce federal and private investments. For example, Alabama has developed a science and technology roadmap that "has assembled the information, developed the strategies, and engaged the key public and private sector decision-makers necessary to enable the State to compete in this challenging environment" (Collaborative Economics, Inc., 2010).

**(B) Opportunities**

1. Build synergies with a statewide focus between disengaged firms.

   Break down the silo mentality and build collaborations with a State-wide focus by leveraging the expertise of large and small firms to pursue larger military and security contracts.

2. Border security technology research and testing.

   This is an area where Arizona enjoys a competitive advantage due to its geographic location. Border security represents a largely untapped source of federal contracts for the State (ANGLE Technology Group, 2008).

3. Increase in UAV research and testing.

   Arizona has some of the best research and testing resources in the country which make UAV technologies a natural fit (The Maguire Company, 2008).

4. Value Engineering.

   By coordinating the efforts of research and industry, both could benefit from the opportunities that lie in improving existing technologies through the US Department of Defense VE program (Wade, 1986).

5. Technology Horizons recommendations for new technologies.

   Align the efforts of research and industry with the military's Technology Horizons recommendations to offer the best solutions for large contracts in a competitive economic landscape.

6. Greater role of Legal and Policy experts in warfare.

   Arizona has excellent Legal and Policy resources that can be leveraged to provide a more comprehensive solution to the military's future needs.

**(C) Weaknesses**

1. Low Number of Second-Tier Suppliers.

   A lack of second-tier suppliers allows federal dollars to potentially leak out of the State. For example, a recent report suggested that one manufacturer working on a federal contract assigned 95% of subcontractor expenditure to work performed by firms outside the State (Seidman Research Institute, 2008). Potential reasons for this could include smaller firms' reluctance or inability to bid for federal contracts, or a general lack of awareness of local suppliers (Applied Economics, 2005).

2. Weak commitment from congressional delegation.

   The lack of support from Arizona's congressional delegation is a major disadvantage compared to other states. For example, Florida has benefited greatly from having two members of its congressional delegation (Suzanne Kosmas and Jeff Miller) join the Modeling & Simulation Caucus formed by Congressman Forbes of Virginia. Their

congressional delegation has also sponsored and co-sponsored large appropriation bills benefitting the Aerospace & Defense industry in Florida. (US Library of Congress, 2011)

3. External perceptions of the State.

   Controversial issues such as gun laws and immigration have potentially tarnished the image of Arizona, prompting at least some out-of-state firms in a variety of industries to hesitate before doing business in the State (Thomason, 2011).

4. Poor development of STEM education.

   A national problem, the State is currently trying to rectify the situation locally with several programs such as those being promoted by the Arizona Aerospace & Defense Commission, but there is still much to be done (ACT, Inc., 2010).

5. Unwillingness to share ideas.

   An insular, silo mentality prevalent amongst A&D firms in the State is demonstrated by a general unwillingness to share ideas. The lack of an intermediary entity to facilitate communication and collaboration between firms and research in the A&D industry has contributed to this weakness (ANGLE Technology Group, 2008).

6. Lack of organized thrust for research.

   Until recently, research in the State has not been closely aligned with industry needs. Significant progress has been made on this front through entities such as the SDSI and the ADRC, but more needs to be done to promote collaboration between research and industry.

7. Weak national marketing of advantageous state policies.

   The State has advantageous policies that, if marketed at the national level, could result in greater procurement of DOD contracts. For example, the aggressive marketing of State policies in Texas has secured a "disproportionate share of DOD prime contracts" (ANGLE Technology Group, 2008, p. 157)

**(D) Strengths**

1. Availability of Restricted Airspace.

   A large amount of restricted airspace sets Arizona apart from other parts of the US. Local development near the likes of Fort Huachuca has raised occasional concern, but the State's airspace remains an invaluable asset that must be protected (The Maguire Company, 2008, p. 13).

2. Military Bases and Testing & Training Ranges.

   Arizona's principal military installations exert a significant impact upon the local economy, creating 96,328 jobs and generating $9.1 billion in economic output. Arizona's A&D industry needs to take advantage of the presence of a large military community within the State by proactively engaging with them to ascertain needs and wants (The Maguire Company, 2008).

3. Active and retired military population in the State.

   Arizona receives substantial stimulus from spending by active and retired military personnel which can be directly linked to the presence of the various military installations in the State (The Maguire Company, 2008, p. 7).

4. Sufficient number of Very Large Manufacturers (VLMs).

   Arizona houses several VLMs, who collectively attract the majority of defense contract dollars to the State (Seidman Research Institute, 2010a).

5. Strong civilian aerospace facilities.

   Greater Phoenix's Civil Aviation facilities, including Sky Harbor, Goodyear and Deer Valley airports, exert a total economic impact of $33 billion for Arizona (W. P. Carey School of Business, 2008)

6. Excellent Research Entities.

   Arizona's three research universities (ASU, UA and NAU) and Embry Riddle Aeronautical University (ERAU) are a key asset. Primarily responsible for the vast majority of university-based R&D within the State, they also help to meet the increasing demand for a skilled workforce in the A&D industry (ANGLE Technology Group, 2008).

7. Unique facilities.

   Unique facilities such as the Air Force Research Laboratory in Mesa, AZ offer an opportunity to perform sensitive research at a "high-level security facility" (The Gold Group, 2008, p. 24).

8. Intermediary Entities.

   Existing intermediary entities in the State like the Security & Defense Systems Initiative (SDSI) and the Aerospace and Defense Research Collaborative (ADRC) strengthen research and industry's ability to collaborate and align their efforts with the military's future needs.

9. Economic Incentives.

   The State has created a more appealing economic environment for businesses by introducing tax incentives such as the Angel Investment Tax Credit and lowering corporate tax to below 5 percent.

10. Arizona Commerce Authority and affiliated statewide entities.

    The Arizona Commerce Authority and its affiliated statewide entities such as Science Foundation Arizona "promote Arizona as a premier location for business expansion" (Arizona Commerce Authority, 2010), and provide key resources that support business growth.

11. Favorable weather conditions.

    Arizona has some of the best and most sought-after flying environments in the world thanks to its optimal weather conditions (The Maguire Company, 2008, p. 23).

This list of threats, opportunities, weaknesses and strengths is then applied to the four distinct strategic alternatives (WT, WO, ST, SO) to provide a snapshot of the range of actions open to a firm or industry at any one time.

Table 10 illustrates the results of a TOWS matrix for Arizona's A&D industry, and the range of strategies available. Priority should be placed upon developing current core competencies and seeding intermediary entities that interact directly with research and industry. This will offer Arizona's A&D industry the greatest return. Implementation of some defensive strategies is also recommended to help protect the industry from a combination of external threats and internal weaknesses. However, the focus should be on the more aggressive, offensive tasks. Maintaining strategies should only be pursued after offensive strategies.

**Table 10: TOWS Matrix Analysis of Arizona's A&D Industry**

| | EXTERNAL OPPORTUNITIES (O) | EXTERNAL THREATS (T) |
|---|---|---|
| | 1. Building synergies<br>2. Border Security research<br>3. Increase in UAV research<br>4. Value Engineering<br>5. Technology Horizons recommendations for new technologies<br>6. Greater role of Legal and Policy experts in warfare | 1. Lack of communication between researchers and military<br>2. Difficulty transitioning from TRL 6 to TRL 7<br>3. Classified domain<br>4. Legal and Policy domain not integrated with other research<br>5. Competing states |
| **INTERNAL STRENGTHS (S)**<br>1. Restricted Airspace<br>2. Military bases & testing<br>3. Military population in State<br>4. Number of VLMs<br>5. Civilian aviation facilities Excellent Research Entities<br>6. Unique facilities<br>7. Intermediary Entities<br>8. AZ Economic Incentives<br>9. AZ Commerce Authority<br>10. Favorable weather | **OFFENSIVE STRATEGIES (SO)**<br>• Focus on core competencies beginning with National Defense, Intelligence & Surveillance and Special Operations, to maintain competitive advantage.<br>• Leverage airspace and testing ranges to obtain new federal contracts in areas like UAV research and testing.<br>• Seed Intermediary Entities to assist in collaboration between research and industry. | **MAINTAINING STRATEGIES (ST)**<br>• Strengthen current assets such as military bases, VLMs and unique facilities via collaboration facilitated by intermediaries to prevent threat from lack of communication between entities.<br>• Facilitate transition from TRL 6 to TRL 7 through collaborative partnerships and intermediary entities. |
| **INTERNAL WEAKNESSES (W)**<br>1. Low number of Second-Tier Suppliers<br>2. Weak commitment from congressional delegation<br>3. Tarnished Image of State<br>4. Poor STEM education<br>5. Silo mentality of firms<br>6. Lack of organized thrust for research<br>7. Weak national marketing of advantageous policy | **MAINTAINING STRATEGIES (WO)**<br>• Promote value engineering opportunities through VLMs and Second-Tier Suppliers.<br>• Mediate between industry and research to remove key roadblocks to collaboration such as IP ownership.<br>• Facilitate engagement between firms and suppliers to build synergy in the industry. | **DEFENSIVE STRATEGIES (WT)**<br>• Protect current assets by supporting unique facilities within the State.<br>• Communicate the importance of the A&D industry to the congressional delegation and encourage participation in industry caucuses (i.e., Modeling & Simulation Caucus). |

## 6. Conclusions & Recommendations for Future Research

Several key conclusions can be drawn from this report.

1. The Aerospace & Defense industry is a complex cluster of systems that relies on a variety of different entities with differing needs and goals. Historically, the A&D industry has been heavily focused on aerospace and neglected other core competencies such as Arizona's unique facilities (e.g. AFRL in Mesa), federally funded research facilities (e.g. NOAO) and Second-Tier Suppliers in new technologies (e.g. directed energy, security and optics). Arizona's A&D industry will benefit to a considerable extent from greater connections and collaborations between these key players. The overarching goal of these collaborative efforts is to obtain larger, more lucrative contracts and grants, thereby enabling the production of cutting-edge, commercially-viable solutions of significant value to the military. This will also benefit Arizona's economy as a whole through the direct, indirect and induced spending of all key stakeholders.

2. The points of intersection analysis identified core competencies in areas such as national defense, cyber warfare, intelligence and surveillance, special operations, counter terrorism and border security. These areas should be leveraged to encourage other entities to focus on them and further enhance the State's reputation.

3. A TOWS analysis suggests several strategies for success, ranging from the offensive to the defensive. Offensive Strategies include focusing on core competencies to maintain competitive advantage, leveraging restricted airspace and testing ranges in the State to obtain large federal contracts, and seeding intermediaries to maximize collaboration between research and industry. Defensive strategies currently available to Arizona's A&D industry include protecting current assets via greater support for the State's unique facilities and attaining greater support from the congressional delegation. Maintaining strategies include a greater emphasis upon collaboration, pursuing opportunities within homeland security and narcotics intervention, promoting value engineering opportunities, building synergies between firms, and removing roadblocks to collaboration such as IP ownership.

4. Offensive strategies will offer Arizona's A&D industry the greatest return because they take advantage of both strengths and opportunities and hence should be the main priority. Defensive strategies are also important to the extent that they will protect the industry from external threats and internal weaknesses – that is, areas where the industry is most vulnerable. The implementation of maintaining strategies would support offensive and defensive strategies, and hence provide a sustained and long-term investment within the industry. However, this latter type of strategy should only be pursued once the offensive strategies have been secured.

5. Securing greater support from the congressional delegation is of particular importance for the Arizona A&D industry to more aggressively pursue Department of Defense contracts.

6. The report recommends the establishment of an Aerospace Institute to seed intermediary entities such as the Aerospace and Defense Research Collaborative and coordinate research efforts through a virtual network of outposts at Arizona's leading research facilities. The co-ordination and enhancement of links between research, industry and the military by an Aerospace Institute will remove key hurdles such as potential disputes over intellectual property rights, and therefore offer a robust foundation for the continued development of the industry within Arizona.

7. Closely aligning the efforts of research and industry around established themes in A&D and through collaborative efforts, guided by the likes of an Aerospace Institute, will enable Arizona to offer the Department of Defense beginning-to-end solutions based on existing and solid competitive advantages.

8. This report has also identified a lack of Second-Tier Suppliers supporting both Arizona's VLMs and other missions outside the State. Further study is recommended within this area to address the following questions:

    a. Which suppliers do Arizona's VLMs currently use the most and why?
    b. Do Second-Tier Suppliers in other States enjoy competitive advantages currently unavailable within Arizona?
    c. Does the lack of local Second-Tier Suppliers impact the ability of VLMs to win new contracts from the federal government?

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# Appendix

## A.1 Arizona's Research Programs and Centers

| ARIZONA STATE UNIVERSITY (ASU) | |
|---|---|
| **Adaptive Intelligent Materials and Systems (AIMS) Center** | Integrates a variety of interdisciplinary areas spanning mechanical, material, electrical and computational engineering, and developing a solid foundation in the area of integrated intelligent system design. Research in this area will solve large-scale problems that have direct benefit to the economy and society as well as a significant impact on aerospace and mechanical systems and civil infrastructures. Such problems are of interest to both industry and government. |
| **Flexible Display Center** | A university, industry, government collaborative venture designed to advance full color flexible display technology and flexible display manufacturing to the brink of commercialization. The principal goal of the FDC is to develop high performance, commercially-viable, conformal and flexible displays that are lightweight, rugged, low power, and low cost. |
| **Information Assurance Center** | A multi-disciplinary center focus on both the research and educational activities to address the broad issues of developing trustworthy information systems (TIS) and ensuring the quality of information being stored, processed and transmitted by information systems and networks. The Center has been certified as a National Center of Academic Excellence in Information Assurance Education (CAEIAE) by the National Security Agency & the Department of Homeland Security. |
| **ASU / NASA Space Grant** | Supports graduate and undergraduate students in a variety of disciplines to further their educational experiences in science, engineering research, and informal education programs. |
| **Sensor, Signal & Information Processing Center** | Develops signal and information processing foundations for next-generation integrated multidisciplinary sensing applications in biomedicine, defense, homeland security, sustainability, environmental technologies, interactive media, wireless communications, and vehicular systems. |
| **Wireless Integrated Nano Technology** | Wireless systems are a budding technology that will go beyond the current cellular telephone application. This young technology will play a dominant role in a variety of fields including information processing, remote sensing, autonomous monitoring, homeland security, bio-medical sensors, and bio-telemetry. |
| **Cognitive Engineering Research Institute (CERI)** | An independent, not for profit 501c3 research institute located in Mesa, AZ, adjacent to ASU's Polytechnic campus. Though not a part of ASU, CERI has a close relationship with ASU through a Memorandum of Understanding that allows mutual sharing of faculty, students, and facilities. In addition, CERI collaborates closely with the Air Force Research Laboratory's Human Effectiveness Directorate. CERI's research focuses on human factors consideration and human systems integration of large scale cognitive and socio-technical systems, particularly the ground control stations for Unmanned Aerial Systems (UASs). CERI specializes in the development of assessment methods and metrics in these environments and the use of synthetic task environments for team experimentation. In addition to UAS research, CERI also conducts research in emergency response, strategic planning, cyber security and healthcare domains. |
| **Unmanned Aerial System Training and Simulation Center** | Currently in the planning stages, this would fill a national need for UAS training and training research, while at the same time addressing a variety of other UAS human systems integration concerns. The plan is for this center to be an arm of the AZ Aerospace Institute and managed by CERI. It will leverage the secure facility currently occupied by AFRL, as well as a sizeable portion of the AFRL skilled workforce that will remain behind in AZ after the USAF BRAC (Base Re-alignment and Closure) which will be complete in 2011. These resources combined with local science and technology strength in the UAS and training and simulation areas, as well as the growing need for UAS training and training research, ideally position the center to succeed and flourish. |

| THE UNIVERSITY OF ARIZONA (UA) | |
|---|---|
| **Center for Astronomical Adaptive Optics** | Focused primarily on the development of adaptive optics techniques for enhancing the resolving power of both imaging and spectrographic instruments at large ground-based telescopes. |
| **Department of Planetary Sciences and Lunar and Planetary Laboratory** | Dedicated to the common goal of understanding and teaching about the formation and evolution of the planetary system. |
| **Funding** | NASA, JPL, NSF, Southwest Research Institute (SWRI), Space Telescope Institute (STSCI). |
| **Research Groups** | Planetary atmospheres, surface composition, climate change, and global warming. Mercury studies, studies of small objects (asteroids & comets), astrophysics, and ultraviolet spectroscopy & imaging. |
| **Projects** | Projects 2007/2008 – Phoenix Mars Lander Mission first mission to Mars led by an academic institution. |
| **Current Special Projects** | • Cassini Visual Infrared Mapping Spectrometer<br>• High Resolution Imaging Science Experiment – Planetary Image Research Laboratory<br>• Space Imagery Center – Research collection of NASA planetary photography, cartographic products & technical documentation. |
| **Department of Astronomy/Steward Observatory** | Currently has 47 Ph.D. students, making it the largest astronomy graduate program in the country. The program is extremely high quality, with admission of approximately 8-10 students per year from among 120-130 applicants. Incoming astronomy graduate students have the highest mean GRE scores among over 100 graduate programs on campus. |
| **Aerospace & Mechanical Engineering Department** | Aerodynamics, active flow control, fluid mechanics, hydrodynamic stability & transition, aero acoustics, design and testing of UAVs and MAVs, CDF, aerospace structures & materials, structural design optimization & combustion. |
| **Research & Test Facilities & Capabilities** | Low speed wind tunnel (50 m/s), low turbulence closed loop wind tunnel (up to 40 m/s), two open-loop wind tunnels, unsteady water tunnel & water jet, anechoic chamber associated with a jet noise lab. Two water channels, a large high-speed water tunnel and two shock tubes. |
| **Space Engineering Laboratory** | Space Engineering Laboratory pursues innovative and challenging concepts through a first engineering demonstration of feasibility, so that future missions can use the product for economical and reliable enhancements of (and enabling) newer spacecraft and unique Rockets and Robots. |
| **Department of Homeland Security Center of Excellence** | Focuses on eight major research areas:<br>• Detection: Humans, Vehicles and Decision Supports<br>• Networks: Interoperability, Reliability and C3<br>• Fusion: Tools and Approaches<br>• Risk: Mitigation, Assessment and Alignment<br>• Population: Methods, Metrics and Estimates<br>• Immigration: Economics, Policies and Alternatives<br>• Governance: Law Enforcement and International Cooperation |

| EMBRY RIDDLE AERONAUTICAL UNIVERSITY (ERAU) | |
|---|---|
| **Research & Test Facilities & Capabilities** | • Aerospace Experimentation and Fabrication Building - Completed in the Fall of 2006, the Aerospace Experimentation and Fabrication Building houses design and testing suites that are used by Aerospace Engineering students in capstone projects and component design courses.<br>• Embry-Riddle faculty have also participated in NASA-Dryden Flight Research Center (DFRC) (via the AERO Institute) research focusing on Unmanned Aviations Systems. |
| **Aerospace Laboratories & Testing Capabilities** | • Mechanical Testing Lab<br>• MTS Hydraulic Load Frame/Actuator Suite<br>• Propulsion Lab<br>• Structural Dynamics Lab<br>• Microscopy Lab<br>• Materials Lab<br>• Structural Testing Lab<br>• Aeronautical Fabrication (AXFAB) Lab and Machine Shop<br>• Rapid Prototyping Lab<br>• Space Lab<br>• Wind Tunnel Facilities |
| **LIGO Optics Lab** | Explores high index layer coatings in order to reduce the optical noise in the next-generation LIGO experiment. The current LIGO experiment is comprised of two 4-km long interferometers that are sensitive to gravity waves produced black hole and neutron star collisions in nearby galaxies. These interferometers can measure shifts in space down to 1/1000th the size of a proton. The implementation of this new optical technology will improve the sensitivity of the interferometers to search for collisions of massive objects in hundreds of nearby galaxies in the Virgo super-cluster. |
| **Particle Physics Lab** | A teaching and research facility set up to explore the properties of elementary particles using liquid scintillators and quantum photomultiplier tubes. As a teaching lab, students learn the basic principles of particle detectors and particle accelerators. As a research lab, students and professors are constructing particle physics detectors with sub-nanosecond timing resolution to track atmospheric cosmic rays as well as byproducts of radioactive decays. |
| **Hydrophone Lab** | A research laboratory developing hydrophone arrays to search for artifacts buried under centuries of silt and mud. This lab investigates the use of high-powered transducers that scan through a large bandwidth of frequencies to produce evanescent sound waves that can travel sideways through the silt and mud to detect ancient artifacts. The use of evanescent sound waves reduces the number of scans required to identify objects, and thus, reduces the time required to complete a search. This new sensor array will soon be used by our professors and students to scan the Venice lagoon for Roman artifacts. |

| NORTHERN ARIZONA UNIVERSITY (NAU) | |
|---|---|
| **Physics and Astronomy** | Part of the College of Engineering, Forestry and Natural Sciences, it is housed in two stories of the Physical Sciences building and is home to 13 faculty members and approximately 165 students. Faculty currently engages in two primary areas of research; materials science and astrophysics. |
| **Materials Research Laboratories** | Currently used for work in chemical sensors and solar storage. The chemical sensor work is based primarily on micro cantilevers, and the solar storage work is centered on thin-film capacitors. The labs house a variety of analytical tools, such as Scanning Tunneling Microscopy (STM), X-ray Photoelectron Spectroscopy (XPS), Scanning Probe Microscopy (SPM), and a full suite of deposition and vacuum systems. |
| **Astrophysics** | Includes the following projects:<br>• Cratering in the Solar System<br>• Studies of Near-Earth Asteroids<br>• Spectroscopy of Kuiper Belt Objects<br>• Transits of Extra-solar Planets<br>• High-Mass Binary Stars<br>• Dust-Disks around Nearby Stars<br>• Astrobiology<br>• Laboratory studies of astrophysical ices |
| **Mechanical Engineering Aerospace and Defense Research** | Part of the College of Engineering, Forestry and Natural Sciences, housed in a newly renovated 90,000 sq. ft. engineering building, the Department has 7 full-time faculty and 400 students. Faculty actively engages in research activities in thermal/fluid sciences, renewable energy, and solid mechanics. An additional 8,500 sq ft of mechanical engineering laboratory space is contained in a separate building, within walking distance from the main engineering building. The following research activities related to aerospace and defense are currently ongoing in the department: |
| **Adaptive Materials and Systems** | This research focuses on modeling, characterization and implementation in practical applications of adaptive/smart materials with a particular focus on magnetic shape memory alloys, magneto-rheological fluids and piezoelectric materials. Micro actuators/sensors, power harvesters, micro pumps and active/semi active vibration isolators are some of the applications under development. Other adaptive materials applications, such as morphing structures and health monitoring, are in the early stages of investigation, with the intent to develop them into another research thrust in the near future. |
| **Advanced Composites and Optomechanics** | Focuses on the characterization and improved design and analysis of advanced composite materials including optomechanical and fracture mechanics applications. For example, models have been developed to predict fracture near singularities at biomaterial anisotropic interfaces in bonded joints. Optomechanics applications include the design, analysis and characterization of an all-composite telescope for the Naval Research Lab. |
| **Improved Models for Plastic Deformation** | Currently researching the development of improved models for plastic deformation in metals that include distortional hardening with applications to manufacturing processes and plastic analysis of structures. Future work includes the extension to large elasto-plastic deformations and implementation of the new models into finite element programs; application of directional distortional hardening to stability problems (e.g. plastic buckling); and predicting elastic spring-back during manufacturing. |

*Source: Arizona Aerospace and Defense Commission*

**A.2 Number of 2000 – 2010 Graduates by Most Recent Degree and University**[5]

| Arizona State University (ASU) | 11,006 |
|---|---|
| **Bachelor** | 6,845 |
| Electrical Engineering | 981 |
| Mechanical Engineering | 799 |
| Computer Science | 790 |
| Computer Systems Engineering | 514 |
| Bioengineering | 491 |
| Microbiology | 365 |
| Chemical Engineering | 349 |
| Biochemistry | 335 |
| Mathematics | 331 |
| Industrial Engineering (includes Systems Engineering) | 301 |
| Molecular Bio Science/Technology | 261 |
| Aerospace Engineering | 259 |
| Chemistry | 195 |
| Physics | 119 |
| Materials Science & Engineering | 108 |
| Industrial Technology (Information Technology) | 103 |
| Applied Sciences (Fire Service Management) | 65 |
| Electrical Engineering Technology (Electrical Sys) | 61 |
| Manufacturing Engineering Technology | 42 |
| Applied Sciences (Computer Systems Administration) | 42 |
| Mechanical Engineering Technology | 35 |
| Sustainability | 45 |
| Manufacturing Engineering Technology (Mechanical) | 24 |
| Industrial Technology (Environmental Technology Management) | 23 |
| Mechanical Engineering Technology (Aerospace) | 23 |
| Applied Computer Science | 20 |
| Industrial Technology (Industrial Technology Management) | 14 |
| Environmental Technology Management | 14 |
| Electrical Engineering Technology (Telecommunication Systems) | 12 |
| Applied Sciences (Software Technology Applications) | 10 |
| Applied Sciences (Microcomputer Systems) | 10 |
| Applied Sciences (Manufacturing Technology & Management) | 10 |
| Electrical Engineering Technology (Microelectronics) | 10 |
| Applied Sciences (Semiconductor Technology) | 9 |
| Electrical Engineering Technology (Computer Systems) | 9 |
| Operations Management Technology | 8 |
| Computer Engineering Technology (Software Technology) | 7 |
| Industrial Technology (Graphic Information Technology) | 7 |
| Applied Sciences (Emergency Management) | 7 |
| Computer Engineering Technology | 6 |

[5] University of Arizona data reflects number of graduates from 2000 to 2009.

| | |
|---|---|
| Mechanical Engineering (Automation) | 5 |
| Computer Systems (Embedded Systems) | 5 |
| Mechanical Engineering Technology (Automotive) | 5 |
| Computer Engineering Technology (Software Engineering Tech) | 4 |
| Computer Engineering Technology (Embedded Systems Tech) | 4 |
| Electrical Engineering Technology (Alternate Energy Tech) | 3 |
| Computer Engineering Technology (Hardware Tech) | 3 |
| Computer Systems (Hardware Tech) | 2 |
| **Master** | **3,300** |
| Electrical Engineering | 1,224 |
| Computer Science | 638 |
| Industrial Engineering (includes Systems Engineering) | 407 |
| Mechanical Engineering | 149 |
| Bioengineering | 104 |
| Technology (Computer Systems) | 89 |
| Mathematics | 84 |
| Tech (Environmental Technology Management) | 69 |
| Technology | 62 |
| Materials Engineering | 57 |
| Chemical Engineering | 45 |
| Chemistry | 44 |
| Technology (Electrical Systems Engineering Technology) | 42 |
| Physics | 42 |
| Technology (Management of Technology) | 38 |
| Aerospace Engineering | 36 |
| Computing Studies | 29 |
| Technology (Information Technology) | 29 |
| Molecular & Cellular Biology | 19 |
| Technology (Fire Science Administration) | 17 |
| Technology (Microelectronics) | 16 |
| Microbiology | 13 |
| Sustainability | 12 |
| Technology(Computer Systems) | 11 |
| Biochemistry | 9 |
| Energy Systems Engineering | 8 |
| Technology (Integrated Electronic Systems) | 6 |
| Civil/Environmental Engineering | 1 |
| **Doctorate** | **861** |
| Electrical Engineering | 240 |
| Chemistry | 124 |
| Computer Science | 100 |
| Industrial Engineering (includes Systems Engineering) | 66 |
| Mathematics | 64 |
| Bioengineering | 59 |
| Mechanical Engineering | 55 |
| Physics | 48 |

| | |
|---|---|
| Molecular & Cellular Biology | 34 |
| Chemical Engineering | 33 |
| Microbiology | 19 |
| Biochemistry | 11 |
| Aerospace Engineering | 7 |
| Sustainability | 1 |
| **University of Arizona (UA)** | **10,160** |
| **Bachelor** | **7,139** |
| Molecular & Cellular Biology | 1,350 |
| Mechanical Engineering | 768 |
| Computer Science | 753 |
| Electrical Engineering | 652 |
| Mathematics | 504 |
| Microbiology | 483 |
| Computer Engineering | 440 |
| Chemistry | 291 |
| Chemical Engineering | 286 |
| Bioscience & Molecular Biophysics | 281 |
| Physics | 262 |
| Aerospace Engineering | 226 |
| Biochemistry | 191 |
| Optical Sciences & Engineering | 174 |
| Environmental Sciences | 147 |
| Materials Science & Engineering | 138 |
| Industrial Engineering (includes Systems Engineering) | 125 |
| Optical Engineering | 45 |
| Environmental Hydrology & Water Reserves | 18 |
| Optics | 4 |
| Biochemical & Molecular & Cellular Biology | 1 |
| **Master** | **1,493** |
| Electrical & Computer Engineering | 334 |
| Optical Sciences | 287 |
| Computer Science | 232 |
| Mechanical Engineering | 164 |
| Industrial Engineering (includes Systems Engineering) | 107 |
| Chemistry | 101 |
| Physics | 59 |
| Environmental Engineering | 48 |
| Aerospace Engineering | 41 |
| Mathematics | 41 |
| Materials Science & Engineering | 29 |
| Chemical Engineering | 21 |
| Microbiology & Immunology | 12 |
| Molecular & Cellular Biology | 8 |
| Biochemistry | 3 |
| Bioscience & Molecular Biophysics | 3 |

| | |
|---|---|
| Microbiology | 1 |
| Electrical Engineering | 1 |
| Computer Engineering | 1 |
| **Doctorate** | **1,528** |
| Medicine | 528 |
| Pharmacy | 495 |
| Chemistry | 165 |
| Electrical & Computer Engineering | 65 |
| Molecular & Cellular Biology | 49 |
| Microbiology & Immunology | 41 |
| Chemical Engineering | 30 |
| Mathematics | 25 |
| Physics | 23 |
| Materials Science & Engineering | 23 |
| Mechanical Engineering | 20 |
| Biochemistry | 13 |
| Environmental Engineering | 12 |
| Computer Science | 11 |
| Biochemistry & Molecular & Cellular Biology | 10 |
| Optical Sciences | 8 |
| Aerospace Engineering | 8 |
| Microbiology | 2 |
| **Northern Arizona University (NAU)** | **1,838** |
| **Bachelor** | **1,699** |
| Computer Information Systems | 482 |
| Mechanical Engineering | 271 |
| Electrical Engineering | 179 |
| Chemistry | 125 |
| Mathematics | 96 |
| Environmental Science - Biology | 88 |
| Microbiology | 85 |
| Computer Science | 71 |
| Physics | 69 |
| Computer Science & Engineering | 68 |
| Environmental Engineering | 61 |
| Environmental Studies | 32 |
| Environmental Science | 31 |
| Environmental Science - Applied Geology | 17 |
| Environmental Chemistry | 10 |
| Environmental Science - Microbiology | 8 |
| Environmental Science - Chemistry | 4 |
| Environmental Science - Applied Math | 2 |
| **Master** | **139** |
| Mathematics | 76 |
| Chemistry | 63 |

| Embry Riddle Aeronautical University (ERAU) | 1,462 |
|---|---|
| **Associate** | **95** |
| Professional Aeronautics | 72 |
| Technical Management | 15 |
| Aviation Maintenance | 7 |
| Aviation Business Administration | 1 |
| **Bachelor** | **876** |
| Professional Aeronautics | 744 |
| Technical Management | 68 |
| Management of Technical Operations | 58 |
| Aviation Business Administration | 5 |
| Aviation Maintenance | 1 |
| **Master** | **491** |
| Aeronautical Science | 266 |
| Technical Management | 172 |
| Business Administration in Aviation | 41 |
| Management | 12 |
| **Grand Total** | 24,466 |

*Source: ASU, UA, NAU and ERAU Alumni Offices*

**A.3 Additional Technical Degree Programs at Branch Campuses[6]**

| Northern Arizona University – Yuma Branch Campus |
|---|
| **Bachelor** |
| B.A. Interdisciplinary Studies – Technology Management |
| B.A.S. Technology Management |
| B.S. Interdisciplinary Studies – Technology Management |
| **Master** |
| M.A.T. Mathematics |
| M.S. Applied Geospatial Sciences |
| Master of Engineering |
| **University of Arizona South – Sierra Vista** |
| **Bachelor** |
| Intelligence Studies |
| Network Administration |
| Computer Science |
| Mathematics |
| **Master** |
| Educational Technology |

*Source: UA South and NAU – Yuma Branch Campus Student Services*
*http://www.uas.arizona.edu/index.php?q=academics*
*http://yuma.nau.edu/DegreeSearch.aspx*

[6] These programs are sub-categories of the degrees listed in A.2

# Glossary

| | |
|---|---|
| **AADC** | The Arizona Aerospace and Defense Commission is the State's sole coordinator of all aerospace and defense related commercial partnerships. It is tasked providing technical support, developing goals and objectives, recommending legislation and providing direction regarding Arizona's aerospace and defense related commerce. |
| **ACE** | The Arizona Center of Excellence serves as the focal point to unite all of Arizona's industrial, academic and public segments in the global marketplace by facilitating the objectives of the State's aerospace, defense, homeland security industry and academic sectors. |
| **ADRC** | The ADRC, funded under the Aerospace and Defense Initiative from Science Foundation Arizona, is an ASU-led state-wide initiative to build broad partnerships between higher education and industry. |
| **AFRL** | The Air Force Research Laboratory is a scientific research organization operated by the United States Air Force Materiel Command dedicated to leading the discovery, development, and integration of affordable aerospace warfighting technologies |
| **Arizona MEP** | Arizona MEP is an affiliate of the U.S. Department of Commerce's Hollings Manufacturing Extension Partnership (MEP), a national network of organizations that provide assistance to small and midsize manufacturers. |
| **ASU** | Arizona State University |
| **ATC** | The Arizona Technology Council is a non-profit trade association founded to connect, represent and support the state's expanding technology industry. |
| **ERAU** | Embry Riddle Aeronautical University |
| **FFRDC** | Federally Funded Research and Development Centers (FFRDCs) conduct research for the United States Government. They are administered in accordance with U.S Code of Federal Regulations, Title 48, Part 35, Section 35.017 by universities and corporations. |
| **MS&T** | Modeling, Simulation & Training is an industry focused on technologies that create abstractions of reality for the purpose of research and training. |
| **NAU** | Northern Arizona University |
| **NDIA** | The National Defense Industrial Association is a Defense Industry association promoting national security. It provides a legal and ethical forum for the exchange of information between Industry and Government on National Security issues. |
| **NextGen** | NextGen is a wide ranging transformation of the entire national air transportation system moving it away from ground-based surveillance and navigation to new and more dynamic satellite-based systems. It introduces new technological innovations in areas such as weather forecast, digital communications and networking. |
| **NOAO** | NOAO is the US national research & development center for ground-based night time astronomy with observatories in Arizona, Hawaii and Chile. |
| **SBIR/STTR** | Small Business Innovation Research and Small Business Technology Transfer are two Department of Defense programs which fund a billion dollars each year in early-stage R&D projects at small technology companies. |

| | |
|---|---|
| **SDSI** | The Security & Defense Systems Initiative at Arizona State University is a transdisciplinary, university-wide institute based on the New American University model to develop technology-enabled solutions for key national and global security challenges. |
| **STEM** | The acronym STEM stands for science, technology, engineering, and mathematics. According to both the United States National Research Council and the National Science Foundation, the fields are collectively considered core technological underpinnings of an advanced society. |
| **TOWS Matrix** | A TOWS matrix is a variant of a SWOT analysis used to evaluate the threats, opportunities, weaknesses and strengths involved in a project, business venture, industry or any situation requiring a decision. |
| **TRL** | Technology Readiness Levels range from 1 to 9 and correspond to the stages new technology passes through, from Basic principles observed and reported to actual system 'flight proven' through successful mission operations. |
| **UAV** | An unmanned aerial vehicle (UAV; also known as Unmanned Aircraft System (UAS)) is an aircraft that is flown by a pilot or a navigator (Combat Systems Officer) depending on the different Air Forces; however, without a human crew on board the aircraft. |
| **UA** | University of Arizona |
| **VLM** | Very large manufacturers as defined in this report are aerospace & defense firms with 500 employees or more. |

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