SOUTHERN CALIFORNIA INDUSTRY CLUSTER SERIES

THE CHANGING FACE OF AEROSPACE *in* SOUTHERN CALIFORNIA

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MARCH 2016

LAEDC INSTITUTE FOR APPLIED ECONOMICS

SAN DIEGO REGIONAL EDC

THE CHANGING FACE OF AEROSPACE IN SOUTHERN CALIFORNIA

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AN INDUSTRY CLUSTER STUDY

Preface by PwC

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Executive Summary

What we learned in this study.

The aerospace industry is facing exponential transformation from within the industry and from outside.

The aerospace industry was built on the vision and dreams of entrepreneurs and risk-takers who have continually pushed the limits of technological innovation. While the technologies that are shaping the future of aerospace continue to evolve, Southern California's rich, deep and strong ecosystem of large and small companies, research and educational partners, an active defense sector amid a culture of risk-taking and future-thinking remains one of the world's most competitive regions for aerospace innovation.

This report examines the state of the industry today and how it will evolve in the future. Its findings are summarized as follows:

The Future Has Arrived

- In Southern California today, leading commercial technologies are moving into the aerospace market. The challenge for the region is to continue to support and enable its technological ecosystem, while the challenge for individual firms is to adopt emerging exponential technologies that are critical to future success in this industry.

- Companies operating in Southern California are blessed with a number of advantages, including a deep ecosystem of talent, expertise and engineering prowess, a synergistic environment for technological innovation, a culture of risk-taking and entrepreneurship, and a workforce with the needed skills for innovation across the most innovative technologies.

Recent Industry Activity

The industry employed 85,500 direct payroll workers in Southern California in 2014, accounting for 14 percent of the US industry employment.

- The value of shipments of the aerospace industry nationwide reached $283 billion in 2014; new orders have climbed back towards pre-recession levels, reaching $346.6 billion in 2014.

- Commercial aircraft have been driving sales in recent years, now representing one-third of all US aerospace industry sales; the industry exports more than twice what it imports, producing a trade surplus of $61.6 billion in 2014.

- As the industry continues its transformation, leading California firms are well-positioned to compete in the modern day Space Race.

Sizing Things Up

- Industry employment was 85,500 in 2014, not including aerospace-related defense personnel, accounting for 14 percent of industry employment nationwide.

- Guided missile and space vehicles (and related parts) manufacturing employment has grown by more than 64 percent since 2004, most of this occurring in Los Angeles County. Almost one quarter of the national employment in this industry segment is in Southern California.

- Aerospace employment in San Diego County grew by 66.7 percent since 2004, drawing employment from both Los Angeles County and Orange County.

- Aerospace industry wages were on average $105,715 per year, among the highest-paid employees in Southern California, almost twice the average paid in all other industries. Inflation-adjusted wages grew by 4.3 percent since 2004, approximately three times as quickly as average wages in all other industries.

- The Southern California aerospace industry is maintaining its competitiveness, with an employment location quotient of 2.1. Further, the region is a leading powerhouse in guided missiles and space vehicles, with a location quotient of 3.5.

Spreading the Wealth

- The aerospace industry spends more than $24 billion on goods and services for inputs into production, and pays $11.1 billion in wages and benefits.

- The industry contributes $30.4 billion in value-added, accounting for 2.4 percent of the total state GDP, and generates 245,770 total jobs (direct, indirect and induced) in Southern California including those in its supply chain.

The industry spends more than $24 billion on goods and services for inputs into production, and pays $11.1 billion in wages and benefits.

Work, Work, Work

- The occupational makeup of the workforce is comprised of two major occupational groups: production workers, which account for 26 percent of the jobs, and engineering occupations, which account for 22 percent of the jobs. Approximately 41 percent of the expected job openings over the next five years will require a bachelor's degree or higher.

- Southern California is home to numerous educational institutions that offer targeted programs and training for aerospace-related work.

What the Industry Says

A survey of aerospace firms in the Southern California region revealed:

- Aerospace firms in Southern California are competing in a global marketplace
    - More than a third of respondents to our survey identified their primary customers as being outside the United States

- More than half of respondents indicated that Southern California was an excellent or good place to do business in their industry
    - Firms are located in Southern California primarily for proximity to customers and suppliers, and due to legacy of the company
    - Southern California's quality of life continues to draw good talent, while its favorable climate allows more testing and hence the ability to develop products faster than in other areas of the nation

- Growth in space and unmanned vehicles, and the commercialization of new products provide expectations that the industry will change considerably over the next 10 to 20 years.

More than half of survey respondents in the industry indicated that Southern California was an excellent or good place to do business.

Continued innovation and exponential technologies in materials, design, digitization, connectivity, artificial intelligence and robotics, combined with the industry's deep roots, established infrastructure and forward-thinking new pioneers in the region will ensure a vibrant and robust future for the aerospace industry in Southern California.

The Future Has Arrived

A perspective from the PwC team.

The industry is facing exponential transformation from within the industry and from outside, offering exciting opportunities—and challenges.

The aerospace industry is in the midst of technological transformation. In Southern California today, leading commercial technologies are moving into the aerospace market. Engineers and innovators are pushing the boundaries of the industry, now no longer focused on avionics alone but introducing increasingly complex systems of communication, autonomy, advanced manufacturing processes, robotics and artificial intelligence. The challenge for the region is to continue to nurture the existing technological ecosystem and to build into this the environment to attract and retain the next generation of aerospace and technology firms. The challenge for aerospace firms themselves is to adopt emerging, exponential technologies that are critical to their future success.

Headwinds

Over the past few years, the aerospace industry has increasingly found itself in a challenging position as it seeks growth and innovation. Historically dependent on government-funded contracts, the industry is now facing headwinds from that direction that are not likely to recede. Among these are budget constraints, costs pressures and political challenges.

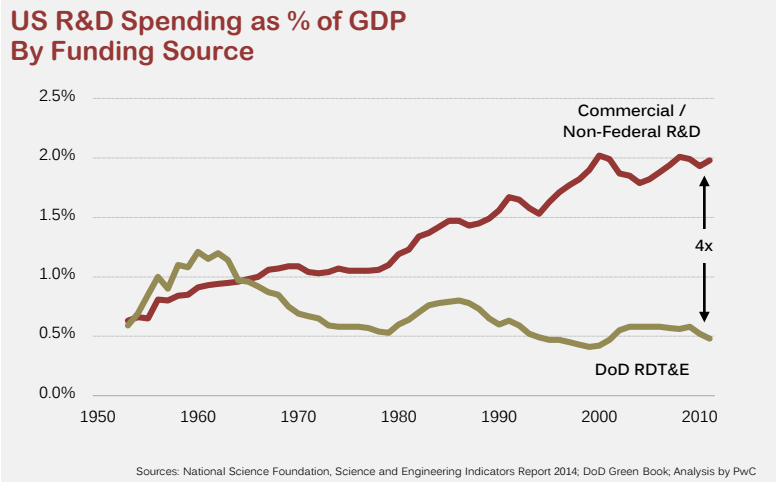
Across the defense industry, the U.S. government has not initiated as many significant new weapons programs as was once common for the industry. The recent award of the Long Range Strike Bomber contract to Northrop Grumman is a rarity in terms of scale. Although overall government budget constraints are not new, they continue to present the realities of current fiscal limits. The President's 2016 budget anticipates an increase of mandatory spending (which includes entitlements and healthcare) of 2.5 percent of GDP over ten years (through 2020), while national defense expenditures are expected to decline by 2.1 percent of GDP over the same period—suggesting a crowding out of defense spending by domestic needs.

Additionally, persistent cost overruns in recent contract delivery has motivated the DoD to issue more fixed price contracts, which often squeezes margins at aerospace firms, inducing those with higher production costs to move to lower-cost locations when feasible, and forcing others to find other clients.

Overriding and amplifying these challenges, the existing political climate appears highly entrenched and will provide no relief. Budget sequestration continues to be in effect, which significantly impacts defense spending and hence aerospace suppliers, and annual budget negotiations themselves have become fractious, intractable and ultimately unpredictable.

The Old and the New: Growth of Commercial Investment

Certainly there will continue to be demand for the platforms and systems that have shaped the current industry, such as aircraft, missiles and satellites. But there is increasing demand for emerging technologies that are being driven by adjacent industries, such as autonomy, artificial intelligence, cloud computing, cybersecurity, robotics, connectivity and analytics.



Consequently, the aerospace industry is being split into a complex, exquisite system of past developments and information-based technologies of the future.

In many ways, this trend has been developing for a long time. Commercial research and development has been outpacing defense four-fold since the 1990s. But for some technologies, such as autonomy, this growth wedge has been much more dramatic. While less than twenty years ago, defense departments were the only funders of unmanned and autonomous systems, today commercial investment far outweighs defense, as virtually all industry interests, from global auto companies to technology giants to startups, are racing to develop a driverless vehicles, autonomous aircraft systems and increasingly capable robotics platforms. This trend is not isolated to autonomy but extends to several technologies central to the future of aerospace. In some key areas, the investment ratio of commercial investment to defense funding is 100 or even 1,000 to one.

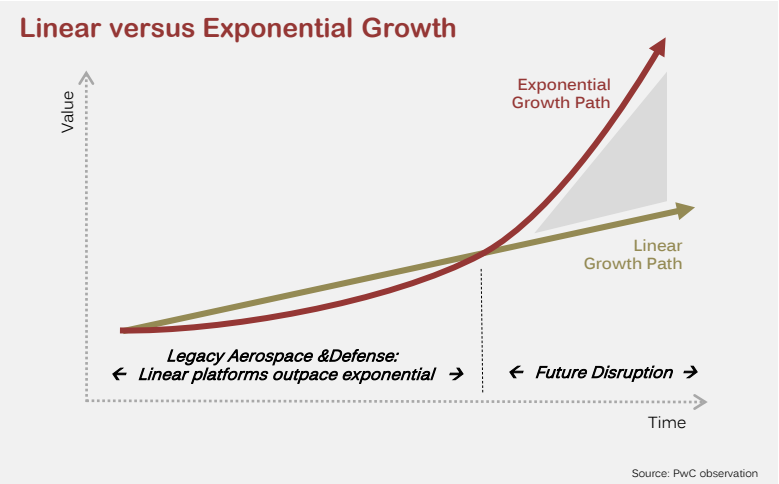
Moving from Linear to Exponential

The extent and reach of commercial investment is both capitalizing on and facilitating the increased speed of transformation in the digital world.

In the mid-1960s, Gordon Moore, then R&D Director at Fairchild Semiconductor and shortly thereafter a founder of what would become Intel Corporation, famously predicted exponential growth in digital technology, a prediction that was dubbed Moore's Law. The law predicted a doubling of computing power every year or so, and the following decades proved the law to be remarkably solid.

The doubling of a variable with each iteration is represented by what is known in mathematics as an *exponential* function. This stands in contrast to a constant multiple of a variable of with each iteration, which is represented as a *linear* function. Early in an exponential growth path, the level change is small, where, for example, a doubling of 2 units to 4 units is a change of merely 2 units. Further on the growth path, however, the level change is enormous, where, for example, a doubling of 4 giga-units to 8 giga-units is a change of 4 trillion units.

Digitization, although it seemed to grow slowly in its early years—not delivering, for example, personalized flying vehicles or the self-lacing sneakers of *Back to the Future*—it is now transforming virtually all industries, including those within the arena of the aerospace industry. Moreover, the transformations are now universally disruptive and



certainly seem to be occurring much faster today than ever in the past. The digital universe is now approaching the upper stages of its exponential growth curve.

Not all processes or industries are subject to exponential growth, of course. Many technologies experience linear growth trends, such as those related to physical infrastructure and assets. These technologies are characterized by capital intensity, high marginal costs and organizational structures that are large and sclerotic. Their growth is constrained by the physical limits of materials and people, and growth is therefore expensive to achieve and not very scalable.

By comparison, exponential technologies are those that are information-based, with digital rather than physical infrastructure, characterized by data and information intensity, minimal marginal costs and organizational structures that are lean and agile. Growth in these technologies is constrained only by information flows and computing power—both of which are themselves growing at exponential rate—which is therefore highly scalable and certainly disruptive.

How is this relevant to the aerospace industry? Emerging exponential technologies include artificial intelligence, machine learning, automation, biotech and bioinformatics, nanotechnology, robotics, unmanned and autonomous systems and 3D printing, many of which have high relevance to the aerospace industry, but are coming increasingly from outside the aerospace industry itself. Hence, much of the attention is shifting to companies that are not part of the core aerospace industry but are in the broader technology sector.

The integration of information technology and digitization into aerospace products and industries—often funded and developed by the commercial sector—is becoming a disruptive force.

Aerospace Companies at a Crossroads

How should this force be interpreted for future developments in the industry? Growth in information technologies is exponential and still has far to go. For example, in the realm of connectivity and the "Internet of Things," we expect a growth of connected devices from approximately 12 billion in 2015 to more than 25 billion in 2020, a five-year compound annual growth rate of 39 percent. At that anticipated rate, by 2030, more than one trillion devices will be connected. Such explosive connectivity will have major implications for every industry, including aerospace. As physical assets become connected, they become information-enabled and will also ride the exponential wave.

This creates a number of challenges for an industry such as aerospace where change and technology development occurs not exponentially, but in a linear fashion and with predictable outcomes. Many traditional aerospace firms are accustomed to linear innovation, which results in only marginal performance improvement, and incorporating

emerging exponential technologies will necessarily involve organizational changes, from talent to investment to processes and structure.

As in any industry facing non-linear competition, the incumbents in the aerospace industry have several options. First, they can maintain their current market position as builders of platforms and hope that the cyclical nature of the aerospace industry or a resurgent international market will drive growth. Second, they can look to adjacent markets involving digital technologies that can become part of a new growth strategy. Third, they can move fully into the information value chain and try to shape and hence control it.

Currently, it would seem difficult for defense firms to pursue the third strategy as they do not have the necessary talent base. Aerospace companies in the U.S. employ less than one of every 150 engineers with expertise in areas such as autonomous systems, secure communications, artificial intelligence and machine learning. Further, these companies spend far less on research and development than do many U.S. technology companies—approximately 2 percent of revenues compared to approximately 8 percent, on average. Such a company will not be able to compete favorably with Amazon in cloud services or with Google, LinkedIn or Facebook in data analysis.

Nevertheless, aerospace companies need to accelerate their ability to use digital technology, which can help them develop products more quickly and economically, increase operational efficiency and improve the value proposition they present in the aftermarket. They cannot afford to wait for their customers to provide complete clarity.

Emerging technology markets are inherently uncertain and develop rapidly. Aerospace firms that do not find a way to innovate and anticipate customer needs will find themselves increasingly sidelined, and in a few years, those that will survive and provide industry leadership are likely to be those that demonstrate an ability to innovate and embrace future technologies despite uncertainty.

The future of the industry in Southern California will depend upon the ability of the region to build into the existing ecosystem the environment to attract the next generation of aerospace technology firms.

Capturing the Future: Opportunities for Aerospace in SoCal

With this background in mind, we believe that aerospace companies operating in Southern California enjoy advantages over the rest of the country:

Ecosystem

Southern California hosts a large number of organizations with technological talent and expertise and engineering prowess, including aerospace firms, NASA, Space and Naval Warfare Systems Command (SPAWAR), Los Angeles Air Force Base (LAFB), Jet Propulsion Laboratory (JPL), startups, universities and venture capital firms, all of whom together create a synergistic environment for technological innovation. Many of these institutions and ecosystem participants are highlighted throughout this document.

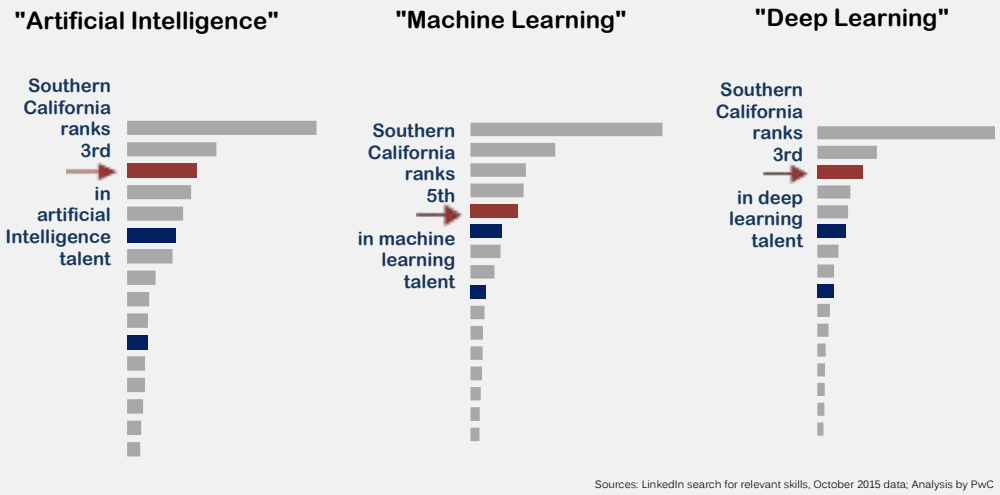
Culture

Culture is a critical element in the innovation sphere. The culture of risk-taking and entrepreneurship is often cited as one of the key reasons the United States has been the world's leader in innovation. This culture is amplified in Southern California, which has a rich and deep heritage of risk-taking, from the days of its early settlers to the growth of the region through the centuries, as pioneers forged new lives and ventures in these far western shores. This spirit is especially evident in aviation, from its early days following the 1910 air meet through the heyday of aircraft manufacturing during World War II and into today's pioneers now reaching beyond the stars.

Skills

Southern California is home to many people with the unique skills necessary for innovation across commercial and aerospace technologies, including those needed for artificial intelligence, facial recognition, product recommendations, machine learning and business intelligence and analytics. The region ranks between third and fifth among U.S metropolitan areas for the number of people working in these areas, as a search of such talent across the nation reveals. With the rich engineering and technology talent produced by regional educational institutions, Southern California has ample resources to lead the nation in the human capital necessary for the exponential growth of this industry.

People Working on AI Technologies by US Metropolitan Areas



Sources: LinkedIn search for relevant skills, October 2015 data; Analysis by PwC

As this report vividly outlines, the aerospace industry is thriving in Southern California, built on the pillars of these three key advantages, and launching into the converging technological ecosystem that will ultimately transform the human experience as it ventures into space. The challenge for aerospace firms is to adopt those emerging exponential technologies that are critical to their future success.

– PwC

Introduction

An industry in transition.

The aerospace industry was built on the vision and dreams of entrepreneurs and risk-takers who have continually pushed the limits of technological innovation. Traditionally dependent on federal defense funding, the industry is now moving into the commercial market, integrating the exponential technologies that will be critical to its future success.

While the technologies that are shaping the future of the aerospace continue to evolve, Southern California's rich, deep and strong ecosystem of large and small companies, research and educational partners, military installations and the culture of risk-taking and future-thinking remains one to the world's most competitive regions for aerospace innovation.

About This Report

This report is the second in our Industry Cluster Series, which examines industry clusters in the larger Southern California region in detail. Industry *clusters* are distinct from more commonly-recognized industry *sectors* as they are formed by firms that are in related industries, that sell related products, employ similar types of labor and have a common geographic concentration of activity.

This clustering of activity is believed to indicate regional specialization and competitiveness and offers the best opportunity for encouraging and sustaining economic development.

As important as they are in driving economic activity, industry clusters are even more significant when they are essentially export industries. By selling goods and services to the global audience, such clusters bring new dollars into the region, which recirculate through their supply chains to local firms and employees, supporting resident households and businesses and allowing them, in turn, to prosper and grow.

Because such industry clusters are not dependent on the local market for their business, these are the very industries that are most able to locate where they find conditions most hospitable – in terms of access to capital and land, cost-effective raw materials, and qualified and available labor pool.

It is the distinction between traded clusters and local clusters that drives our analysis in this report. By understanding the current and historic trends of our leading most competitive industry clusters, we can come to understand the challenges and opportunities, and tailor our economic development programs and policies to strengthen our existing specialties and build them into flourishing, thriving and growing industries. We can ensure that we have a workforce ready and able to fill the jobs of the future in our strongest industry clusters, and remain competitive in a fast-changing global economy.

We can focus our public policy and programmatic efforts on those industries which are most likely to provide the highest wages, which, in turn, produce the highest impacts on the local economy and the best return for our investment, and those that are always at risk of moving elsewhere.

With the vision of the future of the industry as outlined by the analysts and professionals at PwC in our preface—an exciting picture of the evolution of the industry and how its future is being developed here—our discussion proceeds in five parts:

First, we step back and provide an overview of the aerospace industry in terms of its productive activity at the national and state level. We learn that while the industry is highly dependent on federal defense spending, there are significant areas of private sector investment that now contribute to the activity that supports and drives the industry. Our focus is on the Southern California region defined by the counties of Imperial, Kern, Los Angeles, Orange, Riverside, San Bernardino, San Diego and Ventura.

Following this, we focus on the metrics of the industry cluster – its size in terms of employment and wages and how these have performed over the past ten years.

Third, we examine the supply chain of the aerospace industry cluster – what goes into the making of the cluster? What recipe of goods and services is needed to provide the industry with its necessary inputs? With this quantified, we estimate the overall contribution of the cluster to the regional economy through its multiplier impacts.

Fourth, we consider the supply of workers into the industry. It employs a full spectrum of workers, from new job entrants to highly-specialized and experienced labor. The occupational makeup of the industry cluster is examined and regional workforce development programs outlined. An occupational forecast is provided to outline future workforce needs.

Finally, we share the results of a survey of industry participants and several in-depth interviews as we try to understand how the participants themselves see the evolution and future of their industry. Here we learn that in spite of several challenges, the Southern California region is still brimming with optimism and the spirit evocative of the industry's early pioneers, reaching for the moon, the stars and beyond.

This comprehensive picture of an industry cluster that draws a great deal of attention is meant to inform policymakers and local stakeholders as we together develop regional strategies to bring jobs and prosperity to the Southern California economy.

Complete discussion and description of methodologies and data sources are provided in the Appendix, along with more detailed data tables that expand on the exhibits shown throughout.

Recent Industry Activity

Past performance.

For more than a century, the aerospace industry has thrived across the nation and in Southern California. In this section, we examine recent industry activity and discuss the Southern California context.

Value of Shipments

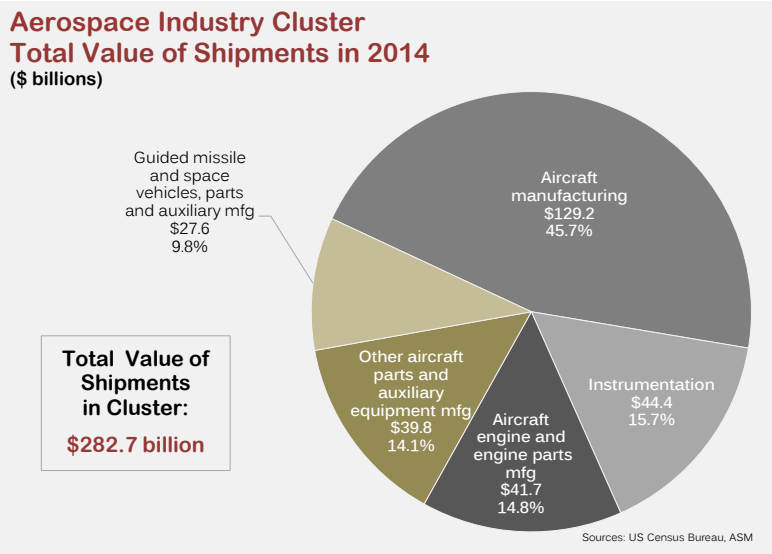
The aerospace industry transforms inputs of production into aerospace products. We often look at the total value of shipments for manufacturing industries as it includes the value of shipments of both primary and secondary products and reflects the value of output of the industry. It also includes miscellaneous receipts, such as repair work, installation and sales of scrap materials.

The total value of shipments of the aerospace industry cluster is available at the national level; the most recent data available is for 2014.

The industry cluster is composed of a collection of a number of industries, as will be discussed below. Each of these industries contributes to the value of shipments of the cluster. Almost three-quarters the total value was contributed by the manufacturing of aircraft, their engines and auxiliary equipment and parts; aircraft manufacturing accounted for 45.7 percent and aircraft engines, parts and other auxiliary equipment combined accounted for another 28.9 percent. Search, detection, navigation, guidance, aeronautical and nautical system and instrument manufacturing (which is here labeled "instrumentation") accounted for 15.7 percent of all shipments, followed by guided missile and space vehicle, propulsion unit, auxiliary equipment and parts manufacturing with 9.8 percent.

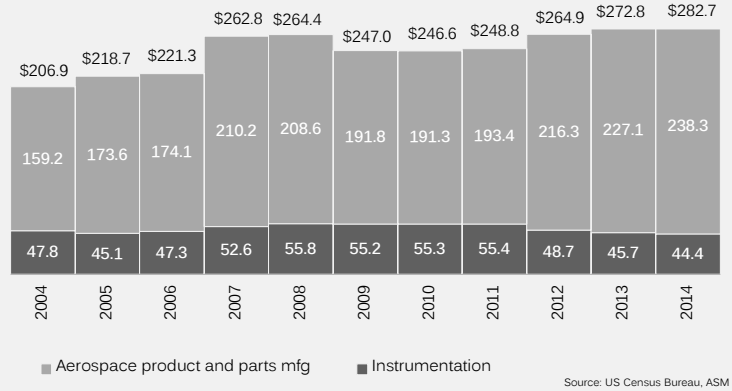
The total value of shipments, adjusted for inflation, has consistently been in excess of $200 billion over the past decade, with peak activity in the most recent year totaling $282.7 billion. The aerospace products and parts industry, which includes the manufacture of aircraft and space vehicles, is the predominant source of the value of shipments in this traded industry cluster, representing 83 percent of the total in 2014.

Aerospace products and parts accounted for 83 percent of the cluster's total value of shipments in 2014.



Aerospace Industry Cluster Total Value of Shipments

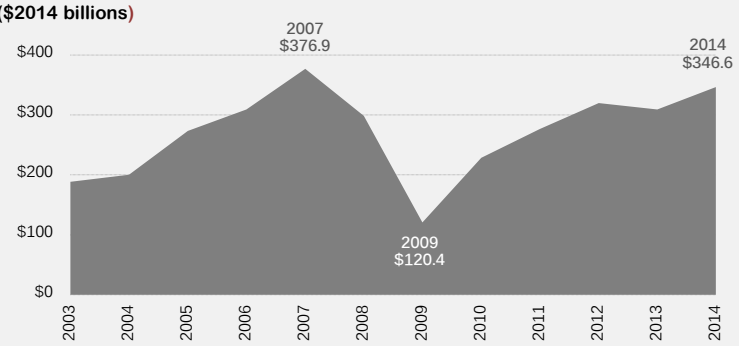
($2014 billions)



Source: US Census Bureau, ASM

New Orders

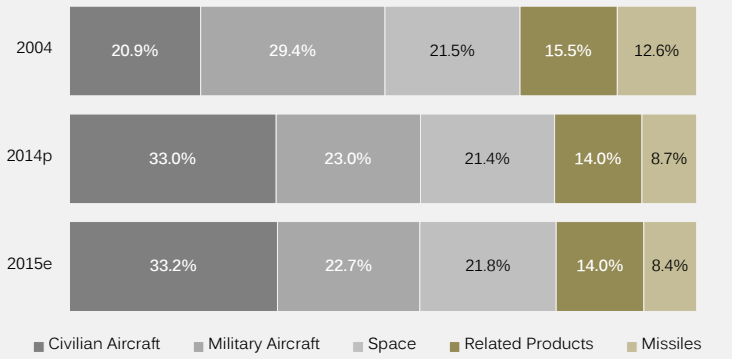
($2014 billions)



Note: Industry includes defense and nondefense aircrafts and parts manufacturing and instrumentation manufacturing

Sources: US Census Bureau M3; BLS; LAEDC

Composition of U.S. Aerospace Industry Sales by Product Group



Source: AIA

New Orders

New orders represent the pipeline of production. These have shown some volatility, with a precipitous fall taking place from 2007 peak levels to its nadir in 2009. The value of new orders has picked back up, with a 2014 value only eight percent below its peak.

Industry Sales

The Aerospace Industry Association (AIA) tracks aerospace industry sales, drawn from company reports. Comparing their composition over a period of time can provide insight into changes occurring within the industry that are not visible in aggregated industry data.

The composition of industry sales has changed over time. In years past, the largest market share in terms of industry sales was military aircraft, while today the largest share is civil aircraft. In 2014 civil aircraft sales cornered a third of all US aerospace industry sales and that share is expected to be the same in 2015. Missiles, almost 13 percent of US industry sales in 2004, now hold roughly eight percent market share. Space and aerospace related products and services have held consistent market shares over the last decade with approximately 21 and 15 percent of sales, respectively.

Data for new orders for civil aircraft from Airbus and Boeing, the two main industry suppliers of the commercial market, show increases in new orders for their commercial aircraft, indicating that future industry sales will continue to be driven by activity taking place in commercial aerospace.

Commercial aircraft have been driving sales in recent years, now representing one-third of all US aerospace industry sales.

Aerospace Trade

Products of the aerospace industry are widely traded in the global marketplace. The United States is engaged in significant export and import activity of these products.

The value of exports has consistently been twice the value of imports, yielding trade surpluses that contribute to the nation's GDP. In 2014, the value of exports reached $118.2 billion, compared to imports of $56.6 billion, resulting in a trade surplus of $61.6 billion.

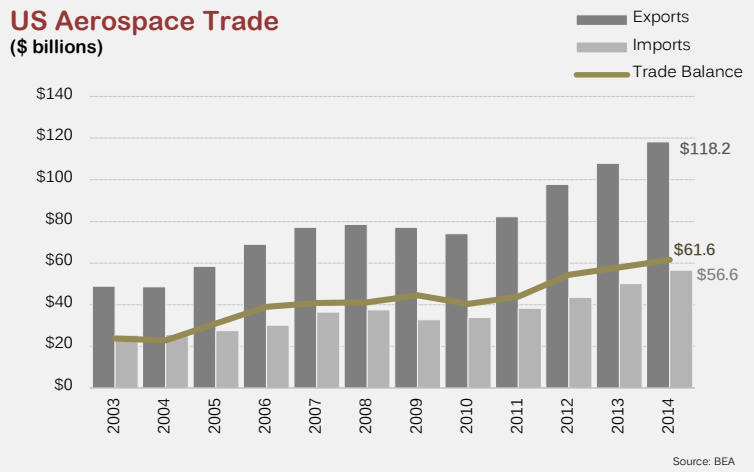
The composition of industry exports differs from that of imports. Built civilian planes are the mainstay of aerospace exports, while aerospace components used in the manufacture of civilian aircraft make up the majority of the value of imports.

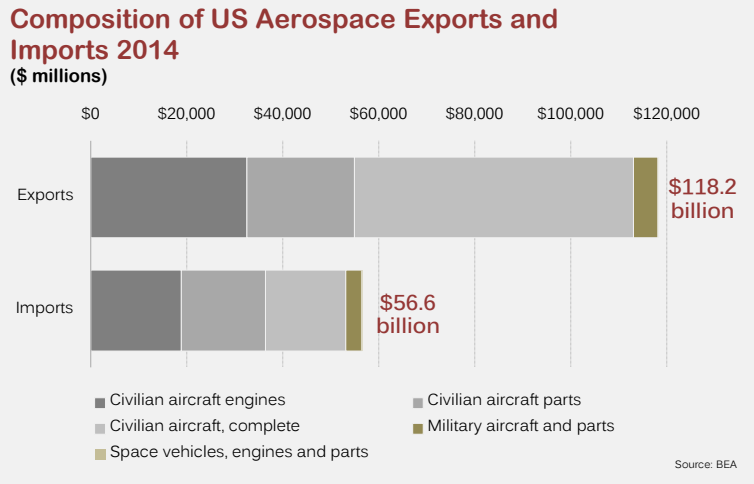
In 2014, civilian aircraft accounted for almost half of the $118.2 billion total value of aerospace exports. Engines and parts for civilian aircraft represented over 64 percent of the $56.6 billion total value of aerospace imports.

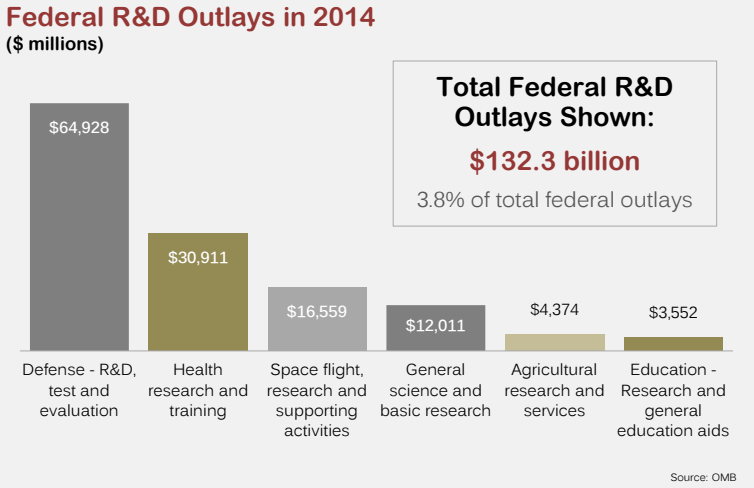
Research and Development

While aerospace related research and development (federally-funded or otherwise) is not included directly in this industry cluster, it is a major driver of activity taking place in the cluster, as the technological innovation discovered through research and development feeds into industries included in this cluster—often in the form of products developed and materials and processes used in their manufacture.

In 2014, federal outlays for research and development activities amounted to $132.3 billion, approximately 3.8 percent of all federal outlays. Of this, $64.9 billion was spent on defense-related research and development, $16.6 billion was allocated to research and support activities of space flight, and $12.1 billion was dedicated to general science and basis research—all of which are valuable in the technological advancements needed in this industry. Nevertheless, the 2001 Budget Control Act implemented rigid budget caps that have adversely affected the aerospace industry by reducing the amount dedicated to aerospace and defense orders and outlays for federally-funded research and development. These caps are still in effect.







The California Experience

California has many attributes which the aerospace industry continues to draw on, including ideal climate conditions for flight-testing, large restricted airspace, a high concentration of military operations, easy access to international manufacturing, an aerospace industry legacy, major international shipping ports, a deep labor pool fed by numerous educational institutions in the region, and an emerging startup scene, which has introduced new players such as SpaceX, Orbital ATK and Virgin Galactic into the area.

The nature of the aerospace industry in the Golden State is changing. Once home to numerous facilities manufacturing conventional airplanes, today the majority of growth in the industry lies in drone development and space-related technologies.

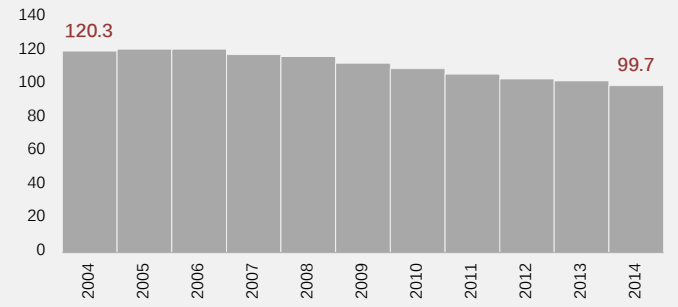
There are, however, many ongoing operations to support existing military aircraft, ranging from the F-16 to the F-35. Additionally, the recent award of the long-range strike bomber (LRSB) contract to Northrop Grumman will lead to significant increases in activity across the state.

While there is good news with the LRSB contract, other large aircraft manufacturing has declined in California. Lack of orders for Boeing's military cargo plane resulted in the recent closure of the C-17 plant in Long Beach—the last conventional airplane production plant, military or civilian, in the state. The final Boeing C-17 Globemaster III cargo plane built at the facility flew into the afternoon sun at the end of November in 2015.

The industry segments that remain and continue to grow are both high-tech and high-value, including space vehicles and components, unmanned aerial vehicles (UAVs) and cybersecurity—an industry which is not typically included in the aerospace industry but which is certainly adjacent to it.

Aerospace employment in California is less than half of what it was in 1990 due to the winding down of defense spending after the end of the Cold War. Declines have continued over the past decade but at a much slower rate. Nevertheless, a loss of employment does not imply a dying industry. Similar to other manufacturing industries, the aerospace industry has maintained sales while simultaneously experiencing significant declines in employment. This stems from innovation, advancements in technology, increases in productivity, efficiency and automation.

Aerospace Industry in California
Total Cluster Employment 2004 to 2014
(000s)



Source:s CMP; QCEW; Estimates by LAEDC

Southern California aerospace companies today include well-known major players, such as Northrop Grumman Corporation, Boeing Company, Airbus, Lockheed Martin, UTC, General Atomics, Raytheon and others. These mainstays are increasingly supplemented by a significant number of second- and third-tier suppliers, as well as entrepreneurs and start-ups. Often these firms produce parts and auxiliary products for myriad industries. In these cases, they may not be classified as aerospace firms this is not their primary activity (although they will be in the industry's supply chain). This may lead to an understatement of direct industry cluster employment. The very structure of the industry has changed over time, and more of it may reside in non-aerospace industries, such as communications equipment, software services, and computer and electronic equipment.

Deep Defense Roots

In addition to the private aerospace industry, there is a significant amount of federal civilian employment in California. In 2014, the number of federal civilian employees across four branches of military (Air Force, Army, Department of Defense and Navy) reached nearly 60,000 employees. Southern California itself is home to 19 military bases, seven of which have airfield, space or missile operations (Exhibit A-3 in the Appendix). Military bases where vital aerospace-related activity occurs in region include Edwards AFB, SPAWAR, SSC Pacific, Los Angeles AFB and Naval Base Ventura County.

Edwards Air Force Base quarters NASA's Armstrong Flight Research Center (formerly Dryden), NASA's primary center for atmospheric flight research and operations. Additionally, the commercial aerospace industry conducts many test activities here. The Los Angeles Air Force Base is a non-flying AFB that houses and provides support to the Air Force Space Command's Space and Missile Systems Center (SMC) headquarters, which manages research, development and acquisition of military space systems.

Los Angeles Air Force Base, located in El Segundo, is the U.S. Air Force's space acquisition center of excellence for developing military space systems. It is the only active duty installation in Los Angeles County and the headquarters for Air Force Space Command's Space and Missile Systems Center (SMC). SMC is credited with the development, production and maintenance of the space-based fleet of Global Positioning System (GPS) satellites and their associated ground control equipment and end-user technologies. GPS is widely recognized as the gold standard in providing critical capabilities to military, civil and commercial users around the globe. Operated by Air Force Space Command, the GPS constellation provides precise positioning, navigation and timing services worldwide as a free utility to the world. It is freely accessible to anyone with a GPS receiver.

SMC's portfolio also includes defense meteorological satellites, space launch and range systems, satellite control networks, space-based infrared systems and space situational awareness capabilities. SMC is tasked with the delivery of resilient and cost-conscious space capabilities and is involved in on-orbit check-out, testing, sustainment and maintenance of military satellite constellations and other DoD space systems.

Naval Base Ventura County is home to the Naval Satellite Operations Center (NAVSOC), responsible for controlling and maintaining the Navy's fleet of communications satellites. The Navy proposed to base four of the Northrop Grumman MQ-4C Triton UAVs here in 2020, which would require an investment of $74.3 million in construction and an additional 700 personnel in support and operation roles.

Space and Naval Warfare Systems Command (SPAWAR), located in San Diego, is responsible for assuring information dominance for the U.S. Navy. As such, SPAWAR develops, delivers and sustains communications and information capabilities for warfighters, keeping them connected anytime, anywhere. With a space support activity, two system centers and through partnerships with three program executive offices, SPAWAR provides the hardware and software needed to execute Navy missions.

SPAWAR Systems Center (SSC) Pacific is the U.S. Navy's leading research, development, test and evaluation (RDT&E) laboratory for command, control, communications, computers, intelligence, surveillance and reconnaissance (C4ISR). SSC Pacific is promoting the Navy's adoption of next generation UAS, big data management, antenna design, clean and renewable energy sources, and offense and defensive cyber programs. The Center collaborates with government entities, private industry and academia.

Four Southern California counties—Los Angeles, Orange, San Diego and Ventura—have been designated an Advanced Manufacturing Partnership (AMP SoCal), a designation that provides preferential access to $1.3 billion in federal funding, focused on aerospace, defense and related innovative manufacturing industries.

California is home to three NASA Field Centers: Jet Propulsion Laboratory (JPL), Armstrong Flight Research Center, and Ames Research Center.

Unmanned aerial vehicles (UAVs) are the focus of much contemporary research and development in California. Northrop Grumman, one of the military's largest sources of advanced UAV technologies, has a Center of Excellence in San Diego. These operations are responsible for the research and development and support for all of Northrop's unmanned platforms, ranging from the Global Hawk to the UCAS. General Atomics manufactures and develops the Predator and Reaper UAVs in Poway.

These platforms have seen extensive use around the world and remain a critical asset for the U.S. military. It still remains to be seen what role both Northrop Grumman and General Atomics will play in the commercial UAV market. With their extensive flight experience, both are well situated to capitalize on what should be dramatic growth in the commercial industry once the FAA releases their guidelines for UAS integration into the national airspace later in 2016.

While California has one of the strongest UAS industries in the nation, the state took a significant hit when it failed to secure designation as one of the Federal Aviation Administration's (FAA) six test sites for unmanned aircraft. If aerospace companies choose to site their operations in close proximity to these test sites instead of in California, the state risks losing its leadership role in this industry.

Today's Space Race

The region's historical role in space-related endeavors is significant. Southern California's JPL designed and built the Explorer I, the first satellite launched into space, the Apollo command module, and NASA's Surveyor lunar landers (which remain on the moon's surface). Each of the five space shuttles were assembled in Palmdale.

Space commercialization encapsulates an expansive variety of technologies, goods, and services. From smart phone navigation software to the proposed lunar exploration by Space Adventures, the variation in space-based technologies seems vast. It brings together scientists, innovators and businessmen alike. This is becoming the modern day Space Race and is being fueled by private sector investment.

Currently, California's SpaceX is competing with Virgin Galactic in an attempt to launch a constellation of microsatellites which will provide affordable internet access across the globe. The Virginia-based space tourism company, Space Adventures, has completed eight successful missions, launching seven high-paying tourists into space, some even visiting the International Space Station (ISS). Proposed offerings include spacewalks, circumlunar missions and cosmonaut training.

ViaSat embodies the change and convergence occurring across the industry. Once a primary defense contractor, ViaSat has diversified its product lines to include commercial satellite broadband and other services, reducing their dependence on federal funding and innovating new products and services on a variety of platforms. Their planned launch of ViaSat II will bring forth an entirely new threshold of connectivity.

In February 2015, Virgin Galactic announced plans to establish its new facility in the City of Long Beach. The company has leased a 150,000-square foot structure adjacent to the Long Beach Airport where an estimated 100 employees (engineers and otherwise) will develop and manufacture LauncherOne, a rocket designed to launch small satellites into orbit. The roughly 50 employees already working on this new launch vehicle in Mojave will be a part of the new operations in Long Beach.

Virgin Galactic is reaching towards its goal of becoming the first to offer private space tourism. They enjoyed success in 2012 when their suborbital plane, the VSS Enterprise, made its first manned glide flight. While this craft crashed in 2014, its replacement, the Virgin Spaceship Unity, has been unveiled. The passenger ship will be carried on the back of the WhiteKnightTwo produced by The SpaceShipCompany (a wholly-owned subsidiary of Virgin Galactic), The SpaceShipCompany facilities are located in Mojave.

SpaceX is located in the City of Hawthorne. The company is currently focused on three major projects: Dragon, Falcon 9 and Falcon Heavy. Dragon was the first commercially-made spacecraft to visit the International Space Station (in 2012) and it has made three additional trips transporting cargo for NASA to and from ISS. Human ridership was always intended, and the company continues to work towards that end, with its first manned test flight slated to take place in two to three years time. The Falcon 9 is a two-stage rocket developed to transport the Dragon spacecraft into orbit. Falcon Heavy is a powerful rocket designed to lift large payloads (117,000 lbs/ 53 metric tons) into orbit. With the ability to lift two times the mass as the Delta IV Heavy (the next largest operational rocket) its building costs total one third of that for the Delta making it a strong competitor.

NASA Armstrong Flight Research Center is an aeronautical research center and flight-testing facility located at Edwards Air Force Base charged with research and development and the testing of advanced aeronautics and space-related technologies essential to space exploration, space operations, scientific discovery and aeronautical research and development. Additionally, the Center operates a small fleet of highly-specialized manned and unmanned aircraft that conduct a wide variety of earth science missions, and manages the flight operations of the Stratospheric Observatory for Infrared Astronomy (SOFIA) program in partnership with NASA's Ames Research Center and the German Aerospace Center.

California's Vandenberg Air Force Base is the space and missile-testing base for the Department of Defense, launching unmanned government and commercial satellites into polar orbit using expendable rocket boosters such as Pegasus, Taurus, Minotaur, Atlas V, Delta IV and SpaceX's Falcon. The AFB leases launch pad facilities to SpaceX and roughly 100 acres to California Spaceport, a commercially-run Satellite Processing facility and Space Launch facility. Vandenberg's proximity to Southern California has truly enabled the emergence of the space vehicles industry in the region.

Space Flights Launched in 2014
Vandenberg Air Force Base

Date	Rocket	Payload	Operator	Function	Launch Service Provider
Apr 3	Atlas V 401	Defense Meteorological Satellite Program (DMSP)	US Air Force/ NOAA	Meteorology	ULA
June 22	Ground Based Interceptor		MDA	ABM Test	MDA
July 2	Delta II	OCO-2	NASA	Climatology	ULA
Aug 13	Atlas V 401	WorldView-3	Digital Globe	Earth Imaging	ULA
Dec 13	Atlas V 541	NRO L-35	NRO	ELINT	ULA

Source: Vandenberg Air Force Base, Media Center

Jet Propulsion Laboratory (JPL) is a federally-funded research and development center whose operation is managed by the California Institute of Technology (Caltech) for NASA. JPL is tasked with the construction and operation of robotic planetary spacecraft, and the conducting and management of earth-orbit and astronomy missions. The work done at JPL's campus in La Canada Flintridge has been integral to major advancements in aerospace, including, among many others, the Mariner missions to Mercury, Venus and Mars, the Mars Viking orbiters, solar system exploration missions, the Cassini-Huygens mission to Saturn

Aerospace Accelerators

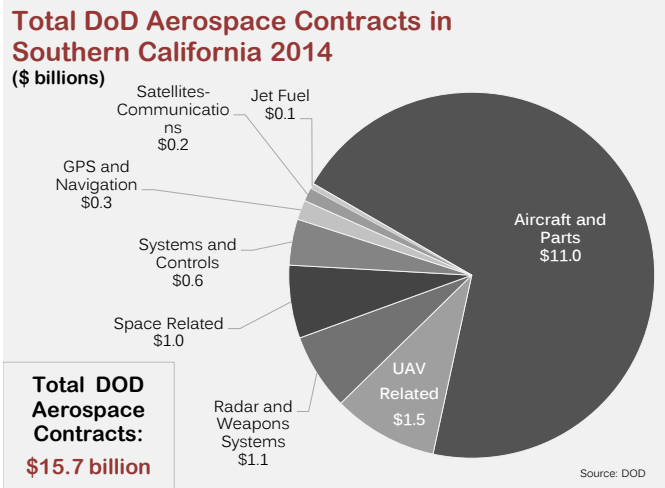
In this environment, a welcome market innovation has been the introduction of aerospace accelerators that provide newly-established firms the network and access to capital needed to survive their transition from market entry to positive cash flow from sales.

One such aerospace accelerator, Starburst Accelerator, has set its roots in Los Angeles County in the City of El Segundo. Already a prominent aerospace innovation organization in Europe, here the program hopes to connect aerospace startups with larger corporations so they may engage and work with these industry leaders and additionally provide access to seed funding via venture capital investors and angel investors.

Emerging technologies in the aerospace industry include unmanned aerial systems (UAS), and aerospace-focused robotics, smart sensors, materials and composites, nanotechnology, artificial intelligence and more.

DOD Contracts

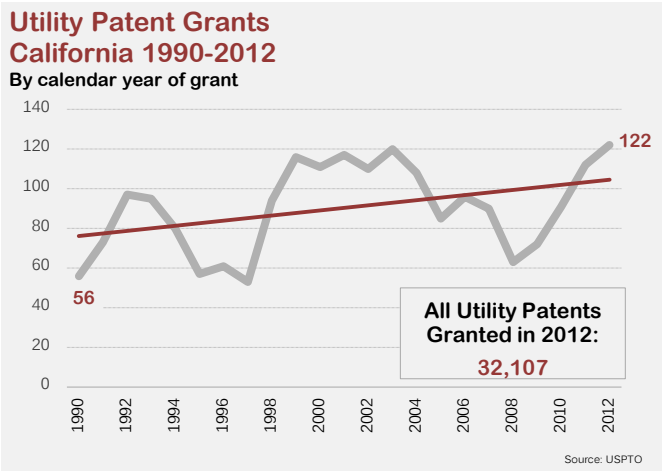
The Department of Defense (DoD) awards contracts to private businesses to perform specialized work. In 2014, the DoD awarded 120 aerospace-related contracts valued at $15.7 billion to firms located in Southern California. These contracts include work on, or the provision of, aircraft and parts, jet fuel contracts, radar and weapons systems, GPS (global positioning systems) and navigation, systems and controls, satellites (launched for communication and other purposes), space-related technologies, and unmanned aerial vehicles (UAVs) or drones. Firms awarded contracts in the Southern California region include The Aerospace Corporation, Boeing Company, General Atomics, Northrop Grumman Corporation and Raytheon Company.



Utility Patents

The U.S. Patent and Trademark Office (USPTO) issues utility patents as a means to protect the owner by preventing others from making, using or selling their invention for a specified period of time—either 17 years or 20 years depending upon filing date—but in some instances the term can be extended. Utility patents have accounted for approximately 90 percent of all patents issued by the USPTO in recent years.

Utility patents granted in California for Aerospace Products and Parts (NAICS 3364) from 1990 to 2012 (the most recent year for which data is available) and its trend line are shown here. There were 122 utility patents granted to firms in this industry in 2012, representing 0.4 percent of all utility patents issued that year. While the number of patents granted has fluctuated over the years, the overall trend shows an increase in the number of aerospace product and parts patents granted. Note that this does not include patents issued for instrumentation. While this is a large and important segment of the overall aerospace industry cluster, and one that is likely to be undergoing significant transformation itself, patent data is not available at the level needed to isolate instrumentation from the larger industry of computer and electronic products.



Sizing Things Up

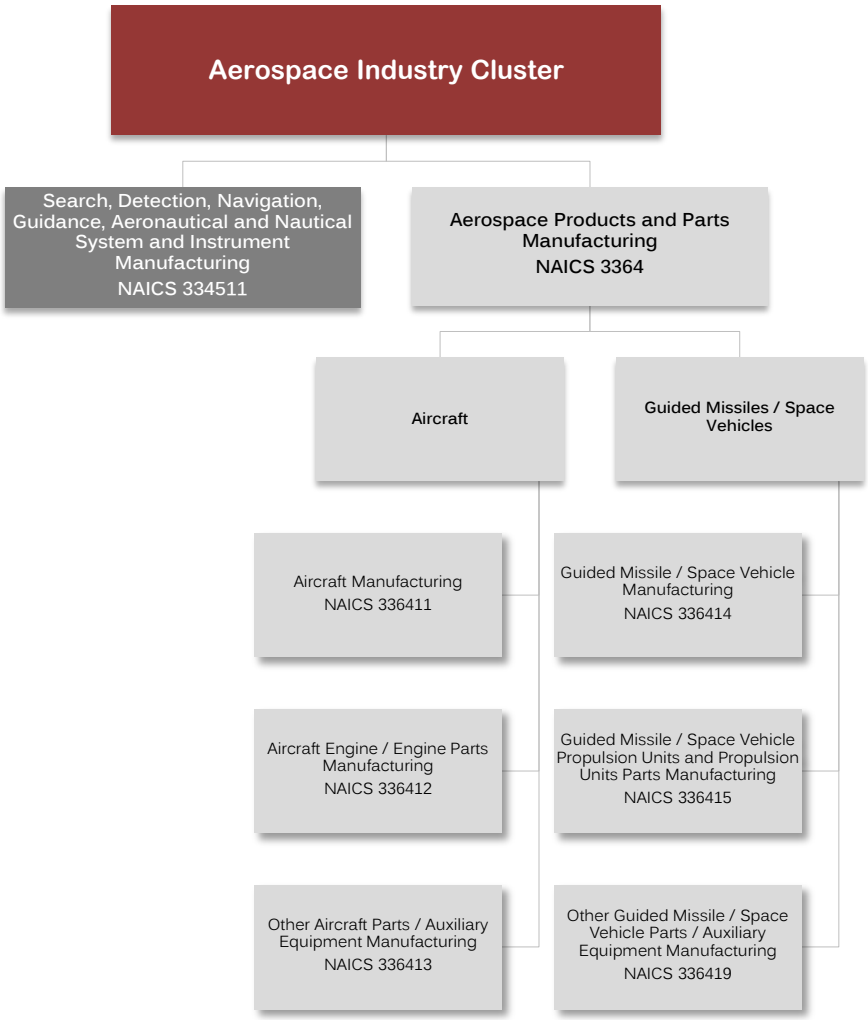
The industry cluster defined.

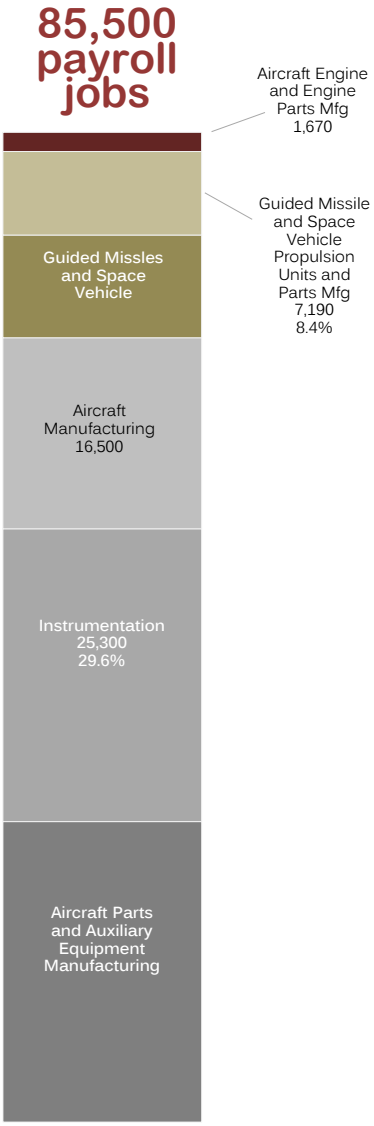
Southern California maintains a large base of aerospace manufacturing, research and design capabilities and strengths. In this section, the cluster will be quantified in terms of current and historical employment, establishments and wages by industry at the regional level for eight counties in Southern California (Imperial, Kern, Los Angeles, Orange, Riverside, San Bernardino, San Diego and Ventura). Current employment will be compared to other regions to illustrate regional specialization. There will also be an assessment of emerging industries within the larger aerospace industry, such as cyber security, unmanned aerial systems, and space commercialization. In this section, we take a systematic approach to measuring the industry by viewing it from its supply side – what is this industry comprised of?

There are many definitions of "Aerospace and Defense." We adopt the definitions produced by the Cluster Mapping Project (CMP) developed by the Harvard Business School (please refer to the Appendix for details). Using a standardized definition allows consistency over regions and time and permits a more nuanced and informed examination. This particular taxonomy provides a distinction between traded clusters (those which produce goods and services that are likely to be traded with markets outside the local economic region) and local clusters that produce goods and services for the local population. (Exhibit A-1 and A-2 in the Appendix provide complete listings of traded and local industry clusters in California.)

The distinction is important from an economic development perspective as we focus on those industries that are most likely to be the source of new money into the regional economy rather than recirculating existing funds.

In this report, we use the nomenclature "Aerospace" for simplicity. Note that the definition and data provided refers only to private sector economic activity. This certainly undercounts the size of the ecosystem, on which we comment throughout the report.





The aerospace industry cluster includes aerospace product and parts manufacturing (NAICS 3364) and search, detection, navigation, guidance, aeronautical, and nautical system and instrument manufacturing (NAICS 334511).

Aerospace product and parts manufacturing is broadly divided into two branches: aircraft and guided missiles and space vehicles. Aircraft includes aircraft manufacturing, aircraft engine and engine parts manufacturing, other aircraft parts and auxiliary equipment manufacturing. Guided missiles and space vehicles includes guided missile and space vehicle manufacturing, guided missile and space vehicle propulsion unit and propulsion unit parts manufacturing and other guided missile and space vehicle parts and auxiliary equipment manufacturing.

Search, detection, navigation, guidance, aeronautical, and nautical system and instrument manufacturing includes products such as aircraft instruments, flight recorders, navigational instruments and systems, radar systems and equipment, and sonar systems and equipment. This industry is referred throughout this report as "Instrumentation."

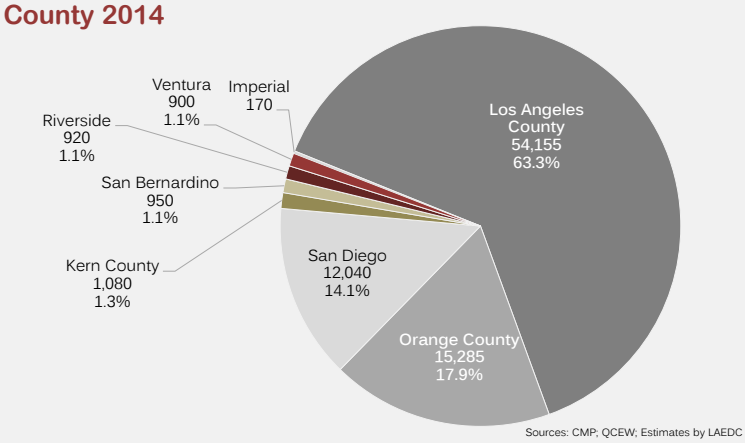
Related industries that are *not included* in this definition include transportation services, such as passenger air services and freight service, research and development, and the manufacturing of communications space satellites and their equipment. These industries are included in other industry clusters, and many of them may be included in the industry's supply chain. Additionally, government-funded launching and operation of space flights and satellites are excluded, as cluster definitions only include private industry. The employment estimates also exclude public employees, including those at JPL, for instance, and NASA's Armstrong Flight Research Center. If these were included, direct aerospace employment would exceed 100,000 in Southern California.

Detailed descriptions of the component industries of the aerospace industry cluster are provided in the Appendix.

Industry Employment

Using this definition, the aerospace industry cluster employed 85,500 payroll workers in the eight-county Southern California region in 2014, accounting for more than 85 percent of all aerospace employment in California. The three largest component industries account for nearly 80 percent of total cluster employment. Approximately 31 percent, or 25,960 jobs, were in aircraft parts and auxiliary equipment manufacturing; just over 29 percent, 25,300 jobs, were in search, detection, navigation, guidance, aeronautical and nautical system and instrument manufacturing; and 19 percent of total cluster employment, 16,500 jobs, were in aircraft manufacturing.

Industry Cluster Payroll Employment by County 2014



Sources: CMP; QCEW; Estimates by LAEDC

As a share of all employment, the aerospace industry cluster accounted for one percent of all payroll employment in the region in 2014.

More than 63 percent of industry employment in Southern California is in Los Angeles County, with 17.9 percent in Orange County and 14.1 percent in San Diego County.

Total employment in the cluster has declined continuously since 2006, with an annual growth rate of -1.8 percent per year.

Over the ten-year period from 2004 to 2014, total payroll employment across all industries in the Southern California region increased by 4.5 percent, while employment in the aerospace industry cluster fell by 16.4 percent.

Despite the overall decline, there is still hope for the cluster. Guided missiles, space vehicles and parts manufacturing employment has grown by 64.4 percent, adding 6,300 jobs in the Southern California region between 2004 and 2014, and employment in the manufacture of aircraft parts (not engines) and auxiliary equipment industries has grown by 24.4 percent over 2004, adding an additional 5,100 jobs. Instrumentation manufacturing and the manufacture of aircraft, aircraft engines and engine parts accounted for the negative job growth in the cluster.

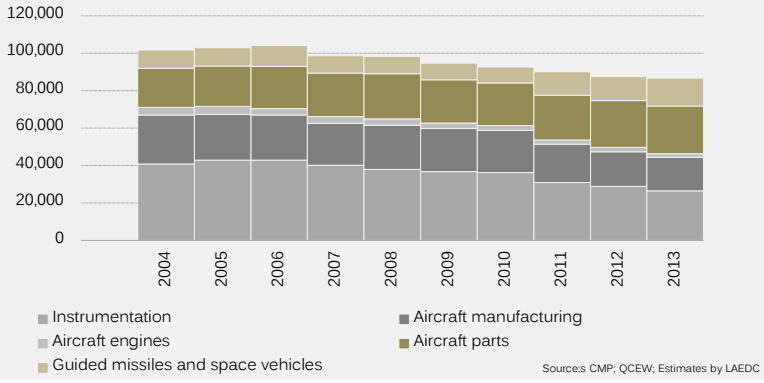
Aircraft manufacturing and the manufacturing of aircraft engines and engine parts combined have experienced steady and deep declines in their employment level over the period, as has instrumentation; each segment has declined by 40 percent since 2004. Aircraft parts (not engine) and auxiliary equipment manufacturing has shown a consistent and relatively steady rate of growth over the period, even through the Great Recession; employment in 2014 is 24 percent higher than 2004.

While industry employment overall has fallen in Southern California, San Diego County has seen an increase of 66.7 percent over 2004, adding 4,820 jobs. Approximately sixty percent of this was job growth in instrumentation, while 39 percent was in aircraft parts manufacturing.

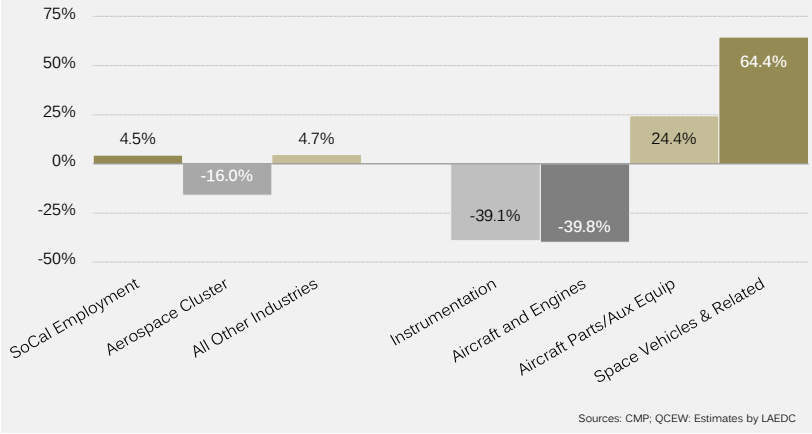
During this same period, Los Angeles County experienced a loss of 12,540 jobs, a decline of 21.2 percent over 2004. In spite of this overall loss, the county added 7,130 jobs in guided missile and space vehicle manufacturing, reflecting the growth of this industry in the region.

The 26.8 percent decline in aerospace employment in Orange County, a loss of 5,610 jobs, was entirely due to the loss of instrumentation jobs.

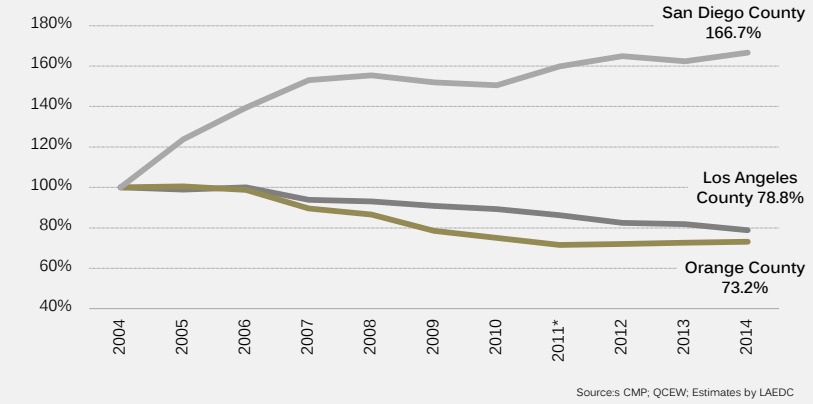
Aerospace Industry Payroll Employment By Component Industry 2004 to 2014



Change in Aerospace Industry Payroll Employment Growth Since 2004



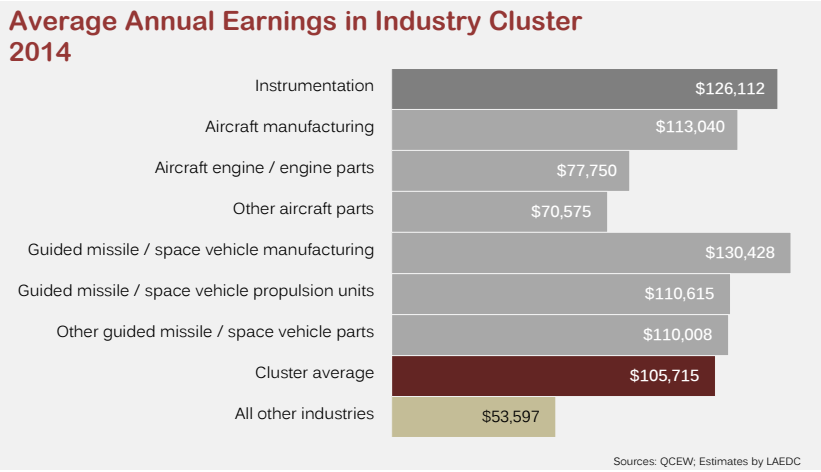
Employment Growth in Aerospace Cluster By County Since 2004

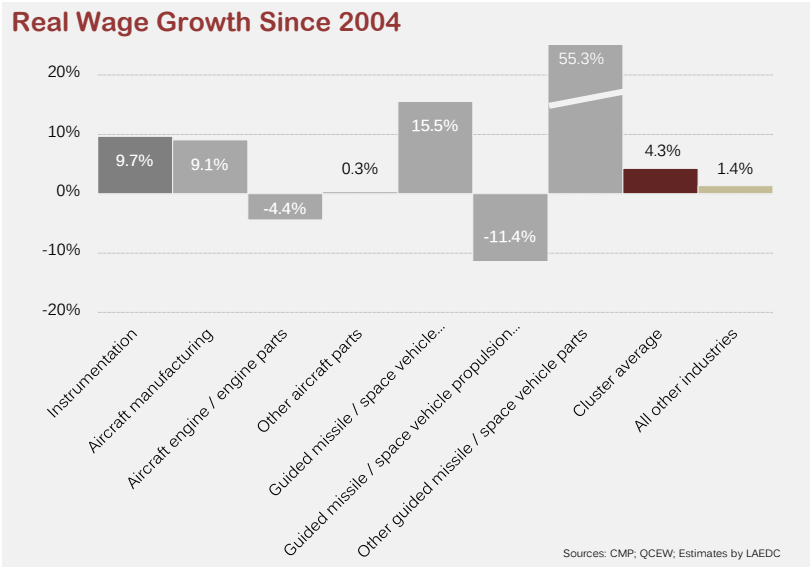


Wages in the Aerospace Industry

Aerospace employees earn a range of wages, but these are among the highest-paid employees in the regional economy. Overall, the average annual wage earned by in all other industries was $53,597 in 2014.

The range across component industries varies as well, from a low of $70,575 average paid in the industry classified as other aircraft parts to a high of $130,428 paid to employees in the guided missile and space vehicle manufacturing industry. These average wages are the result of the combination of different types of workers in the industry, such as, for example, aerospace engineers (who may be highly-compensated), production workers (whose earnings may be mid-range) and administrative workers (whose earnings may be lower on the pay scale). This will be illustrated below as the occupational distribution of the industry cluster is discussed.





Wage growth over the past ten years has been dismal. Inflation-adjusted wages in the Southern California region increased by 1.2 percent – equivalent to an annual average growth rate of a mere 0.1 percent.

In contrast, wages in the aerospace industry cluster grew by 4.3 percent overall, an annual average growth rate of 0.4 percent, or four times the overall growth rate.

Wage growth has been fastest in the guided missile and space vehicle parts industry, experiencing an increase of 55.3 percent between 2004 and 2014.

At the other extreme, wages in the guided missile and space vehicle propulsion industry has fallen by 11.4 percent (in real terms) over the period. As seen above, this is a very small subsector of the overall industry cluster.

The combination of employment growth and wage growth in the other guided missile and space vehicle parts industry implies that this industry is growing and is paying a premium to secure the highly-skilled workforce it needs, competing with other subsectors of the industry.

Overall, it is clear that the space vehicle industry segments are growing and paying increasingly higher wages, while the industries associated with aircraft engines and parts are slowing. This is a harbinger of the future direction of the industry in Southern California.

Competitiveness and Regional Advantage

A region's competitiveness in an industry is a function of many factors, including the attractiveness and value of the product itself, the costs of inputs such as labor and energy, the productive capabilities of individual companies, and the geographic concentration of the industry. Industries that are highly-concentrated in a region are likely to be more competitive. Clear examples would include entertainment in Los Angeles and communication equipment in Orange County as industries with regional strengths because there is a clustering of firms and workers in these industries that enable them to be more specialized, more nimble, and hence more competitive.

A common metric to capture competitiveness is *employment concentration* or *location quotients*. A location quotient for an industry in Southern California shows the percentage of total employment in the industry compared to the average percentage nationwide. For example, if 4 percent of employment in the region is in the motion picture industry compared to 2 percent across the nation, the location quotient for the motion picture industry in Southern California is 2, indicating that Southern California is relatively more specialized in motion pictures.

Similarly, a location quotient equal to one indicates that the employment concentration in Southern California is equal to that elsewhere, meaning the region is not highly-specialized in that industry. Higher location quotients imply a competitive advantage. While there is some variation in this metric, it is thought that the threshold to demonstrate regional specialization (and competitiveness) is a location quotient of at least 1.2.

Using this threshold, it appears that the aerospace industry cluster as a whole continues to be relatively competitive in the Southern California region, with a location quotient of 2.14.

Southern California is gaining competitive strength and becoming a leading powerhouse in guided missile and spacecraft related industries.

Location quotients of the component industries in the industry are consistent with the findings related to employment and real wage growth. Those industries associated with guided missiles and space vehicles are especially strong and competitive—and their competitiveness has grown significantly over the past ten years—while industries related to aircraft are slowing and losing competitive strength.

The region maintains a significant competitive strength in instrumentation, but this too has declined since 2004, raising concerns that other regions are building capacity and may threaten the success of this industry in the future.

It is important to remember that the location quotient as used here reflects *employment levels*, and not the value of product produced or sold. It is certainly true that this industry, as all other manufacturing industries, has become more efficient in terms of labor productivity. A declining employment location quotient may indicate a decline in the competitive strength gained from employment clustering or an innovation in production processes that are less labor-intensive than in other regions, and which have become more productive than other regional industries.

Location Quotients of Aerospace Industries

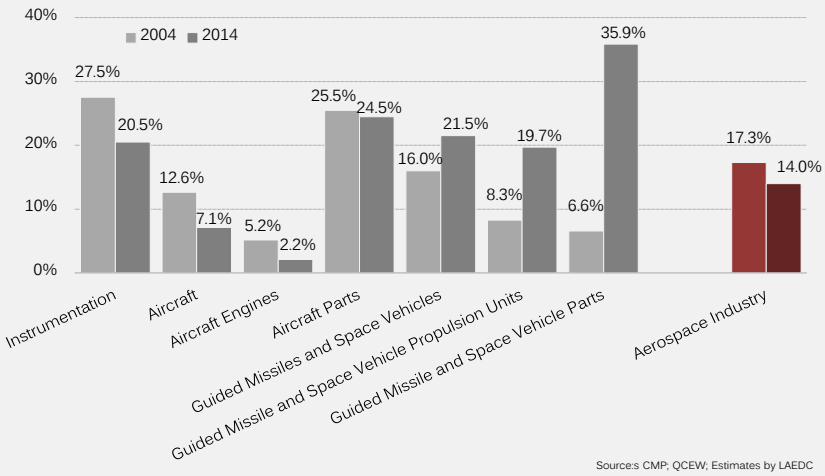
Component Industry	Location Quotient 2014	Change Since 2004
Search, detection, navigation, guidance, aeronautical and nautical system and instrument manufacturing	3.13	↓
Aircraft:		
Aircraft manufacturing	1.09	↓
Aircraft engine and engine parts manufacturing	0.33	↓
Other aircraft parts and auxiliary equipment manufacturing	3.74	↓
Subcluster	*1.62*	↓
Guided missiles and space vehicles:		
Guided missile and space vehicle manufacturing	2.47	↑↑
Guided missile and space vehicle propulsion unit and propulsion unit parts manufacturing	7.58	↑↑
Other guided missile and space vehicle parts and auxiliary equipment manufacturing	5.49	↑↑
Subcluster	*3.45*	↑
TOTAL	**2.14**	↓

Sources: CMP; QCEW; Estimates by LAEDC

While employment has declined in several component industries of the aerospace cluster, the change in the location quotient provided some insight into the *relative strength* of the industry compared to the national average. It could be that employment has fallen in the industry everywhere, and the decline in Southern California employment is simply a reflection of the industry's labor intensity.

Southern California Aerospace Employment Share of National Employment by Component Industry

2004 and 2014

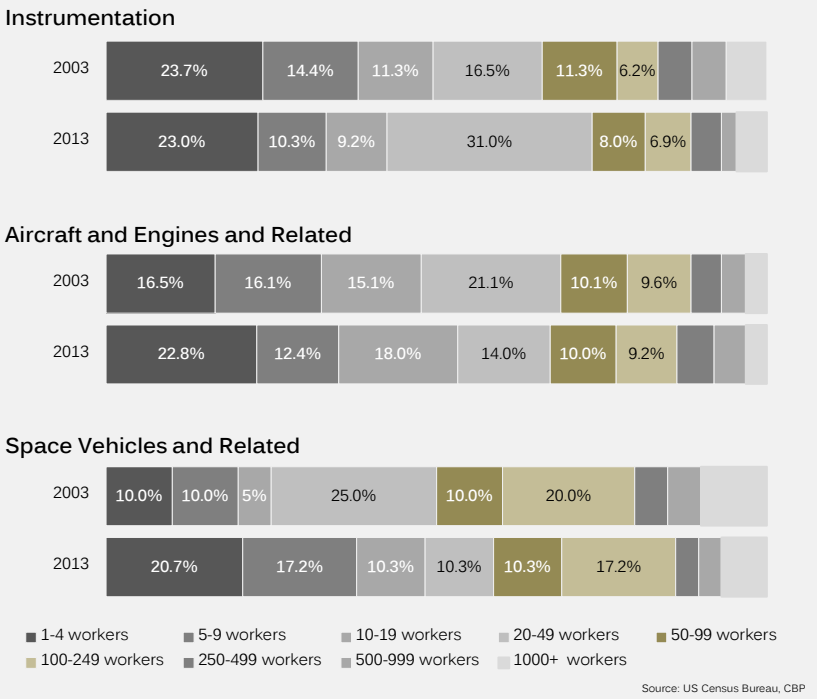


Source:s CMP; QCEW; Estimates by LAEDC

The change in the region's share of national employment is quite surprising. Overall, Southern California accounted for 17.3 percent of all employment in the industry nationwide in 2004. This share declined to 14.0 percent by 2014, indicating a movement of employment to other regions.

A closer examination, however, reveals that the region is pivoting to guided missiles and space vehicles and their related industries. In 2004, employment in guided missiles and space vehicle propulsion units accounted for 8.3 percent of national employment; by 2014, Southern California firms in this component industry accounted for almost 20 percent all employment across the nation. Similarly, the region's employment share in missile and space vehicle parts grew from 6.6 percent in 2004 to 35.9 percent in 2014. The importance of Southern California in manufacturing of these products is undeniable.

Distribution of Firms by Employment Size Southern California Region 2003 to 2013



Source: US Census Bureau, CBP

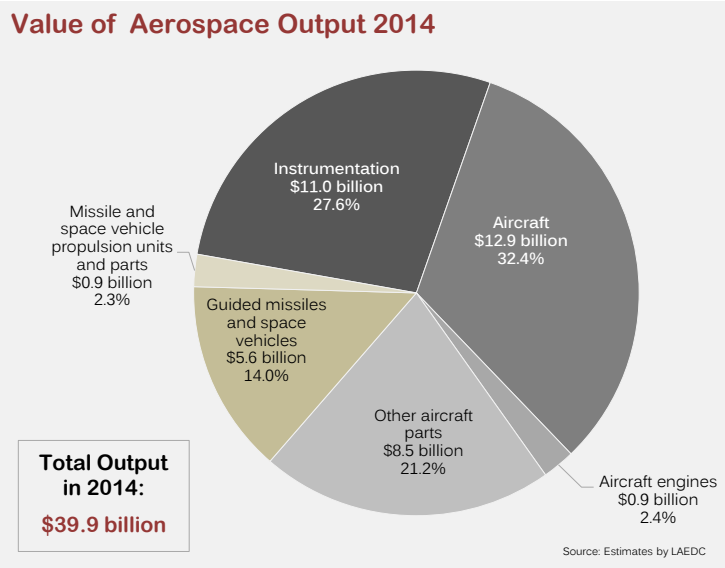
Employment growth in these industries is facilitated by startups and small firms. Small firms with less than 5 employees accounted for 10 percent of all firms in the guided missile and space vehicle related component industries in 2003. This share grew to almost 21 percent by 2013 (the latest year for which data is available). Firms with between 5 and ten employees grew from 10 percent of all firms in this industry segment to 17.2 percent. Although smaller firms are also gaining strength in the aircraft industry segment, the change is not quite as striking, and does not appear at all in the instrumentation industry segment.

This remarkable increase in the representation of small firms is a clear sign that the industry segment in Southern California is innovating quickly as new firms start out small. While the segment is relatively small, it is growing quickly and gaining competitive strength.

Industry Output by Product

Gross output is the value of the industry's production—generally, its revenues. This includes the value of aerospace-related intermediate goods (which are, to some extent, the regional intermediate purchases of others in the industry) and final goods that are sold to end user customers (including governments). In 2014, the value of all products shipped by the aerospace industry in Southern California was $39.9 billion.

Of this, aircraft accounted for the most sales, reaching $12.9 billion, or almost one third of all output. Instrumentation accounted for $11 billion, or 27.5 percent of the total, while aircraft parts accounted for $8.5 billion. The value of production of guided missile and space vehicles and their related parts reached $6.5 billion in 2014.



Spreading the Wealth

Impacts of the aerospace industry are felt across the economy.

Aerospace impacts a broad spectrum of industries through its supply chain.

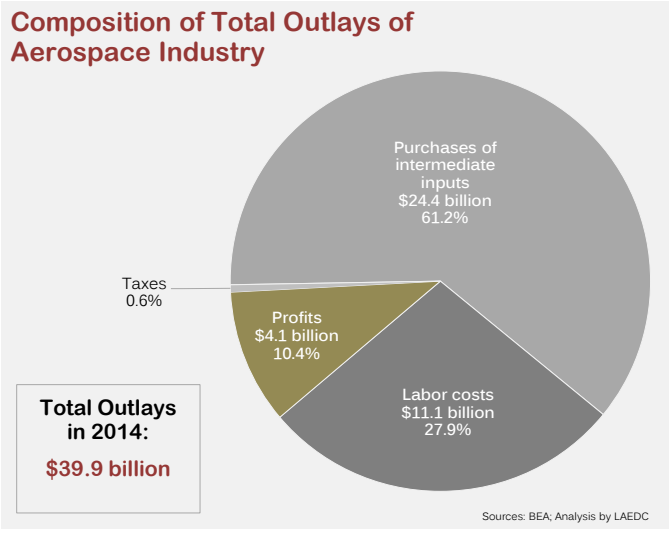
The extent to which an industry's impact extends to other sectors of the economy and into the hands of households depends in great measure on the share of the industry's value (i.e., revenues) that is recirculated within the region. The total economic contribution of the aerospace industry to the Southern California economy multiplies through its supply chain and payroll spending throughout the region, the impacts of which are examined here.

Where the Industry Spends Its Revenues

Firms generate revenues through sales of their products and services, and use those funds to purchase the inputs needed to produce the product, to pay their workers, to pay taxes on production and profits, and to generate a return on capital in the form of profits. Industries can vary substantially in the shares claimed by each of these components.

In 2014, the aerospace industry cluster spent $24.4 billion on intermediate inputs into production, accounting for 61.2 percent of all outlays. Labor payments reached $11.1 billion, accounting for 27.9 percent, and the industry distributed $4.1 billion in profits. Tax payments represent a very small percentage of all outlays.

The overall impact that an industry has on the broader regional economy depends upon the expenditures made within the economic region. In general, outlays for labor costs occur within the region, and households are supported by these earnings.



If most of the inputs used in production are purchased from local suppliers, those firms enjoy demand for their products and can increase their own hiring, supporting additional households in the region. If, on the other hand, most of the inputs are purchased elsewhere in the nation, then these purchases have no impact locally (other than perhaps in their transportation and storage) and the industry itself will generate fewer indirect effects.

Determining the source of inputs can be done through detailed surveys of firms, but this is often cost-prohibitive and is instead usually estimated using econometric techniques that take into account the region's ability to provide the needed inputs, regional price differences and the cost of transporting goods to and from other regions. Together, labor costs and regional purchases of intermediate inputs determine the spillover, or multiplier, impacts of the industry.

Economic Contribution of Aerospace Industry Cluster

The concept of economic contribution answers the question, "what contribution does this industry make to the regional economy?" and measures not only the direct activity but also indirect and induced activity. As outlined above, this contribution is dependent on the payments made to suppliers of intermediate goods and services in the region and payments made to workers, who usually live locally and spend most of their incomes on household purchases from local suppliers.

In addition to the 85,500 direct payroll jobs in the aerospace industry cluster, an additional 68,910 jobs were supported in 2014 through indirect effects of supply chain purchases that are not made within the industry cluster itself, and 92,090 jobs were supported through the household spending of employees in the industry cluster as well as its supply chain.

Labor income (which includes wages and benefits) earned by all aerospace- supported employment in Southern California reached $20.3 billion, accounting for approximately 2.7 percent of all labor income paid in the Southern California region in 2014.

Total Economic Contribution of Aerospace Industry Cluster (2014)

	Direct	Total	% of Southern California Total
Output ($ millions)	$ 39,900	$ 66,230	3.1
Employment (jobs)*	85,500	245,770	1.9
Labor Income ($ millions)	$ 11,120	$ 20,290	2.7
Value-Added ($ millions)	$ 15,480	$ 30,420	2.4

*Includes contingent workers

Source: Estimates by LAEDC

Together, the industry produced $30.4 billion in value-added, which accounted for 2.4 percent of the Southern California region's GDP.

The overall impacts are widely distributed across many sectors of the economy through indirect and induced effects, including in other manufacturing industries, real estate and rental and leasing, wholesale trade, professional and technical services, and administrative support and waste services. (See Exhibit A-4 in the Appendix for complete and detailed contribution by industry sector.)

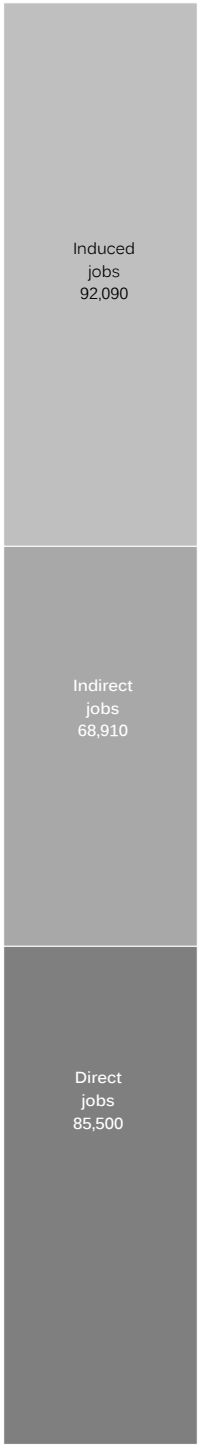
Total Fiscal Impacts by Type

	$ millions
By Type of Tax:	
Personal income taxes	$ 2,340
Social insurance	2,330
Sales and excise taxes	740
Property taxes	530
Corporate profits taxes	760
Other taxes	330
Total	**$ 7,030**
By Type of Government:	
Federal	$ 4,850
State	1,390
Counties	550
Cities	240
Total	**$ 7,030**

Source: Estimates by LAEDC

The total fiscal impact of the economic activity in 2014 attributable to the aerospace industry cluster, including direct, indirect and induced activity, exceeded $7.0 billion. This includes, for example, property taxes paid by firms and households, sales taxes on consumption purchases, personal and corporate income, and payroll taxes paid for and by employees.

245,770 total jobs



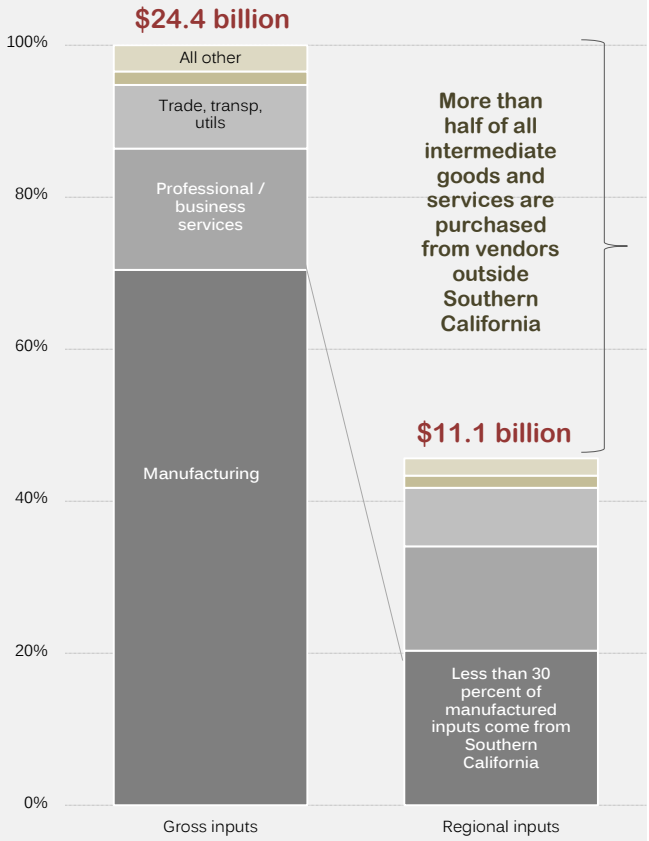
Supply Chain Analysis

The overall impact of the aerospace industry is largely due to its regional purchases.

The intermediate purchases of the aerospace and defense industry cluster comprise an important part of the overall economic contribution of the industry. It was shown above that these account for 61.2 percent of the industry outlays, or $24.4 billion in 2014.

Gross inputs are a combination of goods and services. In this industry, approximately 70 percent of intermediate goods are manufactured products, such as aircraft parts and supplies, computer products, metals, electronic components, plastic products and valves and fittings (see left panel in exhibit below). Professional and business services account for almost 16 percent of intermediate inputs. These include management services, advertising and public relations, employment services, banking and other business support services. Trade, transportation and utilities account for 8.4 percent of intermediate inputs, including such services as wholesale trade and truck transportation. The remaining 5.2 percent of inputs are provided by other industries. A complete list of gross and regional input purchases by industry sector is provided in Exhibit A-5, with a detailed list of the top 50 inputs by value in Exhibit A-6.

Aerospace Industry
Regional Provision of Intermediate Inputs



Source: Estimates by LAEDC

Regional Purchase Gap

The ability of a region to fill the demands of its industries speaks to the richness and diversity of the regional economy. Not all regions can effectively compete, or wish to compete, with suppliers of specific goods and services based elsewhere. Industries making purchases of goods elsewhere are clearly benefiting from lower costs, better quality or other advantages to importing intermediate goods rather than purchasing from local firms.

From an economic development perspective, it may be preferable, however, to develop deep and broad local supply chains in order to capture a larger share of industry purchases, especially those that can be economically supported within the region.

The percent of all inputs purchased regionally are shown in the right panel of the exhibit. In general, trade, transportation and utilities are purchased from regional suppliers. Firms in the aerospace industry cluster purchase more than 90 percent of these services from region suppliers. Similarly, the region is able to supply the industry with more than 85 percent of its needs for professional and business services.

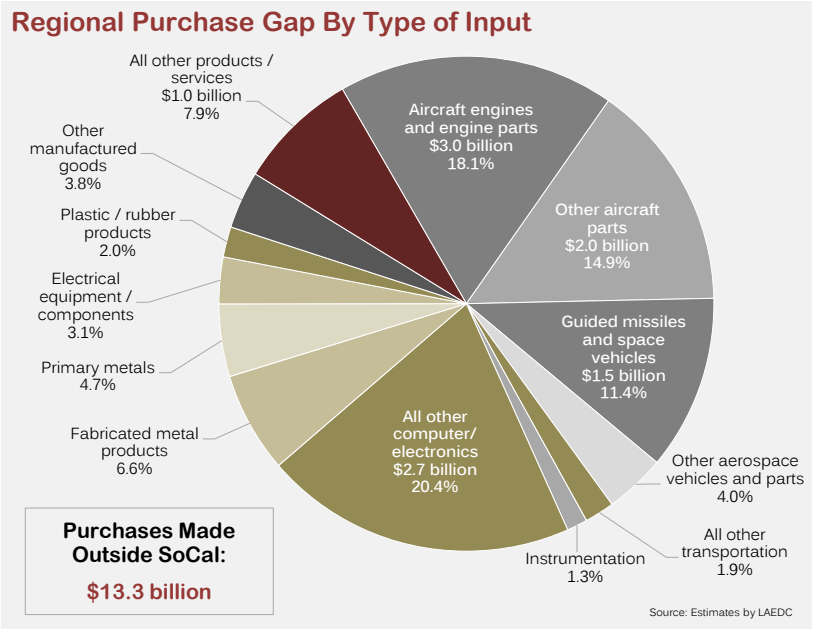
In contrast, less than 30 percent of the industry's purchases of manufactured goods occur in the Southern California region. Because this represents a significant share of the industry's intermediate inputs, the impact on the overall regional supply pipeline is devastating in the magnitude of this lost opportunity. In terms of value, the industry spends more than $13 billion with firms outside the Southern California region.

In this case, a closer examination of the gap between gross manufactured input purchases and regional supplies may inform regional leaders of lost opportunities that might be ripe

for recapture. These potential opportunities are highlighted in the exhibit at left.

Approximately half of the gap between gross inputs and regional supplies is of transportation equipment—mostly aerospace products. More detail of this gap is discussed below.

Almost 22 percent of the gap between gross and regional inputs is of computer and electronic components. As the Southern California region is not a big supplier of these products, it is understandable that they are purchased elsewhere.



Other products that account for most of the intermediate inputs purchased from outside the region are fabricated metal products (such as fasteners), primary metals (such as steel sheets, strips and wire), electrical equipment and components, plastic and rubber products and other manufactured goods. Only 7.9 percent of the gap between gross input purchases and regional supplies thereof are due to goods and services that are not manufactured goods, such as legal and financial services.

A closer look at transportation equipment purchases show that the aerospace industry is highly tradable. The industry spends more than $3.2 billion on aircraft parts and equipment purchased from other industry partners, but less than 40 percent of this is purchased from firms located in Southern California. It also spends $2.6 billion on aircraft engines and engine parts, of which less than 9 percent is purchased in the region.

The percentage of intermediate goods and services that an industry is able to purchase from local suppliers has a direct impact on its contribution to the region's economic activity. The higher that percentage, the larger the multiplying effects that its revenues will have.

Work, Work, Work

About the kinds of jobs that make this industry cluster successful.

More than 26 percent of jobs in the industry are in production occupations, and 22 percent are in engineering occupations.

The work that people do in their jobs is commonly classified using the Standard Occupational Classification (SOC) system, developed by the Bureau of Labor Statistics. Workers are classified into particular occupations with similar job duties, skills, education and training. In Southern California, there are approximately 650 detailed occupations represented in the workforce, which are not generally industry-specific but are common to many industries.

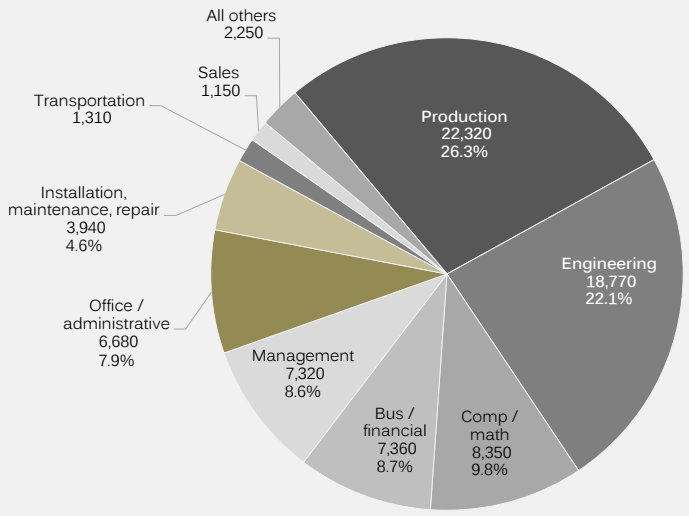
The aerospace industry cluster employs workers in occupations across the skills spectrum, but it is weighted towards workers engaged in production occupations and in engineering occupations. While some of these workers may be highly skilled, many others learn their occupational skills on-the-job and are less likely to need higher levels of education.

In total, there are almost 22,320 workers in production occupations, which include such roles as electrical assemblers, computer numerically-controlled (CNC) machine tool operators, machinists, inspectors and welders. Another 18,770 are engineers, mostly electrical engineers and industrial engineers, but also mechanical engineers, electronics engineers, electrical engineering technicians and aerospace engineers. Computer and math occupations for the most parts include mostly software developers, computer systems analysts, system administrators and support specialists, together accounting for almost 8,350 jobs. Business and financial occupations including accountants and auditors, market research analysts and business operations specialists accounted for more than 7,350 workers.

Exhibit A-7 in the Appendix lists the top 50 detailed occupations in the industry cluster by current employment.

Is the distribution of occupations in the aerospace industry in California similar to that across the nation? Is it typical for aerospace industries in other regions to hire more production workers than engineers, and more computer specialists than managers?

Major Occupational Groups in the Industry



Sources: Census Bureau, OES; Analysis by LAEDC

It might be reasonable to expect that California, reputedly a high-cost state, may specialize in work that requires higher compensation and would allow lower-cost regions to capture more of the manufacturing operations, at which California is less competitive.

To see whether this is true, it is helpful to compare the occupational distribution by major occupational group of the industry in California compared to the national average in 2014. This is shown at right.

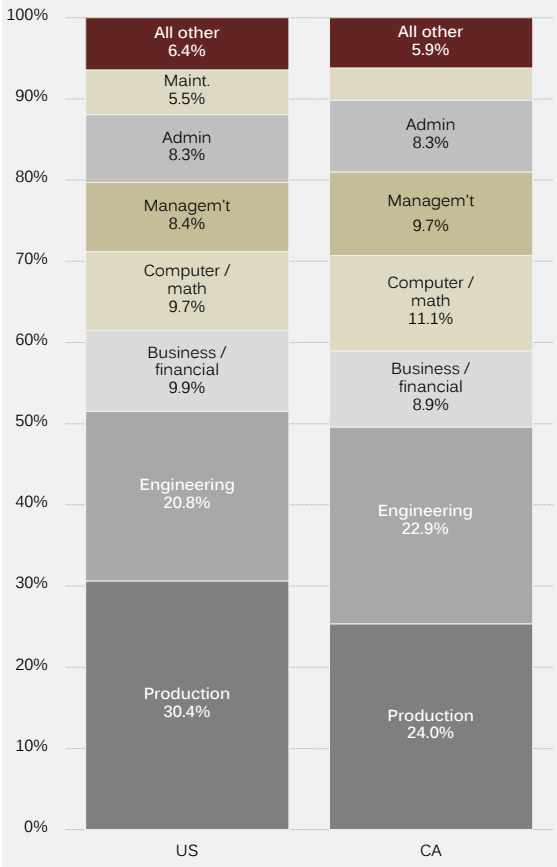
Several differences appear. California aerospace firms have a lower share of production workers and a higher share of engineers as a share of total employment. They also hire a higher percentage of computer and math workers, and more management than the national average. This would confirm that California's aerospace industry is more highly specialized in design and engineering than in production (and manufacturing). It can also suggest that manufacturing operations in California are more highly specialized.

Given the speed of technological progress in this industry and others, another area of inquiry would be to see how the occupational distribution of aerospace has changed over time. Consistent and comparable data is available at the national level for the past ten years and is shown below. (This data is not available at the state level.)

Interestingly, the occupation distribution within the industry has not significantly changed during the ten years. There is a slightly larger share of workers in production occupations and a slightly smaller share of engineering workers. The nature of the skills and education required in these various occupations may certainly have changed over the time period, however, so the occupational groups, although identically labeled may reflect workers with quite different knowledge, skills and abilities.

Occupational Distribution of Aerospace Industry

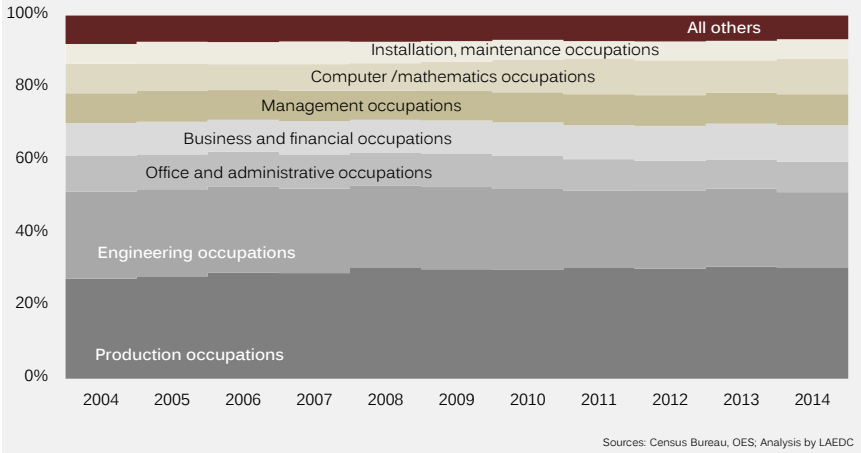
US vs CA 2014



Sources: Census Bureau, OES; Analysis by LAEDC

National Occupational Distribution in Aerospace

2004 to 2014



Sources: Census Bureau, OES; Analysis by LAEDC

Future Workforce Needs

Given the expected growth of the industry over the next five years, and assuming a fairly consistent composition of occupations within the industry, the skills needed over the next five years can be reasonably projected.

At its current projected rate of employment growth, industry employment is expected to grow slowly. In some areas of Southern California, employment in the cluster may continue its decline, in spite of the recent significant growth in space vehicles. That industry segment is still quite small in terms of employment hence the projected occupational needs are small.

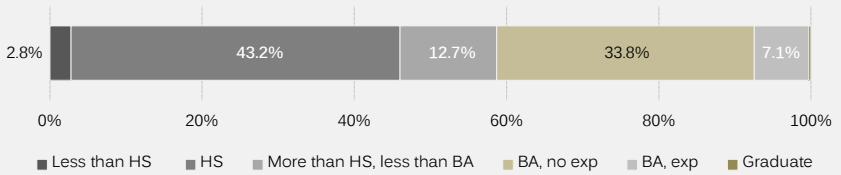
Many of the overall job openings expected over the next five years may be due to the retirement of existing workers rather than to new job openings being created. Replacement needs are estimated by the Census Bureau and depend on many factors, including the age profile of the existing workforce, and skills acquisition through on-the-job training (leading to promotion).

5 Year Aerospace Occupational Needs in Southern California by Major Occupational Group

SOC	Occupational Group	New Jobs	Replacement Jobs	Total Job Openings
11-0000	Management occupations	170	190	360
13-0000	Business and financial	240	210	450
15-0000	Computer and mathematical	260	210	470
17-0000	Engineering	520	910	1,440
19-0000	Life, physical, social science	5	5	10
27-0000	Arts, entertainment, sports and media	10	20	30
33-0000	Protective services	20	20	40
37-0000	Building/grounds maintenance	10	10	20
41-0000	Sales and related occupations	20	30	50
43-0000	Office and administrative	180	230	410
47-0000	Construction and extraction	20	10	30
49-0000	Installation, maintenance / repair	110	130	240
51-0000	Production	630	1,330	1,960
53-0000	Transportation / material moving	40	50	90
	All Others	*10*	*20*	*30*
		2,250	**3,380**	**5,630**

Sources: CMP, Census Bureau, OES; Estimates by LAEDC

Educational Requirements for Entry Level Positions



Source: Estimates by LAEDC

Overall, it is expected that 2,250 new job openings will be created in the industry in Southern California over the next five years. The industry will need an additional 3,380 replacement workers over the same period.

The highest number of openings will be found in occupations related to production, such as inspectors, assemblers, machinists and technicians. Engineering occupations will provide the second highest number of openings, with 520 new jobs created over the next five years and 910 jobs needing replacement workers. That the number of replacement workers is greater than the number of new jobs is an indication that the existing workforce is reaching retirement.

A full list of projected occupational openings is shown in Exhibit A-7 in the Appendix.

Of all openings over the next five years, more than forty percent will require a bachelor's degree or higher. These workers are likely to be employed in engineering occupations. Approximately 53 percent of openings will be available to workers with a high school diploma or some college or post-secondary education. These workers are likely to be employed in production occupations.

Preparing the Workforce

To retain and expand the industry, a need for a continuous supply of workers, ranging from low skilled to very high skilled, exists. Educational and training programs are highly valuable as they provide paths to careers in aerospace for all skill levels. Universities and community colleges, as well as trade and technical schools, have formed targeted programs aimed at reducing the time spent by new entrants in on-the-job training to create an occupation-ready workforce.

Programs include: targeted aerospace STEM education programs for middle and high school students; certificates of achievement for individuals looking to improve their skill set and/or start a new career in the industry; associate of science degrees and non-degree transfer programs; and bachelor of science, master's and Ph.D. programs for those looking to enter the industry as highly-skilled employees.

Many programs, certificates, non-degree transfer programs and college degrees are broadly applicable to positions outside the aerospace industry, while others feed directly into a career in the industry.

Industry-specific curriculum has been developed to provide individuals interested in pursuing careers in the aerospace industry with the knowledge and skills required to successfully perform their job duties. Included in these are:

- Aerospace and Mechanical Engineering
- Aviation Safety and Security Program
- Aeronautics
- Aircraft Fabrication and Assembly
- Astronautics
- Unmanned Systems
- Licensing and Certification

Exhibit A-8 in the Appendix lists all aerospace-related degree and certificate programs currently offered at regional colleges and universities. These are briefly described below.

STEM Education

Unlike educational programs discussed below that target adults, STEM education programs exist to engage youth so as to increase their interest in studying fields that include science, technology, engineering and mathematics.

The Aerospace Corporation is affiliated with several STEM programs in the region. The company is a federally-funded research and development center (FFRDC) that works with the U.S. Air Force and the National Reconnaissance Office to support space programs that involve national security. Its STEM programs include:

- Greater Los Angeles Education-Aerospace Partnership (Great-LEAP) program, which brings industry members into the classroom;
- US FIRST Robotics competitions, which sponsor King Drew and Crenshaw High Schools;
- Mentors are provided as part of the national Math Counts organization;
- Participation in Change the Equation initiative, which aims to cultivate literacy within STEM programs; and
- The Mathematics, Engineering, and Science Achievement (MESA) program, which works with disadvantaged students.

The Aerospace Corporation, headquartered in El Segundo, is an example of industry involvement in STEM programs in the region.

Certificate Programs

Wide varieties of certificate programs exist in the region to provide individuals with the opportunity to learn skills applicable in the aerospace industry, although many programs are broadly applicable to positions outside the industry. Examples include mechanical design, computer-aided manufacturing (CAM), computer numerical control (CNC), pre-engineering and machine technology. Those that feed directly into a career in the industry include the Aircraft Fabrication and Assembly Certificate program at Antelope Valley College in Los Angeles County.

Associate Degrees

Associate degrees can act as a bridge to further education by combining general education, theoretical and applied coursework, or they may focus more heavily on applied knowledge in the same way that a certificate would, with additional background in general education and theory. Non-degree transfer programs also exist, which set students on a direct path to a bachelor's degree by helping them fulfill necessary transfer requirements for their school or program of choice.

Associate degree and non-degree transfer programs are also either broadly applicable or industry specific. The flexibility of associate degrees gives students wider options as they can choose to enter a career or pursue further education. For those who wish to enter the workforce after receiving an associate degree, programs such as Embry-Riddle Aeronautical University's aeronautics associate of science degree program exists, whereas those students with an interest in higher education can pursue an associate degree in pre-engineering followed by a bachelor's degree in mechanical or aerospace engineering.

Bachelor's Degrees

Due to the complex nature of the industry, completing tasks requires multi-disciplinary teams of engineers and therefore there is a wide range of possible positions for the highly-skilled. Workers at this level need an extensive knowledge of mathematics and physics, as well as a strong familiarity with computer-aided design (CAD) and materials science.

Aerospace-related bachelor's degrees include aerospace engineering, mechanical engineering, materials science, industrial engineering, and so on. The latter years of such engineering programs tend to couple education with career training in the forms of internships, fellowships and part-time or full-time employment within the industry. Having this experience expedites entry into the workforce upon graduation.

Graduate Degrees

Education for industry goes well beyond the bachelor's degree level. The Southern California region hosts many related graduate and doctoral degree programs. Students at this level focus more heavily on the research that pushes the boundaries of modern technology and practices by envisioning creative solutions to industry-wide problems. Many state schools in the area offer at least one relevant master's degree, while larger research institutions such as University of California San Diego (UCSD), University of California Los Angeles (UCLA) and the University of Southern California (USC) offer multiple relevant doctoral programs. Overall, students advancing their education beyond that of a bachelor's degree are sure to enter the workforce at the top tiers of the industry.

Aerospace & Mechanical Engineering

Many four-year universities in the Southern California region offer aerospace, mechanical, or combined aerospace & mechanical engineering degrees. These are highly technical and require practical laboratory experience alongside theoretical science and mathematics courses. Almost 60 percent of aerospace engineers in the US have

bachelor's degrees and more than 30 percent have a master's degree, while more than 80 percent of mechanical engineers have bachelor's degrees and more than 10 percent have less than that. This is likely due to the amount of specialization required by the aerospace industry, as well as the larger number of mechanical engineers, yet the general foundation for each career is very similar. Undergraduate programs often prepare students for a career in the industry following graduation, with a heavier focus on applications over research, whereas graduate and Ph.D. programs concentrate more on advanced applications, theory and research.

The Aerospace & Mechanical Engineering bachelor's degree program at USC's Viterbi School of Engineering gives students a balance of theory and practical education. Undergraduates are given the opportunity to participate in any of three design-and-build challenges. Senior-level students undertake a yearlong laboratory course. In providing these opportunities to engineering students, USC's program ensures that they have the knowledge and skills they will need when entering the complex aerospace engineering workforce—while simultaneously promoting strong alumni networks.

Students in the Aerospace and Mechanical Engineering bachelor's degree program at USC's Viterbi School of Engineering participate in one of three design-and-build challenges which include faculty and graduate student mentoring.

Aviation Safety and Security Programs

There are two institutions in Los Angeles County with aviation safety and security programs. USC offers a 5-course certificate program which has been in place since 1952, while Embry-Riddle Aeronautical University offers an online bachelor's of science degree in aviation security.

The USC program provides students with twenty courses, categorized into five groups, of which they must choose one course regarding safety management, one regarding accident investigation, one regarding human factors in aviation and two other courses from a variety of focuses.

The Embry-Riddle program is geared towards high school or 2-year college graduates, active or transitioning military and security professionals. It not only focuses on specific topics in aviation, such as airport, airline and corporate security, as well as aviation legislation, but also teaches broader topics such as national security and intelligence alongside general education courses. Upon completion of this program, students will be prepared to take the Airport Security Coordinator Exam, as well as the ASIS International Certified Protection Professional (CPP) Exam.

Aeronautics

Los Angeles is also home to two aeronautics programs, a Master of Science degree offered by the California Institute of Technology (CalTech) and an online Bachelor of Science degree offered by Embry-Riddle Aeronautical University.

The CalTech program is geared towards students continuing on to a master's degree in aerospace engineering or a Ph.D. in Aeronautics or Space Engineering. As such, the program does not require a final thesis or research project, and even grants students the option of forgoing the master's degree entirely as long as they choose to continue their education. The Embry-Riddle program aims to prepare students for a career in the aerospace industry upon graduation. It is multi-disciplinary, offering general education courses along with aviation science, management and safety courses. Students may also choose a concentration within the aviation industry as part of their studies.

Aircraft Fabrication and Assembly

Antelope Valley College in Los Angeles County provides a career technical education program in aircraft fabrication and technology. Suitable for both new students with no

Antelope Valley College has partnered with the National Science Foundation's Center for Aerospace Technical Education (SpaceTEC) to provide a career technical education program in Aircraft Fabrication and Technology.

relevant skills, as well as experienced students who would like to further advance their skills in the industry, students learn industry standards, how to operate the necessary tools, safety practices, aerodynamics, fabrication techniques and uses of composite materials, and upon completion earn a certificate.

Antelope Valley College also offers training in aerospace composites fabrication and repair through a partnership with SpaceTEC (the National Science Foundation's Center for Aerospace Technical Education). Students must complete four courses which will prepare them to enter entry-level manufacturing jobs within the aerospace industry, such as structural or composite technician positions. Through SpaceTEC, the college also provides aerospace manufacturing, aerospace composites and aerospace vehicle processing certifications.

Astronautics

Students educated in astronautics have a wide variety of space-related employment opportunities available to them. These could include careers in space craft design, remote sensing, orbital mechanics, space navigation and space instrumentation and sensing. Such topics form the foundation for operations of manned space flight, satellite communication, weather and ground monitoring and global positioning and navigation.

USC offers a bachelor's degree, master's degree, graduate certificate and Ph.D. in astronautics. Students begin by learning the fundamentals of aerospace engineering, followed by specialized work in astronautics and space technology, as well as technical electives. Practicing engineers and scientists wanting to enter space-related fields or undergo training in specific space-related areas can earn a graduate certificate in astronautics by completing four subject-specific courses provided by the school.

Unmanned Systems

Embry-Riddle Aeronautical University offers a bachelor's degree in unmanned systems applications and a master's degree in unmanned systems. Having a specialization in this nascent industry will give students an advantage in the job market and may better direct them towards a specific career. Undergraduates must choose between three paths: administration, operations and development. Those who focus on administration will learn management topics and administrative functions within the industry, while those who choose to focus on operations will learn the logistics of mission planning and execution, as well as how to make operations safe and efficient. Students who specialize in development will learn about the design, development and validation of unmanned systems applications with a foundation of engineering. Graduate studies are more analytical and research-based.

Licensing and Certification

At a point near or following the completion of an undergraduate degree program, engineers take either the Engineer in Training or Fundamentals of Engineering exam. Doing so prepares students for the Professional Engineers (PE) licensing exam, which they may take after four years of experience. A PE license is not required within the industry, but mechanical and electrical PE licenses may be desired by aerospace employers.

Throughout the Southern California region, the National Center for Aerospace and Transportation Technologies (NCATT) provides certification for aerospace/aircraft assembly, aircraft electronics technician, autonomous navigation systems, dependent navigation systems, onboard communications safety, radio communication systems and unmanned aircraft system maintenance.

Ongoing Pipeline of Workers

With such a broad array of educational institutions offering programs related to aerospace industries, Southern California appears well-equipped to continue supplying the needed workforce for the industry. In the most recent academic year, the region graduated more than 3,700 students with bachelor's degrees in engineering (from the selection of universities listed in the exhibit), of which more than 1,300 were mechanical engineering majors and 300 were aerospace engineers. More than 2,000 students were granted graduate degrees in engineering, 260 of which in mechanical engineering and 115 in aerospace engineering.

The data is incomplete as several schools do not report their graduation rates by major.

Selected Engineering Degrees Conferred from Universities 2014-2015

University	Major & Degree Type: Aerospace			Mechanical			All Engineering		
	BS	MS	Ph.D	BS	MS	Ph.D	BS	MS	Ph.D
Caltech (2013-14)	*	*	12^	*	*	4^	*	*	38^
USC (2013-14)	*	*	6^	*	*	8^	*	*	93^
UC Irvine	52	54	13	190	"	"	636	310	90
UC Los Angeles	36	20	2	104	82	25	*	*	*
UC Riverside	-	-	-	106	13	8	454	87	77
UC San Diego (2013-14)	45	*	-	106	*	11^	1,063	433	132
CSU Fullerton	-	-	-	89	26	-	215	166	-
CSU Long Beach	44	19	-	163	20	-	585	168	-
CSU Los Angeles	-	-	-	70	28	-	183	106	-
CSU Northridge	-	-	-	127	30	-	327	201	-
Cal Poly Pomona	81	-	-	185	19	-	854	87	-
CSU San Diego	46	7	-	176	12	-	465	89	-
TOTAL	304	100	15	1,316	230	33	3,719	1,647	299

Sources: Data reported by individual universities
^ = Data reported by NSF
* = Data not published
- = Program not offered
" UC Irvine offers a joint Aerospace and Mechanical Engineering graduate program

Sources: NSF; CSU; UCI, UCLA; UCR; UCSD

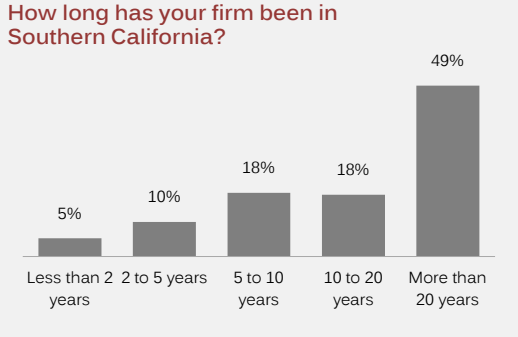
What the Industry Says

Results of survey and interviews.

Where do industry players themselves see their industry going and what might their individual challenges and opportunities be? To help answer these questions, an online and telephone survey was conducted of known firms in the industry in Southern California, a universe of approximately 1,000 firms, of which 192 completions were achieved over a three-month period in late 2015. The survey was administered by BW Research Partnership. Once these were received, in-person interviews were conducted with high level executives of a number of firms. The results of the survey and interviews are discussed here.

Overview of Survey Responses

The survey instrument was broadly divided into three sections. The first asks a series of questions about the respondent's business profile and supplier connections. The second inquires about the firm's research funding sources and employment outlook. The third section inquires about the firm's general business outlook and the availability of needed inputs. Survey responses are as follows:



Firm permanence

Aerospace and defense is a **mature industry** in Southern California, with larger firms that have considerable experience and longevity in the region.

- Thirty percent of respondents had more than 100 employees in Southern California, while more than a third of respondents reported fewer than ten employees;
- Two-thirds of respondents have been in Southern California for more than 10 years.

Global marketplace

Aerospace firms in Southern California are competing in a **global marketplace.**

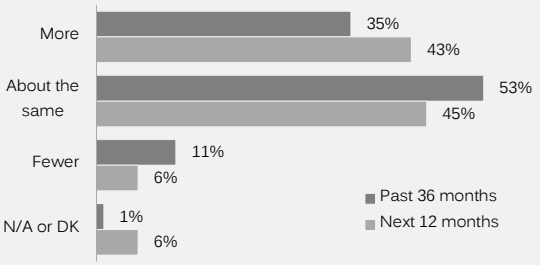
- Almost 35 percent of respondents identified their primary *customers* as being outside the United States, and almost 20 percent identified their primary *suppliers* as being outside the United States;
- Approximately 59 percent of respondents sold their products in the national marketplace and 60 percent purchased from the suppliers across the nation.

Employment trends

Respondents have been and expect to continue **increasing employment** in the region.

- Over the last three years, 35 percent of respondents reported having increased employment, while only 11 percent had reduced jobs;
- Over the next twelve months, 43 percent of respondents expect to add jobs, while only 6 percent expect to shed labor.

How have your employment numbers changed in the last 36 months, and how will they change in the next 12 months?



Business climate

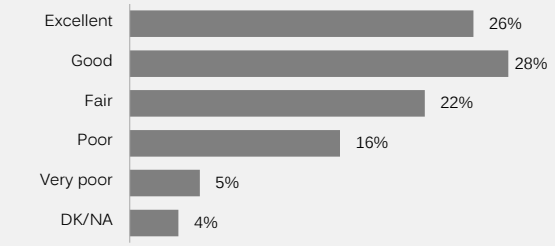
More than half of respondents indicated that Southern California was an **excellent or good place to do business** in their industry.

- The primary reasons for being in Southern California include proximity to customers, firm legacy and proximity to the supply chain;

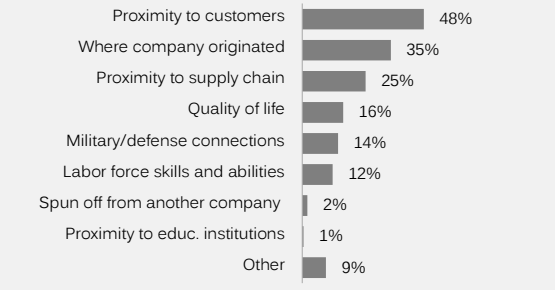
Many respondents indicated their **satisfaction with several business needs** in Southern California.

- More than two-thirds of respondents with an opinion were very satisfied or somewhat satisfied with their access to capital in Southern California;
- Almost eighty percent were very or somewhat satisfied with their access to customers in the region;
- The region's major strength appears to be the concentration of suppliers, as more than 86 percent of respondents with an opinion were very satisfied or somewhat satisfied with their access to suppliers;
- The ability to access either highly-skilled talent or entry- to mid-level workforce was somewhat lower on the satisfaction scale, with 21.8 percent dissatisfied with their ability to access higher-skilled talent and 18.9 percent dissatisfied with their ability to access entry level or mid-level workers.

How would you rate Southern California as a place for aerospace firms to do business?

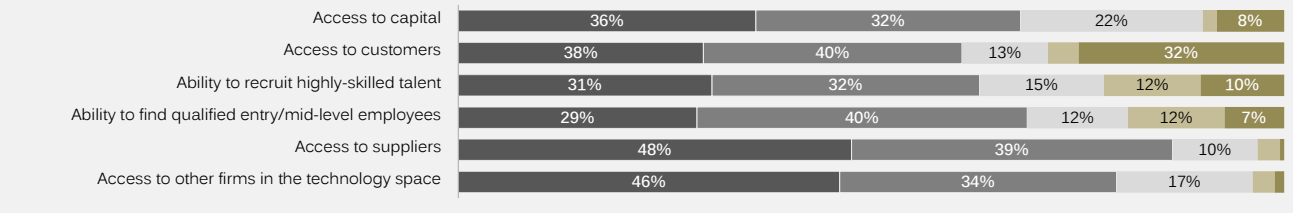


What are the primary reasons your aerospace work is located in Southern California?



Multiple responses allowed. Percentages may sum to more than 100%.

How satisfied is your firm with the following in Southern California?



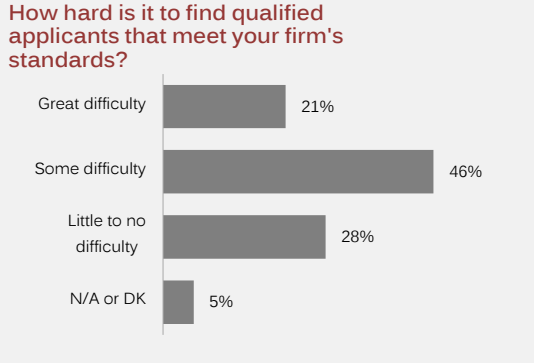
Of those stating an opinion

Executive Interview Responses

Five major themes were consistent across the executive interviews:

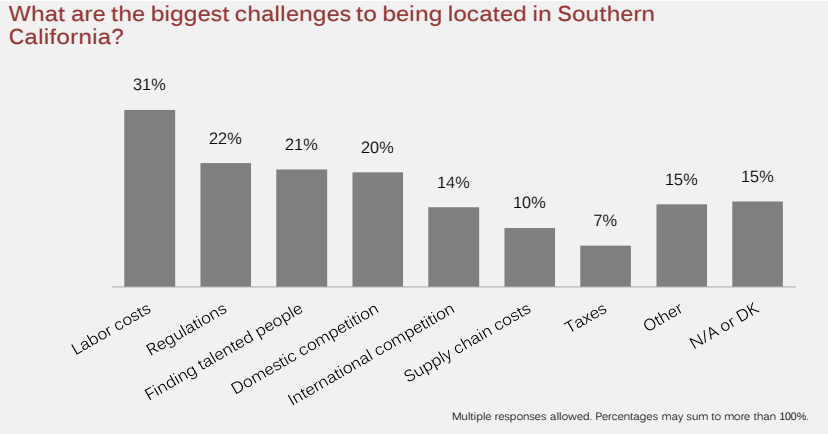
Strengths of the Southern California aerospace industry cluster

- The region hosts a diverse and professional group of specialized manufacturers and suppliers who support aerospace and related high-value products, a network that can assist in getting complex products to market quickly—a critical asset of the region's aerospace cluster;
- The resources and infrastructure of higher education, including UC schools, Cal Poly, CSU schools and other private institutions, not only produce smart and capable engineers but also engage in valuable partnerships and research that benefit the industry;
- Southern California's quality of life continues to draw good talent while at the same time its favorable climate allows more testing and hence the ability to develop products faster than in areas with more inclement weather;
- Southern California fosters a spirit of risk-taking and innovation, and its support network for entrepreneurs and of funding opportunities facilitates product commercialization.



Weaknesses of the Southern California aerospace industry cluster

- Workforce challenges remain at the forefront:
  - Smaller or newer firms do not have adequate resources to compete with the larger industry players for top talent;
  - Finding candidates with industry experience (an important qualification) is difficult given the lack of internships and many security restrictions;
  - High level talent is usually available, but it is aging and now more costly;
  - The cost of living in many parts of Southern California impedes a deepening of the talent pool, while the quality of life in more remote areas of the region fail to attract possible employees.
- Costs of doing business in California can also be a burden:
  - The regulatory environment is restrictive, in particular regarding environmental compliance issues;
  - Real estate costs, especially in Los Angeles and San Diego, can be a barrier to firms wishing to grow.

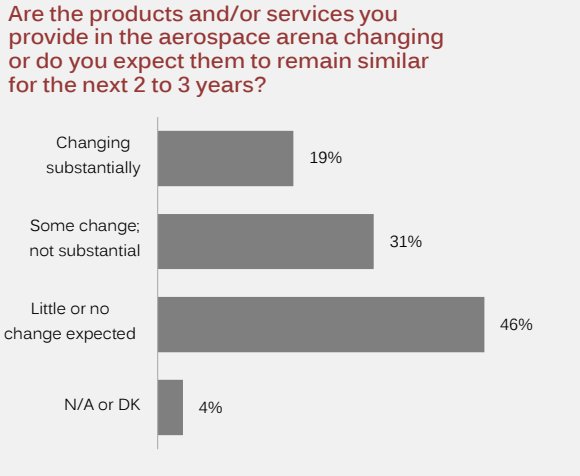


Suggestions for developing a thicker pipeline of talent for the industry

- Increase relevant and industry-specific internships and externships that expose high-level students to the aerospace industry;
- Introduce applied STEM curriculum that connects the rigorous requirements of higher-level math and science with the hands-on work associated with experimenting, designing and building new products;
- Expand the universe of students by reaching out to those of diverse backgrounds, ethnicity and socio-economic status, as well as to the veteran population.

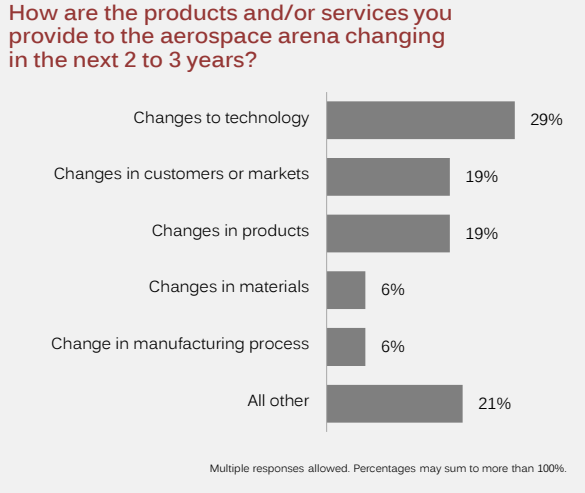
Industry outlook

- The short-term outlook is fair as overall defense spending and aviation work is relatively strong;
- Longer term, however, projections are not nearly as optimistic, with traditional aeronautics and aviation seen as a slowing industry;
- While the industry is still closely connected to large government contracts, their importance has declined over time. Still, government funding is still a useful metric of health in the aerospace industry.



Opportunities for industry growth and innovation

- Growth opportunities in space and unmanned vehicles, and the opportunity to commercialize new products and related research provide expectations that the industry could change considerably over the next 10 to 20 years;
- Cyber and information security and its integration into new aerospace products is not only a challenge but also a great opportunity for innovation and industry growth going forward, and are considered a strength of the Southern California region;
- Robotics, nanotechnology and the continued development of new materials, while important to all advanced manufacturing, is critical to aerospace and related defense industries.



Appendix

How (and why) we did what we did.

Here we explain why we are interested in learning about our industry clusters in more detail, and how we measure them. Data sources and methodologies are outlined, and a description of the components industries in the aerospace industry cluster is provided. A series of exhibits fill in some of the details that were summarized in the report.

Cluster Theory and Economic Development

Clusters are agglomerations of related industries, consisting of companies, suppliers and service providers, as well as government agencies and other support institutions. By bringing together the talent, technology, information and competing companies, such geographic proximity allows firms to learn from each other, develop specialized labor, shared infrastructure, service providers, and suppliers and support institutions. This local collaboration and competition spurs innovation and productivity, attracting other firms to the region as they seek to benefit from spillovers present in the clustered industry.

We look at the economy by categorizing its industries into clusters rather than aggregating them into larger sectors. Clusters allow us to see industries linked with others through technology, skills, common supply chains, specialized labor pools, infrastructure needs and so on.

Research shows that regions with comparatively strong industry clusters achieve better economic performance through increased job creation, wage growth, business formation and entrepreneurial activity and innovation.

Michael E. Porter, professor in the Harvard Business School at the Institute for Strategy and Competitiveness, is a leading expert on the competitiveness of businesses and his insights have brought focus to how regions can develop competitiveness and economic prosperity by recognizing the importance of industry clusters. Funded by the Economic Development Administration of the U.S. Department of Commerce, Porter's Cluster Mapping Project (www.clustermapping.us) has provided a categorization of industries into industry clusters based on their locational correlation of employment.

A further distinction is made between industry clusters that serve the local market, such as retail industries, health services and restaurants, and those that sell goods and services to larger markets outside the economic region.

Because local industry clusters exist wherever there is a local population base, they are likely to grow at the rate of population growth. They may also provide the majority of the region's jobs.

Traded clusters, on the other hand, are not dependent on local sales but find markets outside the region in which they are located. Because they are exposed to the global

market, they must be competitive in order to thrive and grow, and will choose to locate where there exist locational advantages, such as availability of labor, land and capital suited to their needs, as well as supplier networks and other supporting institutions.

Hence, investments made by such firms in technology, innovation, labor and the upgrading of their goods and services result in improved productivity and efficiency, increasing the firm's competitiveness in the global marketplace, growing the market share of the industry and driving industry growth, which creates higher-wage jobs and regional prosperity.

The first step in this virtuous cycle is to foster an environment where industry clusters can grow organically. Knowing our regional strengths and weaknesses provides us with a useful baseline on which we can build economic development strategies. The full list of traded industry clusters in California for 2014 is in Exhibit A-1; local industry clusters are shown in Exhibit A-2.

Data Sources

All data was obtained from the Bureau of Labor Statistics and the Census Bureau. Annual employment and payroll data are from the Census of Employment and Wages series. Estimates for non-disclosed employment and payroll data were produced using proportional shares of the prior year's data or using midpoint estimates from the County Business Patterns program. Occupational data are from the Occupational Employment Statistics program. Unless noted otherwise, all data is for the 2014 calendar year.

Supply Chain and Output Analysis

Composition of gross output is a metric tracked by the BEA at the state level. It is assumed that the proportion attributable to each component of this metric at the county level is comparable to that at the state level. This seems reasonable given the size of the Southern California region and its economic activity in the state. Estimates of regional purchases of intermediate goods and services are produced using econometric models by the IMPLAN Group, LLC.

Economic Impact and Contribution Analysis

Economic contribution analysis is used to estimate the portion of a region's economic activity that can be attributed to an existing industry sector. The primary economic contribution to the Southern California economy of the aerospace industry is the expenditure of billions of dollars towards goods and services from regional vendors. These purchases circulate throughout the regional economy.

The aerospace industry also spends billions of dollars every year for the wages and benefits of employees and contingent workers. These workers, as well as the employees of all suppliers, spend a portion of their incomes on groceries, rent, vehicle expenses, healthcare, entertainment, and so on. This recirculation of household earnings multiplies the initial industry spending through such indirect and induced effects.

The extent to which the initial expenditures multiply is estimated using economic models that depict the relationships between industries (such as aerospace and its suppliers) and among different economic agents (such as industries and their employees). These models

are built upon data of expenditure patterns that are reported to the U.S. Bureau of Labor Statistics, the U.S. Census Bureau and the Bureau of Economic Analysis of the U.S. Department of Commerce. Data is regionalized so that it reflects local conditions such as wages rates, commuting patterns, and resource availability and costs.

The magnitude of the multiplying effect differs from one region to another depending on the extent to which the local region can fill the demand for all rounds of supplying needs. For example, the automobile manufacturing industry has high multipliers in Detroit and Indiana since these regions have deep supplier networks, while the same industry multiplier in Phoenix is quite small. In another example, the jobs multiplier for the construction industry is higher in, say, Arkansas, than in California because a given amount of spending will purchase fewer workers in Los Angeles than in Little Rock. Multipliers also differ from year to year as relative material and labor costs change and as the production "recipe" of industries change. For example, the IT revolution significantly reduced the job multiplier of many industries (such as manufacturing, accounting and publishing) as computers replaced administrative and production workers.

The metrics used to determine the value of the economic contribution are employment, labor income, value-added and the value of output. *Employment* includes full-time, part-time, permanent and seasonal employees and the self-employed, and is measured on a job-count basis regardless of the number of hours worked. *Labor income* includes all income received by both payroll employees and the self-employed, including wages and benefits such as health insurance and pension plan contributions. *Value-added* is the measure of the contribution to GDP made by the industry, and consists of compensation of employees, taxes on production and gross operating surplus (otherwise known as profit). *Output* is the value of the goods and services produced. For most industries, this is simply the revenues generated through sales; for others, such as retail, output is the value of the services supplied.

Estimates are developed using software and data from IMPLAN Group, LLC which traces inter-industry transactions resulting from an increase in demand in a given region. The economic region of interest in this document is Southern California defined as including the eight counties of Imperial, Kern, Los Angeles, Orange, Riverside, San Bernardino, San Diego and Ventura. The activity is reported for 2014, the most recent year for which a complete set of data is available. Estimates for labor income and output are expressed in 2014 dollars to maintain consistency with the reported industry activity.

The total estimated economic contribution includes *direct*, *indirect* and *induced* effects. *Direct activity* includes the materials purchased and the employees hired by the industry itself. *Indirect effects* are those which stem from the employment and business revenues resulting from the purchases made by the industry and any of its suppliers. *Induced effects* are those generated by the household spending of employees whose wages are sustained by both direct and indirect spending.

Contribution analysis differs from economic impact analysis in that linkages between the individual component industries are removed so that indirect activity is not double-counted as also part of direct activity. For example, firms in the aerospace industry purchase supplies from smaller manufacturers of aerospace parts, which would then be included as both direct revenue of the parts supplier and as an expense of the aerospace industry, resulting in a double-counting of overall revenue. Breaking these inter-industry linkages eliminates this double-counting and is a more accurate method of estimating the economic contribution of the industry cluster.

Industries of Aerospace Industry Cluster

The following industries comprise the aerospace industry cluster:

NAICS 334511: Search, detection, navigation, guidance, aeronautical and nautical system and instrument manufacturing
Establishments in this U.S. industry are primarily engaged in manufacturing search, detection, navigation, guidance, aeronautical and nautical systems and instruments, such as flight recorders, radar systems and equipment, sonar systems and equipment, navigational instruments and systems, and aircraft instruments.

NAICS 336411: Aircraft manufacturing
Establishments in this U.S. industry are primarily engaged in one or more of the following: (1) manufacturing or assembling complete aircraft; (2) developing and making aircraft prototypes; (3) aircraft conversion (such as, for example, major modifications to systems); and (4) complete aircraft overhaul and rebuilding (such as, for example, periodic restoration of aircraft to original design specifications).

NAICS 336412: Aircraft engine and engine parts manufacturing
Establishments in this U.S. industry are primarily engaged in one or more of the following: (1) manufacturing aircraft engines and engine parts; (2) developing and making prototypes of aircraft engines and engine parts; (3) aircraft propulsion system conversion (such as, for example, major modifications to systems); and (4) aircraft propulsion systems overhaul and rebuilding (such as, for example, periodic restoration of aircraft propulsion system to original design specifications).

NAICS 336413: Other aircraft parts and auxiliary equipment manufacturing
Establishments in this U.S. industry are primarily engaged in (1) manufacturing aircraft parts or auxiliary equipment (other than engines and aircraft fluid power subassemblies) and/or (2) developing and making prototypes of aircrafts parts and auxiliary equipment. Auxiliary equipment includes such items as crop dusting apparatus, armament racks, in-flight refueling equipment and external fuel tanks.

NAICS 336414: Guided missile and space vehicle manufacturing
Establishments in this U.S. industry include those primarily engaged in (1) manufacturing complete guided missiles and space vehicles and/or (2) developing and making prototypes of guided missiles or space vehicles.

NAICS 336415: Guided missile and space vehicle propulsion unit and propulsion unit parts manufacturing
This industry is comprised of establishments primarily engaged in (1) manufacturing guided missile and/or space vehicle propulsion units and propulsion unit parts and/or (2) developing and making prototypes of guided missile and space vehicle propulsion units and propulsion unit parts.

NAICS 336419: Other guided missile and space vehicle parts and auxiliary equipment manufacturing
This industry includes establishments primarily engaged in (1) manufacturing guided missile and space vehicle parts and auxiliary equipment (other than guided missile and space vehicle propulsion units and propulsion unit parts) and/or (2) developing and making prototypes of guided missile and space vehicle parts and auxiliary equipment.

Exhibit A-1
Traded Industry Clusters of California 2014

Industry Cluster Name	Establishments	Employment	Average Annual Wage	Location Quotient
Business Services	79,680	1,024,220	$ 101,246	1.1
Trade	63,170	847,480	70,890	1.0
Hospitality and Tourism	13,520	353,560	38,650	1.0
Education and Knowledge Creation	10,890	317,380	98,470	1.2
Information Technology and Analytical Instruments	4,820	274,310	155,710	2.0
Marketing, Design and Publishing	19,300	209,120	152,104	1.4
Agricultural Inputs and Services	3,780	208,770	25,620	4.9
Financial Services	21,550	206,520	148,840	0.9
Entertainment	20,470	183,740	113,460	2.8
Food Processing and Manufacturing	3,880	154,550	51,810	1.3
Aerospace Vehicles and Defense	760	99,660	106,642	1.4
Insurance Services	4,100	98,690	89,330	0.7
Biomedical	1,440	97,610	123,170	1.5
Fashion	4,310	77,560	36,650	1.5
Communication Equipment and Services	2,250	61,050	110,060	1.5
Construction Products and Services	2,400	55,200	73,010	0.6
Production Technology and Heavy Machinery	1,930	53,600	71,560	0.5
Metalworking Technology	2,070	44,250	53,360	0.8
Printing Services	3,390	42,580	46,220	0.8
Plastics	1,210	41,990	49,750	0.6
Oils and Gas Production and Transportation	980	39,960	149,090	0.4
Furniture	1,870	30,640	40,280	0.7
Automotive	890	30,610	57,170	0.3
Downstream Metal Products	1,380	29,490	56,490	0.6
Lighting and Electrical Equipment	980	27,110	67,780	0.8
Upstream Metal Manufacturing	730	24,100	60,840	0.5
Recreational and Small Electric Goods	1,490	23,980	58,480	1.2
Livestock Processing	370	22,040	36,950	0.4
Downstream Chemical Products	880	21,940	65,820	0.7
Paper and Packaging	490	21,800	59,680	0.5
Wood Products	910	20,830	41,310	0.5
Electric Power Generation and Transmission	390	16,660	130,410	0.8
Environmental Services	580	14,320	58,920	1.1
Vulcanized and Fired Materials	540	12,540	47,010	0.4
Upstream Chemical Products	210	5,640	81,640	0.3
Metal Mining	40	5,450	76,330	1.0
Nonmetal Mining	230	4,580	74,570	0.4
Forestry	440	4,340	45,340	0.5
Trailers, Motor Homes and Appliances	120	4,030	49,530	0.3
Fishing and Fishing Products	240	1,530	51,830	0.3
Coal Mining	10	70	69,930	0.0
Tobacco	10	50	37,970	0.0
TOTAL Traded Industry Clusters	**278,650**	**4,813,540**	**$ 89,020**	**1.0**

* Data is not disclosed

Sources: CMP; QCEW: Estimates by LAEDC

Exhibit A-2
Local Industry Clusters of California 2014

Industry Cluster Name	Establishments	Employment	Average Annual Wage
Local Health Services	92,520	1,439,810	$ 60,000
Local Hospitality Establishments	75,900	1,396,380	18,980
Local Commercial Services	70,230	1,031,780	50,180
Local Real Estate, Construction and Development	113,140	990,810	56,270
Local Community and Civic Organizations	418,760	690,530	20,630
Local Retailing of Clothing and General Merchandise	21,880	509,590	23,620
Local Food and Beverage Processing and Distribution	24,650	473,990	32,840
Local Motor Vehicle Products and Services	39,710	422,170	41,280
Local Personal Services (Non-Medical)	34,870	263,890	28,850
Local Financial Services	24,400	235,390	74,550
Local Logistical Services	13,660	232,390	44,270
Local Household Goods and Services	19,230	187,740	34,180
Local Entertainment and Media	11,800	183,210	51,790
Local Education and Training	5,740	151,570	38,310
Local Utilities	3,720	115,950	94,350
Local Industrial Products and Services	5,520	63,520	53,770
TOTAL Local Industry Clusters	**975,710**	**8,391,720**	**$ 41860**

Sources: CMP; QCEW: Estimates by LAEDC

Exhibit A-3
Military Bases in Southern California

	Airfield/ Space/ Missile	Estimated Base Population*
Los Alamitos Armed Forces Reserve Training Base (aka Los Alamitos Joint Forces or Los Alamitos Army Airfield)	yes	3,700
Edwards Air Force Base	yes	11,200
Los Angeles Air Force Base	yes	4,870
March Air Reserve Base	yes	6,750+
Fort Irwin Army Base		
Camp Pendleton Marine Corps Base		
Marine Corps Air Station (MCAS) Miramar	yes	12,440
Marine Corps Logistics Base (MCLB) Barstow		
Marine Corps Recruit Depot (MCRD) San Diego		
Marine Corps Air Ground Combat Center (MCAGCC) Twentynine Palms		
Chocolate Mountain Arial Gunnery Range (CMAGR)		
Naval Base Ventura County	yes	20,400
Naval Air Facility El Centro		
Naval Base Coronado Navy Base		
Naval Hospital Pendleton Navy Base Camp Pendleton		
Naval Medical Center Navy Base		
NAWS China Lake Navy Base	yes	6,310
Naval Station (NS) San Diego Naval Base		
Point Loma Navy Base		

* Includes available estimates of active duty, reserves, family members, civilian employees and retirees

Source: DOD

Exhibit A-4
Economic Contribution of the Aerospace Industry Across Industries

NAICS	Industry Sector	Direct Jobs	Total Jobs	Direct Labor Income ($ millions)	Total Labor Income ($ millions)	Direct Output ($ millions)	Total Output ($ millions)
11	Agriculture, forestry and fishing		350		$ 23.7		$ 60.1
21	Mining		310		35.8		183.4
22	Utilities		280		41.8		279.0
23	Construction		1,860		102.6		320.1
31-33	Manufacturing	84,940	94,580	$ 11,123.6	11,853.3	$ 39,897.7	43,932.6
42	Wholesale trade		9,080		729.4		2,253.7
44-45	Retail trade		13,580		520.6		1,226.6
48-49	Transportation and warehousing		7,280		401.7		1,104.6
51	Information		3,540		426.0		1,854.0
52	Finance and insurance		9,220		675.6		1,952.1
53	Real estate and rental		6,520		250.0		3,166.8
54	Profession and technical services		14,900		1,137.1		2,032.0
55	Management of companies		7,660		914.6		1,756.9
56	Administrative and waste services		25,110		918.3		1,633.0
61	Educational services		3,520		164.0		272.6
62	Health and social services		18,830		1,045.9		1,804.4
71	Arts, entertainment and recreation		3,440		129.1		309.5
72	Accommodation and food services		13,440		337.0		823.0
81	Other services		10,390		395.5		774.8
92	Government		1,890		189.6		489.6
	TOTAL All Industry Sectors	**84,940**	**245,770**	**$ 11,123.6**	**$ 20,291.5**	**$ 39,897.7**	**$ 66,228.8**

Source: Estimates by LAEDC

Exhibit A-5
Aerospace Industry Purchases of Intermediate Goods and Services

NAICS	Industry Sector	Gross Inputs ($ millions)	% of All Intermediate Purchases	Regional Inputs ($ millions)	% of Gross Inputs Purchased Regionally
11	Agriculture, Forestry, Fishing and Hunting	-	-	-	-
21	Mining, Quarrying and Oil and Gas Extraction	$ 21.4	0.1	$ 2.9	13.7
22	Utilities	271.6	1.1	143.1	52.7
23	Construction	99.5	0.4	84.7	85.1
31-33	Manufacturing	17,199.1	70.4	4,969.9	28.9
42	Wholesale Trade	1,286.1	5.3	1,289.1	100.0
44-45	Retail Trade	42.1	0.2	42.0	99.7
48-49	Transportation and Warehousing	445.5	1.8	403.8	90.6
51	Information	395.9	1.6	313.8	79.3
52	Finance and Insurance	157.4	0.6	126.5	80.4
53	Real Estate and Rental and Leasing	274.2	1.1	271.8	99.1
54	Professional, Scientific and Technical Services	1,113.2	4.6	960.1	86.2
55	Management of Companies and Enterprises	1,721.1	7.0	1,433.8	83.3
56	Administrative and Support and Waste Management and Remediation Services	1,068.9	4.4	958.8	89.7
61	Educational Services	-	-	-	-
62	Health Care and Social Assistance	-	-	-	-
71	Arts, Entertainment and Recreation	8.0	0.0	7.7	96.0
72	Accommodation and Food Services	50.0	0.2	39.0	77.1
81	Other Services	73.9	0.3	72.5	98.1
92	Public Administration	191.7	0.8	27.4	14.3
	TOTAL All Intermediate Purchases	**$ 24,419.8**	**100.0**	**$ 11,143.5**	**45.6**

Sources: IMPLAN Group; Analysis by LAEDC

Exhibit A-6
Detailed Purchases of Intermediate Goods and Services (Top 50 by Value)

NAICS	Industry Sector	Gross Inputs ($ millions)	% of All Intermediate Purchases	Regional Inputs ($ millions)	% of Gross Inputs Purchased Regionally
336413	Other aircraft parts and auxiliary equipment	$ 3,161.6	12.9	$ 1,182.0	37.4
336412	Aircraft engines and engine parts	2,627.4	10.8	229.0	8.7
336414	Guided missiles and space vehicles	2,110.2	8.6	595.3	28.2
55111	Management of companies and enterprises	1,721.1	7.0	1,433.8	83.3
42	Wholesale trade distribution services	1,286.1	5.3	1,286.1	100.0
334413	Semiconductors and related devices	1,094.2	4.5	384.2	35.1
336415/9	Propulsion units / parts for space vehicles and guided missiles	586.0	2.4	256.1	43.7
334511	Search, detection, and navigation instruments	479.5	2.0	300.9	62.7
331110	Iron and steel and ferroalloy products	475.6	1.9	125.5	26.4
334220	Broadcast and wireless communications equipment	450.4	1.8	2.1	0.5
334419	Other electronic components	383.5	1.6	117.2	30.6
326191/9	Other plastics products	315.2	1.3	110.3	35.0
334419	Printed circuit assemblies (electronic assemblies)	312.3	1.3	56.7	18.2
332911/2	Valve and fittings, other than plumbing	311.9	1.3	105.3	33.8
5418	Advertising, public relations, and related services	269.3	1.1	264.4	98.2
336390	Other motor vehicle parts	261.6	1.1	66.3	25.4
484	Truck transportation services	259.1	1.1	254.1	98.1
336411	Aircraft	255.7	1.0	59.4	23.2
5614	Business support services	252.1	1.0	186.7	74.1
5613	Employment services	250.7	1.0	249.0	99.3
332613/8	Spring and wire products	250.1	1.0	90.7	36.3
334417	Electronic connectors	233.1	1.0	89.4	38.3
533110	Leasing of nonfinancial intangible assets	232.5	1.0	232.5	100.0
334519	Watches, clocks, other measuring / controlling devices	225.4	0.9	8.9	4.0
334515	Electricity and signal testing instruments	221.2	0.9	31.9	14.4
332312	Fabricated structural metal products	213.6	0.9	71.1	33.3
541512	Computer systems design services	211.2	0.9	100.9	47.8
221121/2	Electricity	200.0	0.8	72.1	36.0
5182	Data processing, hosting, and related services	199.7	0.8	126.7	63.4
5616	Investigation and security services	182.1	0.8	191.7	99.8
334112	Computer storage devices	175.5	0.7	37.7	21.5
5413	Architectural, engineering, and related services	173.0	0.7	165.6	95.7
5414	Specialized design services	138.5	0.6	137.6	99.4
5619	Other support services	132.5	0.5	126.4	95.5
335931/2	Wiring devices	128.7	0.5	69.2	53.8
332721/2	Turned products and screws, nuts, and bolts	126.3	0.5	84.5	66.9
561210	Facilities support services	112.8	0.5	77.0	68.3
332510	Hardware	110.0	0.5	17.6	16.0
517110	Wired telecommunications	109.3	0.4	106.1	97.0
331315	Aluminum sheets, plates, and foils	107.6	0.4	24.3	22.6
541511	Custom computer programming services	102.8	0.4	97.6	94.9
2362x	Maintained and repaired nonresidential structures	99.5	0.4	84.7	85.1
335929	Other communication and energy wires	98.0	0.4	11.9	12.1
334513	Industrial process variable instruments	95.3	0.4	12.4	13.0
332710	Machined products	92.5	0.4	62.0	67.1
332111	Iron and steel forgings	89.6	0.4	56.8	63.4
5231/2	Securities / commodity contracts intermediation / brokerage	81.8	0.3	63.7	77.9
335314	Relay and industrial controls	81.0	0.3	7.9	9.7
493	Warehousing and storage services	80.5	0.3	80.5	100.0
32551	Paints and coatings	80.3	0.3	37.4	46.6
	All other intermediate purchases	*2,999.8*	*12.3*	*1,502.3*	*50.1*
	TOTAL All Intermediate Purchases	**$ 24,419.8**	**100.0**	**$ 11,143.5**	**45.6**

Sources: IMPLAN Group; Analysis by LAEDC

Exhibit A-7
Detailed Aerospace Occupations (Top 50 by Employment)

SOC	Occupation Title	2014 SoCal Payroll Jobs	Projected Openings Over SoCal 5 Years	Education Needed for Entry Level	Work Experience Needed for Entry Level	On-the-Job Training to Attain Competency	Average Annual Wage CA 2014
15-1133	Software Developers, Systems Software	470	30	3	None	None	$ 130,114
17-2112	Industrial Engineers	3,325	450	3	None	None	105,123
51-2022	Electrical and Electronic Equipment Assemblers	1,660	430	7	None	ST OJT	35,449
17-2141	Mechanical Engineers	2,680	420	3	None	None	109,743
17-2011	Aerospace Engineers	3,670	400	3	None	None	118,405
51-2092	Team Assemblers	2,700	310	7	None	MT OJT	31,116
17-2131	Materials Engineers	530	300	3	None	None	113,473
51-9061	Inspectors, Testers, Sorters, Samplers, Weighers	3,810	270	7	None	MT OJT	49,386
17-2072	Electronics Engineers, Except Computer	2,910	210	3	None	None	119,777
51-1011	First-Line Supervisors of Production and	1,410	200	5	< 5 yrs	None	75,217
51-2011	Aircraft Structure, Surfaces, Rigging, Systems	2,200	190	7	None	MT OJT	55,140
15-1131	Computer Programmers	4,300	190	3	None	None	92,864
51-4041	Machinists	2,330	180	7	None	LT OJT	44,188
51-4031	Cutting, Punching, and Press Machine Setters	270	180	7	None	MT OJT	26,180
13-1023	Purchasing Agents, Except Wholesale, Retail,	1,850	140	7	None	LT OJT	79,012
11-3051	Industrial Production Managers	850	140	3	≥ 5 yrs	None	136,001
51-4011	Computer-Controlled Machine Tool Operators,	1,730	140	7	None	MT OJT	41,630
49-3011	Aircraft Mechanics and Service Technicians	1,540	130	5	None	None	73,950
11-9041	Architectural and Engineering Managers	1,810	120	3	≥ 5 yrs	None	170,834
17-3026	Industrial Engineering Technicians	415	120	4	None	None	60,760
17-3013	Mechanical Drafters	210	110	4	None	None	49,840
17-3021	Aerospace Engineering and Operations	610	90	4	None	None	70,893
51-2041	Structural Metal Fabricators and Fitters	410	90	7	None	MT OJT	36,360
13-1199	Business Operations Specialists, All Other	1,450	80	7	None	None	101,068
17-3023	Electrical and Electronics Engineering	930	80	4	None	None	59,853
51-4033	Grinding, Lapping, Polishing, and Buffing	750	70	7	None	MTOJT	32,154
17-2199	Engineers, All Other	1,040	70	3	None	None	114,498
51-4121	Welders, Cutters, Solderers, Brazers	530	70	7	None	MT OJT	41,898
13-2031	Budget Analysts	500	70	3	None	None	81,830
51-2023	Electromechanical Equipment Assemblers	460	70	7	None	ST OJT	34,733
43-6011	Executive Secretaries and Executive	850	60	7	< 5 yrs	None	67,345
11-1021	General and Operations Managers	1,240	60	3	< 5 yrs	None	171,824
17-3029	Engineering Technicians, Except Drafters, All	570	60	4	None	None	65,494
43-5071	Shipping, Receiving, and Traffic Clerks	820	60	7	None	ST OJT	36,205
43-5081	Stock Clerks and Order Fillers	525	50	8	None	ST OJT	33,912
13-2011	Accountants and Auditors	750	40	3	None	None	86,389
15-1121	Computer Systems Analysts	970	40	3	None	None	103,643
53-7062	Laborers and Freight, Stock, Material Movers,	565	40	8	None	ST OJT	34,235
43-9061	Office Clerks, General	670	40	7	None	ST OJT	41,262
11-3021	Computer and Information Systems Managers	920	40	3	≥ 5 yrs	ST OJT	170,749
49-2091	Avionics Technicians	500	40	4	None	None	67,930
17-3027	Mechanical Engineering Technicians	430	40	4	None	None	58,460
51-4081	Multiple Machine Tool Setters and Operators	350	40	7	None	MT OJT	40,070
51-9198	Helpers--Production Workers	450	40	8	None	ST OJT	24,455
51-2099	Assemblers and Fabricators, All Other	640	30	7	None	MTOJT	34,310
13-1111	Management Analysts	700	30	3	< 5 yrs	None	97,177
15-1131	Computer Programmers	470	30	3	None	None	88,220
17-2071	Electrical Engineers	670	30	3	None	None	117,340
11-9199	Managers, All Other	520	30	7	< 5 yrs	None	175,134
49-9071	Maintenance and Repair Workers, General	500	30	7	None	LT OJT	54,636
	All Other	*25,200*	*460*				
	TOTAL All Occupations	**85,500**	**5,630**				**$ 83,970**

Education: 1=Doctoral or professional degree; 2=Master's degree; 3=Bachelor's degree; 4=Associate's degree; 5=Postsecondary non-degree award; 6=Some college, no degree; 7=High school diploma or equivalent; 8=Less than high school; **On-the-Job Training**: LT OJT=Long-term on-the-job training (more than one year); MT OJT=Moderate-term on-the-job training (1-12 months); ST OJT=Short-term on-the-job training (1 month or less) Sources: Estimates by LAEDC; Education and skills requirements from BLS

Exhibit A-8
Regional Colleges and Universities Providing Aerospace Related Degrees or Certificates

County	Institution	Type	Program	Degree
Los Angeles County	Antelope Valley College	2-Year	Aircraft Fabrication Assembly Technician	Cert.
			Engineering Technology	AS, Cert.
	Long Beach City College	2-Year	Mechanical Maintenance Technology	AS, Cert.
			Drafting -- Mechanical Design (Occupational Program) -- Engineering	AS, Cert.
			Mechanical Maintenance Technology -- Engineering and Industrial	AS, Cert.
			Machine Operator -- Manufacturing Technology -- Engineering and	AS, Cert.
			Numerical Control Technician -- Manufacturing Technology --	AS, Cert.
			Tool Designer, Manufacturing Technology -- Engineering and Industrial	AS, Cert.
			Engineering -- Engineering and Industrial Technologies	AS
			Industrial Systems Technology Maintenance	AS, Cert.
			Mechanical Drafting	AS, Cert.
			Metal Fabrication Technology	AS, Cert.
			Aeronautical and Aviation Technology	AS, Cert.
	California Institute of Technology	4-Year	Aeronautics	MS, Ph. D
			Aerospace Engineering	Minor, MS
			Space Engineer	Ph. D
			Mechanical Engineering	BS, MS, Ph. D
	CSU Long Beach	4-Year	Aerospace Engineering	BS, MS, Joint Ph. D
			Mechanical Engineering	BS, MS, Joint Ph. D
	CSU Los Angeles	4-Year	Mechanical Engineering	BS, MS
			Aviation Administration	BS
	Embry-Riddle Aeronautical	4-Year	Aeronautics	AS, BS, MS
			Aviation Business Administration	AS, BS
			Technical Management	AS
			Aviation Security	BS
			Unmanned Systems Applications	BS, MS
			Systems Engineering	MS
			Cybersecurity Management and Policy	MS
			Aviation Finance	MS
			Information Security and Assurance	MS
	UC Los Angeles	4-Year	Aerospace Engineering	BS, MS
			Materials Science	BS
			Mechanical Engineering	BS
	University of Southern California	4-Year	Aviation Safety and Security Program	Cert., Open Courses
			Aerospace and Mechanical Engineering	BS, MS, Ph. D
			Astronautical Engineering	BS, MS, Graduate
			Materials Science	MS, Ph. D
			Materials Engineering	MS
			Manufacturing Engineering	BS
Orange County	Fullerton College	2-Year	Industrial Drafting (CAD)	AS, Cert.
			Manufacturing Technology	AS
			Machine Technology (MACH)	Vocational Cert.
			CNC Operator	Vocational Cert.
			Computer Numerical Control (CNC)	Vocational Cert.
			Machine Technology Level I Skills	Vocational Cert.
			Machine Technology Level II Skills	Vocational Cert.
			Mastercam Skills	Vocational Cert.
			Surfcam Skills	Vocational Cert.
	Golden West College	2-Year	Computer Aided Design	Cert.
	Irvine Valley College	2-Year	Design, Modelling, and Rapid Prototyping	AS, Cert.
			Electronics Technology	AS
	Mt. San Jacinto College	2-Year	Engineering Technology	AS, Cert.
	Norco College	2-Year	Engineering/Drafting	AS, Cert.
			Machine Shop Technology	AS, Cert.

Exhibit A-8 (cont'd)

County	Institution	Type	Program	Degree
	Orange Coast College	2-Year	Manufacturing Technology	AA, Cert.
			Machinist	Cert.
			CNC Machine Operator	Cert.
			CNC Machine Programmer	Cert.
			CNC Programming	Cert.
			Tooling	Cert.
			Test & Troubleshooting	Cert.
	Saddleback College	2-Year	Electronic Technology	Cert.
	CSU Fullerton	4-Year	Mechanical Engineering	BS, MS
	UC Irvine	4-Year	Aerospace Engineering	BS
			Mechanical Engineering	BS
			Mechanical & Aerospace Engineering	MS
Riverside	UC Riverside	4-Year	Materials Science and Engineering	BS, MS, Ph. D
			Mechanical Engineering	BS
San Bernardino	San Bernardino Valley College	2-Years	Avionics Technology	AS, Cert.
	CSU San Bernardino	4-Year	Aerospace Studies	Air Force ROTC
San Diego County	San Diego City College	2-Year	CNC Operator	Cert.
			CNC Technology	Cert.
			Advanced Electromechanical Technology	Cert.
			Mechanical Design	Cert.
			Advanced Mechanical Design	Cert.
			Advanced Mechanical Design	Cert.
			Advanced Manufacturing	Cert.
			Computer Numerical Control (CNC) Technology	Cert.
			Computer Aided Manufacturing (CAM)	Cert.
			Electronics Manufacturing	Cert.
			Fabrication Manufacturing	Cert.
			Manufacturing Engineering Technology	AS
			Computer Aided Manufacturing (CAM)	AS
	San Diego Miramar College	2-Year	Aviation Business Administration	AS
			Professional Aeronautics	AS
	National University	4-Year	Manufacturing Design Engineering	BS
			Cyber Security & Information Assurance	MS
			Engineering Management	MS
	Point Loma Nazarene University	4-Year	Engineering Physics	BS
	San Diego State University	4-Year	Aerospace Engineering	BS, MS
			Aerospace Studies	Minor
			Mechanical Engineering	BS, MS
	UC San Diego	4-Year	Mechanical & Aerospace Engineering	BS, MS, Joint Doctoral
	University of San Diego	4-Year	Mechanical Engineering	BS

BA=Bachelor's degree program; BS=Bachelor's of Science program; MA=Master's degree program; MS=Master's of Science program; AA=Associate's degree; AS=Associates of Science program
C/D=Certificate or diploma; Cert=Certification; Voc Cert=-Vocational Certificate
Excludes 2-year Pre-Engineering programs and 4-year General Engineering, Computer Science and Computer Science Engineering programs
Sources: Various; Compilation by LAEDC

About the Authors

The IAE team.

Christine Cooper, Ph.D.

Senior Vice President, LAEDC

Dr. Cooper leads both the LAEDC Institute for Applied Economics and the Kyser Center for Economic Research. Her work involves research in regional issues such as economic impact studies, regional industry analysis and forecasts, workforce development analysis and policy studies. Her fields of expertise include development economics, environmental economics, regional analysis and urban sustainability.

Prior to joining the LAEDC, Dr. Cooper was co-founder of a start-up company in Hong Kong concentrating on equity transactions software and computer accessories manufacturing, which expanded production into the special economic zone of Shenzhen, China and distributed products throughout the United States and Asia. She was a co-founder of the first authorized Apple Computer retailer in China. She has been a lecturer at California State University, Long Beach and at the Pepperdine Graziadio School of Business and Management.

Dr. Cooper is a citizen of the United States and Canada. She earned a Bachelor of Arts in Economics from Carleton University in Ottawa, Canada, and a Ph.D. in Economics from the University of Southern California. With funding from the National Science Foundation, she earned a Graduate Certificate in Environmental Sciences, Policy and Engineering.

Shannon M. Sedgwick

Economist

In her current capacity as an Economist at the LAEDC, Ms. Sedgwick develops subject-specific information and data interpretation for economic impact, demographic, transportation, industry and issue studies. She performs research, data collection and organization, analysis and report preparation. Her work focuses on demographics, industry clusters and occupational analysis. Ms. Sedgwick is also proficient at conducting geospatial analysis and has experience working with IMPLAN.

Ms. Sedgwick joined the LAEDC in June of 2008 as an Economic Research Assistant with the Kyser Center for Economic Research. In that role she assisted both Economic Research and the Consulting Practice of the LAEDC with data collection and research covering the State of California, Southern California and its counties.

Before joining the LAEDC, Ms. Sedgwick managed an industrial and steel supply company located in the Inland Empire. There she identified and targeted a diverse customer base, and analyzed product and customer patterns in the local industrial market to successfully increase revenues.

A Southern California native, Ms. Sedgwick received her Bachelor of Arts in Economics from the University of Southern California (USC) with a minor in Architecture.

Somjita Mitra, Ph.D.
Economist

Somjita Mitra joined the LAEDC Institute for Applied Economics as an Economist in June 2013. She is involved in planning, designing and conducting research and analysis for consulting clients and local businesses and governments, as well as for LAEDC's internal departments. Her focus is in regional analysis, economic impact studies and the industrial and occupational structure of local economies.

Before joining the LAEDC, Dr. Mitra was an Economist for a local economic research and litigation consulting company evaluating economic damages, estimating lost profits, identifying key economic issues and developing necessary analytical and empirical frameworks. Prior to this, Dr. Mitra was Project Director for a consumer research firm in Los Angeles where she managed projects that identified and analyzed key market issues for local firms as well as multinational corporations.

Dr. Mitra received her Bachelor of Arts in Economics and Political Science from the University of California, Los Angeles and her Master of Arts in Politics, Economics and Business as well as her Ph.D. in Economics from Claremont Graduate University. Dr. Mitra enjoys volunteering in the local community and is actively involved in both women's welfare and animal rescue organizations.

Wesley DeWitt
Research Analyst

Wesley DeWitt is a research analyst with the IAE, where he has contributed to industry cluster reports, workforce analysis and data visualization needs for the Institute's private and public sector clients.

Mr. DeWitt received undergraduate degrees in Economics and Environmental Science and Policy, and a master's degree in Geographic Information Science from California State University Long Beach.

Outside of the LAEDC, Mr. DeWitt provides GIS consulting services. His projects have included the statistical and spatial analysis of landfill air chemistry, the identification of spatial trends in the residential and commercial real estate market in Los Angeles, and the monitoring of humanitarian aid distribution in East Africa. His academic research uses geo-referenced social media data to plot and analyze trends in public health, equality, hate speech and issues of internet privacy.

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