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Unmanned Aircraft Systems (UAS): Commercial Outlook for a New Industry

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Summary

Unmanned aircraft systems (UAS)—commonly referred to as drones—have become a staple of U.S. military reconnaissance and weapons delivery in overseas war zones such as Afghanistan. Now some new technologies and pending federal regulations are enabling the manufacture and use of UAS in domestic commerce, giving rise to a growing commercial UAS industry.

Flying small, unmanned aircraft has been a hobbyists' pastime for decades. However, the Federal Aviation Administration (FAA) currently prohibits the use of UAS for commercial purposes, except where it has granted an exemption permitting specific activities. FAA has granted such exemptions since May 2014, primarily to firms wishing to use UAS for agricultural, real estate, film and broadcasting, oil and gas, and construction activities. As of September 2, 2015, it had granted more than 1,400 such exemptions. FAA also has authorized limited use of UAS within defined areas of Alaska, as required by the FAA Modernization and Reform Act of 2012 (P.L. 112-95).

Around 89 companies in the United States now produce UAS, which can range from hobbyist planes that fly on a single charge for about 10 minutes and cost under \$200 to commercial-level craft that can stay aloft much longer but can cost as much as \$10,000. Manufacture of the aircraft, known as unmanned aerial vehicles (UAVs), is relatively simple. The aircraft's basic elements include a frame, propellers, a small motor and battery, electronic sensors, Global Positioning System (GPS), and a camera. Some UAVs are operated by controllers, but others can be guided by the operator's smartphone or tablet. The widespread availability of electronic sensors, GPS devices, wifi receivers, and smartphones has reduced their cost, enabling manufacturers to enter the market without worrying about the supply of components. It has been estimated that, over the next 10 years, worldwide production of UAS for all types of applications could rise from \$4 billion annually to \$14 billion. However, the lack of a regulatory framework, which has delayed commercial deployment, may slow development of a domestic UAS manufacturing industry.

FAA announced a notice of proposed rulemaking in February 2015 that would permit UAS weighing less than 55 pounds to fly in limited circumstances and locations during the daytime, as long as there is a visual line of sight between the UAS and its operator, who would have to meet FAA standards and pass tests. Such rules, if adopted, would likely lead to limited commercial use of UAS, but would preclude the use of UAS for some purposes. FAA is not expected to announce final rules until 2016 or 2017.

The growth of UAS manufacturing and the rate at which UAS are deployed commercially are likely to be determined by technological and regulatory issues. FAA has approved establishment of six test sites to explore issues related to the integration of unmanned aircraft into the national airspace, but it is unclear whether those sites will provide information helpful to FAA rulemaking. Sense-and-avoid technology, critical to the safe operation of unmanned planes in crowded airspace, is not yet suitable for small, inexpensive UAS. In addition, concerns about privacy may delay expanded use of UAS by businesses and government agencies.

Contents

Introduction	1
Origin of Unmanned Aircraft Systems	1
UAS Manufacturing	2
Market Forecasts	6
Who Manufactures Commercial UAS?.....	7
Profile of Civil and Commercial UAV Uses.....	8
Agriculture	10
Real Estate.....	10
Utilities.....	10
Construction	10
Filmmaking	11
Local Law Enforcement and Public Safety Agencies	11
Factors Affecting Growth Prospects.....	11
FAA Testing Plans.....	12
Final Federal Drone Regulations.....	13
Privacy Concerns	14
Sense-and-Avoid and Airspace Management Technology	14

Figures

Figure 1. Basic Elements of a UAV.....	4
Figure 2. Potential Growth in Commercial Use of UAS.....	6
Figure 3. FAA’s UAS Research and Test Sites.....	12

Tables

Table 1. Types of UAVs in Commercial Operation.....	9
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Contacts

Author Contact Information	14
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Introduction

New technologies spawn new issues and industries. When the automobile was introduced more than 100 years ago, engine noise, speeding, reckless driving, collisions, and pedestrian fatalities were new problems requiring new solutions. It took more than a decade after the first motor vehicles were on the road for center lines to be painted on a highway to separate vehicles, for municipal ordinances to be passed regulating horn use, and for states to require vehicle licensing.¹ There were many manufacturers, each using unique components, and a wide range of steam, gasoline, and electric vehicles to choose from.

The commercial unmanned aviation industry is in its early days, raising a similar set of new legal and social issues and presenting a similar diversity of products. Unmanned aircraft systems (UAS) have the potential to bring many changes in the way businesses and government agencies operate. Even as companies and public-sector organizations are considering ways to make productive use of UAS, inventors are already at work on new generations of vehicles that may be able to not only fly, but also crawl up a wall, swim, or walk. These more sophisticated capabilities would permit a vehicle to more completely explore, provide search and rescue, or monitor an environmental site or natural disaster. A prototype of a Deployable Air Land Exploration Robot, which can fix its wings for flight and then turn the wings into legs for walking through rough terrain, is under development.²

UAS are now being produced and deployed in many countries. The rate of development in the United States will depend, in part, on the issuance of Federal Aviation Administration (FAA) regulations governing the operation of UAS by commercial and public-sector users. UAS development has been driven to date primarily by military applications, but that likely will soon change as commercial uses of UAS begin to take off.

Origin of Unmanned Aircraft Systems

An unmanned aircraft system comprises an aircraft with no onboard pilot, controlled from a remote operating station. The aircraft is sometimes referred to as an unmanned aerial vehicle (UAV) or a drone. Aviation experts distinguish three basic types of aircraft, other than missiles, that fly without onboard pilots: those that are

- steered from a remotely controlled position;
- reprogrammed and possibly controlled by onboard navigation systems that maintain altitude, direction, and location; and
- designed with limited flexibility and fly in a repetitive manner.³

The public's understanding of UAS has been shaped by military use of drone aircraft in overseas conflicts.⁴ Drones were first put to limited military use in World War I and then again in World

¹ *History of the American Auto* (Lincolnwood, Illinois: Publications International, Ltd., 2004), pp. 23, 60.

² Nick Adde, "Research in Motion: Finding New Ways to Move With Unmanned Technology," *Unmanned Systems*, Vol. 33, No. 4, April 2015, p. 38.

³ Paul Fahlstrom and Thomas Gleason, *Introduction to UAV Systems* (West Sussex, United Kingdom: John Wiley & Sons, 2012), p. 7.

⁴ The use of the word "drone" for such aircraft appears to have originated before World War II, when the U.S. Navy used unmanned aircraft for target practice. The British Royal Navy had named its unmanned target aircraft the Queen Bee, and so the U.S. Navy used the term "drone" for its targets, a reference to a type of male bee that does not do any (continued...)

War II.⁵ The U.S. military applied UAS technology for reconnaissance missions and some combat roles during the Vietnam conflict, and later in Operation Desert Storm and in Bosnia. UAS first became part of a weapons delivery system during wars in Iraq and Afghanistan and in antiterrorist activities by U.S. intelligence agencies.

The unmanned aircraft now being sold in the commercial and hobbyist marketplace do not generally look like military drones. The civilian industry is consciously seeking to use another terminology, such as UAS, to differentiate its product from the military version.

Following World War II, the nonmilitary UAS market was essentially a hobbyist market. Today there are more than 2,500 model airplane clubs and reportedly more than 175,000 members of the Academy of Model Aeronautics.⁶ Hobbyists are allowed to fly unmanned planes below 400 feet in areas not adjacent to airports. Federal law bars FAA from regulating their activities, except that the agency may act against hobbyists whose activities endanger manned aircraft or who operate their planes in prohibited airspace.

FAA currently prohibits the use of UAS for commercial purposes, except where it has granted an exemption permitting specific activities. This prohibition has proven difficult to enforce, in part because hobbyist UAVs may be physically identical to commercial ones; a hobbyist may legally fly a UAV equipped with a video camera, but the flight may retrospectively be deemed illegal if the resulting video is subsequently used for a commercial purpose. The use of UAVs for commercial purposes has not developed significantly largely because of FAA restrictions and the related lack of standards and protocols for flying such vehicles.⁷

UAS Manufacturing

Compared to a motor vehicle with more than 10,000 parts, a UAV is fairly simple to build. The main elements of a UAV are

- frame
- electronic speed controllers, which send signals to the motors
- motors
- battery
- flight controller
- radio and receiver
- propellers

UAVs are constructed of various materials including aluminum and composites, which make them lightweight and durable, two factors that enable them to withstand outdoor environments

(...continued)

work. Jack Nicas, “Why Some Drone Makers Hate the Word ‘Drone’ and Want to Change It,” *Wall Street Journal*, October 9, 2014, <http://www.wsj.com/articles/why-some-drone-makers-hate-the-word-drone-and-want-to-change-it-1412821801>.

⁵ During World War II, the Radioplane Company built thousands of small, remotely controlled UAVs that were used for aerial targets for gunnery practice. (One of Radioplane’s assemblers was Norma Jean Daugherty, who was later to change her name to Marilyn Monroe.) Paul Fahlstrom and Thomas Gleason, *Introduction to UAV Systems*, p. 4.

⁶ AMA was founded in 1936. http://www.modelaircraft.org/museum/ama_history.aspx.

⁷ As described later in this report, FAA is granting exemptions to allow limited UAS flights. As of September 2, 2015, it had granted more than 1,400 exemptions. http://www.faa.gov/uas/legislative_programs/section_333.

and the impact of rough landings. Composites are a growing share of UAV construction because they have a high strength-to-weight ratio and can easily be molded without expensive machinery or highly skilled workers.⁸ UAV parts are typically made with a sandwich technique in which a core material—usually lightweight polystyrene, polyurethane, aluminum honeycomb, or even balsa wood—is coated with an exterior skin such as aluminum or with composite laminates.

The UAV's skin provides much of the strength to the vehicle; multiple layers can be added to provide greater strength to specific parts. Resins, which bond the outer skin to the core materials, are used in UAV construction because they provide high strength and harden irreversibly when cured. The UAV fuselage assembly process has been described by industry analysts:

the most common construction practice is to cut the foam core to the desired shape either with a hot wire or with a saw.... The foam is then sealed to prevent too much absorption of the resin and a supply of resin is mixed. The resin is spread over the surface and a precut piece of reinforcing material (skin) is laid over the wet resin at the proper orientation. The liquid resin will seep through the skin material and the excess is removed. Layers of material are added in the specified direction and numbers to obtain the final laminate having the desired strength.⁹

The spread of new technologies is influencing the construction of drones. Major parts of UAVs have traditionally been assembled from components made of molded plastic, but the development of additive manufacturing, sometimes called 3-D printing, presents the option of printing UAV parts instead. The National Aeronautics and Space Administration (NASA) is using 3-D printing to develop drone prototypes that may someday be used to explore the surface of Mars.¹⁰ The U.S. and British navies are using 3-D printers to make customized UAVs, and have flown UAVs made aboard ship.¹¹ The commercial UAS market is exploring 3-D printing as well.

A number of the key components in UAS (**Figure 1**), such as electronic sensors, Global Positioning System (GPS) devices, and wifi receivers, and the smartphones and tablet computers used to control the aircraft, are also employed extensively for other purposes. This reduces unit costs and enables manufacturers to enter the market without worrying about the supply of components. A Parrot Bebop drone, for example, uses a GPS system to bring the drone back to its takeoff point; contains a navigation computer and eight gigabytes of flash memory; has dual-band wifi antennas that generate a wifi hot spot; and is operated with a smartphone or tablet. None of these is manufactured by Parrot, the company that produces and sells the drone.¹²

⁸ Paul Fahlstrom and Thomas Gleason, *Introduction to UAV Systems*, p. 96.

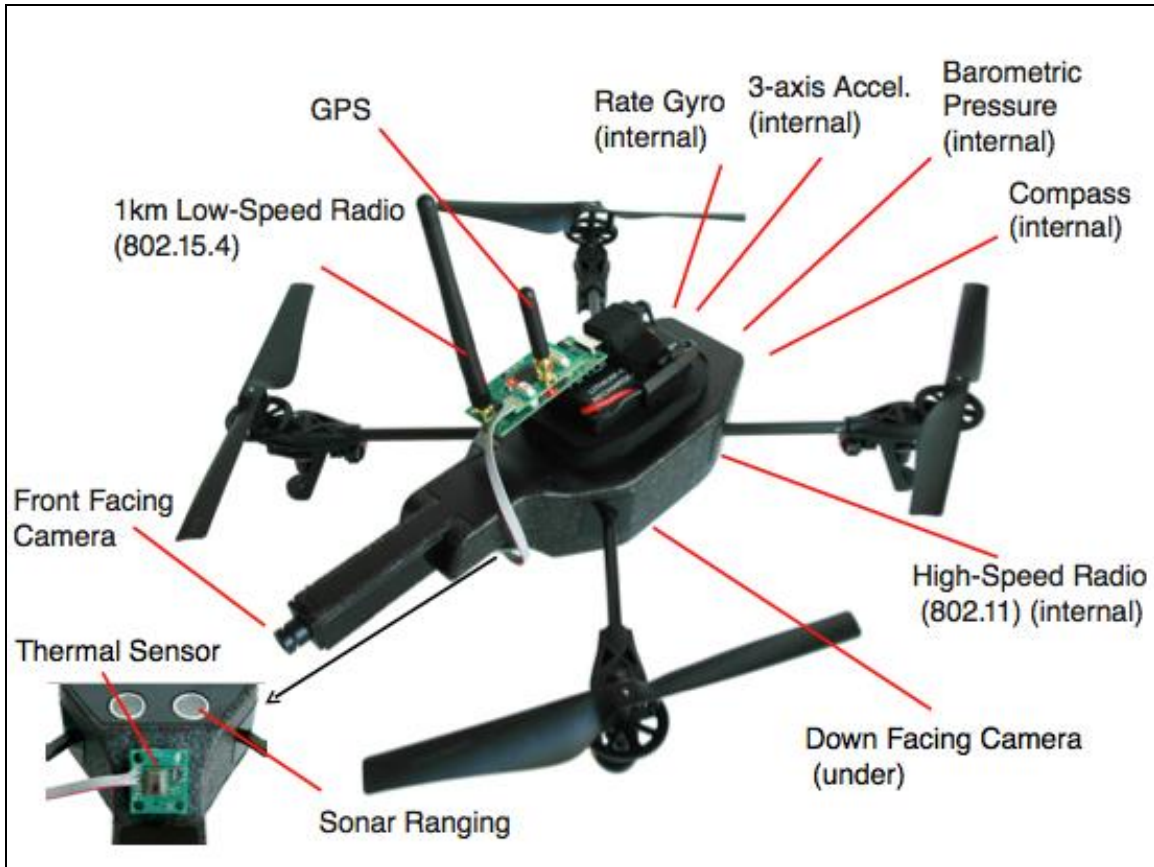
⁹ *Ibid.*, p. 98.

¹⁰ 3DPrint.com, *NASA 3D Prints Parts for Future Space Drones—May Explore Volcanoes on Mars or Asteroids*, August 3, 2015, <http://3dprint.com/86313/nasa-space-drones-3d-print/>.

¹¹ 3ders.org, *US Navy now 3D printing custom drones aboard ships*, July 30, 2015, <http://www.3ders.org/articles/20150730-us-navy-now-3d-printing-custom-drones-aboard-ships.html>.

¹² <http://www.parrot.com/uk/products/bebop-drone/>.

Figure 1. Basic Elements of a UAV



Source: Electrical and Computer Engineering Department, Carnegie Mellon University, <http://wise.ece.cmu.edu/redmine/projects/drone-rk/wiki>.

UAVs can be propelled by various types of engines. Larger craft often use two-cycle internal combustion engines powered by a gasoline/oil mixture, similar to those in lawn mowers, or four-cycle gasoline engines similar to automobile engines. Internal combustion engines, however, may produce excessive vibration, leading some manufacturers to prefer rotary engines or gas turbines. Some hobbyists have developed engines that run on diesel fuel or jet fuel, but these are generally not used in commercial production. Electric motors are increasingly popular for smaller UAVs, drawing energy from batteries,¹³ solar cells, or fuel cells.¹⁴

Most small UAVs on the market today use a series of horizontal propellers for lift, much as a helicopter, resulting in product names such as quadcopter or octocopter, depending on the number of propellers. The manufacturer may offer a controller unit, but increasingly operators control their craft through a smartphone or tablet, using software provided by the manufacturer.

¹³ The batteries may be nickel-cadmium, nickel-metal-hydride, lithium-ion or lithium-polymer. Paul Fahlstrom and Thomas Gleason, *Introduction to UAV Systems*, p. 85.

¹⁴ In a small UAV powered by a hydrogen fuel cell, the hydrogen gas stored in its hollow internal frame allows it to fly without a payload for up to four hours (compared to the half an hour a similar UAV with a small electric battery could fly). "World's First Fuel Cell Drone Unveiled," *The Maritime Executive*, May 13, 2015, <http://www.maritime-executive.com/article/worlds-first-fuel-cell-drone-unveiled>, and Kelsey Atherton, "Could This Hydrogen-Powered Drone Work?," *Popular Science*, May 22, 2015, <http://www.popsoci.com/could-hydrogen-fuel-cell-drone-work>.

The costs of UAS vary considerably, depending upon the product specifications and the uses to which the craft is to be put. The market and price points for military and commercial UAS are very different. One recent report¹⁵ identified distinct segments within the civilian drone market:

- Entry-level hobbyists pay up to \$500 for a UAS kit that includes the drone, four rotors, batteries, chargers, GPS, and spare propellers. Cameras are an added charge. These planes can fly for up to 10 minutes on a battery charge at up to 22 mph, with a range of about 150-200 feet. They are controlled by a smartphone or tablet.
- Consumers with a higher professional interest may pay \$750-\$2,000 for a kit that includes similar elements as a hobbyist kit, but with a UAV that can remain airborne for up to 25 minutes with a range of more than half a mile. These UAS may have more advanced cameras, and usually have a separate controller.
- Commercial users may pay \$10,000 or more for a UAV that has six rotors, larger propeller blades, or even an alternative configuration with wings. They are designed to carry a larger payload than the smaller UAVs and may have a battery capacity that would let them fly for up to an hour. Their controller software may include a database of no-fly zones to ensure the UAV does not get close to airports or other prohibited areas.

FAA Regulation of Civil and Commercial UAVs

Operations that do not meet the statutory criteria for a public (i.e., governmental) aircraft operation are considered a civil aircraft operation, and must be conducted in accordance with all applicable FAA regulations. There are presently two methods of gaining FAA authorization to fly civil (nongovernmental) UAS:

- Section 333 Exemption—a grant of exemption in accordance with Section 333 of the FAA Modernization and Reform Act of 2012 (P.L. 112-95) and a civil Certificate of Waiver or Authorization (COA). This process may be used to perform commercial operations in low-risk, controlled environments.
- Special Airworthiness Certificate (SAC)—applicants must be able to describe how their system is designed, constructed, and manufactured, including engineering processes, software development and control, configuration management, and quality assurance procedures used, along with how and where they intend to fly.¹⁶

In addition to these procedures for commercial operation of UAS, FAA announced a notice of proposed rulemaking in February 2015 that would permit UAS weighing less than 55 pounds to fly in limited circumstances and locations during the daytime, as long as there is a visual line of sight between the UAS and its operator. This rulemaking is still pending.¹⁷

As a commercial UAS market has developed, the systems have moved well beyond hobbyist craft to more sophisticated types of planes. Product development will likely accelerate once FAA issues rules governing commercial drone use, and especially if it eventually permits nighttime flights and flights beyond the operator's line of sight. The types of systems that are sold may depend upon the details of FAA regulations, especially if other countries adopt similar rules. For example, FAA has indicated that each UAV should have a human controller and that each controller should operate only one aircraft at a time. This might lead to different technical

¹⁵ Deloitte Touche Tohmatsu Limited, *Drones: High-Profile and Niche*, 2015.

¹⁶ Summarized and excerpted from Federal Aviation Administration, *Unmanned Aircraft Systems*, Civil Operations (Non-Governmental), https://www.faa.gov/uas/civil_operations/.

¹⁷ The proposed rulemaking may not be finalized until late 2016 or early 2017. The terms of the proposal are summarized at https://www.faa.gov/regulations_policies/rulemaking/media/021515_sUAS_Summary.pdf.

considerations, costs, and deployments than if an automated system could use a computer to control multiple UAVs.

Figure 2 shows one analyst’s forecast of how the commercial capability might unfold.

Figure 2. Potential Growth in Commercial Use of UAS



Source: Timeline developed by CyPhy Works Inc. and reported in DroneLife.com, April 8, 2014, <http://dronelife.com/2014/04/08/greiner-2015-the-year-of-the-protecting-and-inspecting-drone>.

Market Forecasts

The economic impact of UAS is tracked by a number of industry groups and private consulting firms. Their forecasts concerning the outlook for drone manufacturing and sales vary widely.

IBISWorld estimates that of the \$3.3 billion in revenue generated in the United States by all UAS sales in 2015 (military, civil, and commercial), the civil and commercial segments will account for about 3.8%, or about \$125 million.¹⁸ It calculates that drone manufacturers currently employ about 8,300 U.S. workers. IBISWorld predicts that the U.S. market will grow to \$4.3 billion by 2020, with just under 10,000 jobs.¹⁹

Deloitte estimates that this year about 300,000 nonmilitary UAVs will be sold worldwide (resulting in more than 1 million in consumers’ hands), with projected revenues of \$200-\$400 million. The report adds, “We are not foreseeing a breakthrough year for drones in 2015.”²⁰

On the other hand, the Teal Group, a U.S. aerospace consulting firm, sees a strong growth potential. It believes UAVs are “the most dynamic growth sector of the world aerospace industry,” and “new unmanned combat aerial vehicle programs, commercial, and consumer

¹⁸ Maksim Soshkin, *Unmanned Aerial Vehicle (UAV) Manufacturing in the US*, IBISWorld, OD4424, April 2015, p. 15. The IBISWorld report on UAS says that the other shares of the 2015 UAS market are accounted for by the U.S. Navy (36%), U.S. Air Force (34%), U.S. Army (15%), U.S. Marines (2.4%), and other defense markets (9%).

¹⁹ Ibid., p. 35.

²⁰ Deloitte Touche Tohmatsu Limited, *Drones: High-Profile and Niche*, 2015.

spending all promise to drive more than a tripling of the market over the next decade.”²¹ Teal Group predicts that over the next 10 years, worldwide UAS production will rise from \$4 billion annually to \$14 billion.²² The consultants forecast that the United States will account for 64% of research and development spending and 38% of military procurement spending.

A commercial drone report from *Business Insider* predicts that the commercial and civil UAS market will pick up slack from declining military spending on drones, growing at a compound annual growth rate of 19% over the next five years, compared to growth in the U.S. military’s drone spending of about 5%.²³

Who Manufactures Commercial UAS?

There are about 89 U.S. manufacturers of UAS, including large defense-related manufacturers such as Boeing, Lockheed Martin, Northrop Grumman, and Sikorsky Aircraft.²⁴ To date, however, the defense manufacturers appear to have a relatively small role in the civilian market, which is currently dominated by small, battery-powered drones targeted at hobbyists and for some nascent commercial uses.

The largest manufacturer of commercial UAS is SZ DJI Technology Co. (DJI), based in Shenzhen, China. The founder of the company developed ways to provide an internal stabilization system that makes the machines easier to fly and navigate. While DJI started out with hobbyist drones, it has moved into other models. Its Phantom drone, selling for around \$1,000, is popular around the world for filmmaking and aerial photography and in humanitarian rescue after natural disasters.²⁵

The second-largest UAS maker is reportedly Parrot SA, which dominates the lower-end consumer marketplace. Its inexpensive drones can be purchased at retail outlets and generally sell for under \$500. Based in France, Parrot also markets a \$25,000 UAS called the eBee, a hand-launched battery-powered drone used for monitoring agricultural crops and surveying construction projects.²⁶

Several smaller companies have also drawn attention:

- AeroVironment is a California technology company that manufactures smaller drones, such as the Nano Hummingbird, which is shaped like its tiny namesake and is designed for urban surveillance. The drone, weighing less than an ounce, can hover silently for more than eight minutes and relay live videos to a control

²¹ The Teal Group has released worldwide UAS market analyses annually, but the 2015 report is the first to include consumer UAV projections because of the rapid growth of that segment. Teal Group Corporation, *Teal Group Predicts Worldwide UAV Production Will Total \$93 Billion in its 2015 UAV Market Profile and Forecast*, August 14, 2015, <http://www.prnewswire.com/news-releases/teal-group-predicts-worldwide-uav-production-will-total-93-billion-in-its-2015-uav-market-profile-and-forecast-300128745.html>.

²² Teal Group forecasts that worldwide R&D for military UAS will add \$30 billion in spending during the decade.

²³ Business Insider Intelligence, *The Drones Report: Market Forecasts, Regulatory Barriers, Top Vendors, and Leading Commercial Applications*, May 27, 2015, <http://www.businessinsider.com/uav-or-commercial-drone-market-forecast-2015-2>.

²⁴ <http://www.uavglobal.com>.

²⁵ Jack Nicas and Colum Murphy, “Who Builds the World’s Most Popular Drones?” *Wall Street Journal*, November 10, 2014.

²⁶ Jack Nicas, “Low-Cost Drone Maker Takes on Rivals,” *Wall Street Journal*, July 7, 2015.

station miles away. The company also makes the Puma, a military system that has been certified by FAA for use by an oil company in the Arctic.²⁷

- 3D Robotics was founded initially to serve UAS do-it-yourself hobbyists, its predecessor company being called DIYDrones.com. Since it began design and production in 2012, it has grown rapidly and is now rated as the third-largest drone manufacturer in the world.²⁸ It has also partnered with Intel, Linux, and Qualcomm to found the Dronecode Foundation to encourage the development of open-source consumer and commercial UAS software.²⁹
- Titan Aerospace is a drone startup that makes large, high-altitude UAVs. It was acquired by Google in 2014. Google has announced that it would like to use a network of UAVs to bring the Internet to remote places, as well as to assist with its mapping initiative.³⁰ The wingspan of the planned Titan Solara 50 UAV would be larger than a Boeing 767's. The craft would be solar-powered and fly 12 miles above the ground.
- Aurora Flight Sciences is a 25-year-old Virginia-based company that designs and manufactures UAS for military and commercial purposes. In June 2015, its large, optionally piloted, fixed-wing Centaur³¹ was flown for the first time at an FAA-designated UAS test site in upstate New York.

In addition to these manufacturers, several large U.S. technology companies have made it clear they intend to become developers of specialized UAS. For example, Amazon has said it is working on a delivery drone that could one day deliver a package to a customer in 30 minutes or less. Facebook has teamed up with Ascenta, a British manufacturer of solar-powered UAS, to build a medium-altitude drone that could fly for months or even years, with a goal to expand Internet service around the world.³² Neither UAS would be permitted under current FAA regulations, which require UAVs to fly within the operator's line of sight at altitudes below 400 feet.

Profile of Civil and Commercial UAV Uses

In May 2014, FAA began accepting requests for exemptions from its ban on commercial UAV flights, permitting a wide range of commercial enterprises to begin use of UAVs. An industry group, the Association for Unmanned Vehicle Systems International (AUVSI), reviewed the

²⁷ Murray Newlands, "6 Drone Companies to Look Out For in 2015," *inc.com*, February 12, 2015.

²⁸ Jack Nicas and Colum Murphy, "Who Builds the World's Most Popular Drones?," *Wall Street Journal*, November 10, 2014.

²⁹ <http://opensource.com/life/15/7/the-dronecode-foundation>.

³⁰ Murray Newlands, "6 Drone Companies to Look Out For in 2015," *inc.com*, February 12, 2015.

³¹ An optionally piloted UAS can operate as a regular, manned plane, and be quickly converted to a UAS. It could be flown as a manned aircraft to a firefighting staging area, where it could be converted to a UAS to fly riskier aerial surveillance. <http://aviationweek.com/awin/flying-centaur-optionally-piloted-aircraft>.

³² Sally French and Benjamin Pimentel, "13 Cutting-edge drone companies you should know," *MarketWatch.com*, June 25, 2014.

1,500 petitions filed in the first year and the 500 exemptions granted.³³ The report provides the first factual insights on the potential interest in commercial uses of UAS.³⁴

The first 500 exemptions granted by FAA and reviewed by AUVSI were made to more than 20 major industries, with real estate, aerial surveying, aerial photography, agriculture, and aerial inspection being the top five categories mentioned in approved applications. More than 80% of the applicants were small businesses; among the large companies receiving exemptions were Chevron, Amazon, and Dow Chemical. California, Texas, and Florida were the top three states where operators received exemptions, although exemptions were provided to operators in 48 states altogether.

The 681 platforms approved by FAA had a total cost of \$6.6 million. Of these platforms, 114 (about 15%) were sourced from U.S. manufacturers. China was the source of the largest number of platforms—446. However, the AUVSI analysts concluded that Chinese platforms were of low-end or consumer UAVs; their total value was \$895,000, compared with the \$1.9 million value of U.S.-made platforms. Looking at the domestically sourced platforms, 21 states made UAVs, but the largest number were made in California (50), Florida (18), and North Carolina (11). As shown in **Table 1**, the average weight of approved drones varies from about 5 pounds for real estate use up to more than 12 pounds for film and television recording. The duration of the flights of these UAVs also varies, with oil and gas industry inspection UAVs operating for more than an hour and a half.

Table 1. Types of UAVs in Commercial Operation

First 500 Exemptions Approved by FAA, May 2014-June 2015

Industry	UAV Platforms Approved Through FAA Exemptions	
	Average Weight (in pounds)	Average Endurance (in minutes)
Agriculture	9.14	37.59
Real estate	5.37	23.1
Film and TV	12.39	19.05
Oil and gas	9.83	97.4
Construction	7.22	26.85

Source: Scott Kesselman and David Klein, *Snapshot of the First 500 Commercial UAS Exemptions*, Association for Unmanned Vehicle Systems International (AUVSI), July 2015.

FAA has also established two other UAS programs that may expand its understanding of commercial use of UAS. The Pathfinder Program will experiment with flying UAS beyond the line of sight. The agency has permitted BNSF Railway Co. to use UAS to inspect track and monitor trains, and PrecisionHawk to learn how farmers can efficiently use UAS.³⁵ Separately, the 2012 FAA reauthorization legislation required FAA to create permanent areas in the Arctic within which small UAS may operate for research and commercial purposes. The agency has

³³ As of September 2, 2015, FAA had granted more than 1,400 exemptions. FAA regularly updates the number of exemptions on its website; see https://www.faa.gov/uas/legislative_programs/section_333.

³⁴ Scott Kesselman and David Klein, *Snapshot of the First 500 Commercial UAS Exemptions*, Association for Unmanned Vehicle Systems International (AUVSI), July 2015, <http://auvsilink.org/advocacy/Section333.html>.

³⁵ Federal Aviation Administration, “FAA-Industry Initiative Will Expand Small UAS Horizons,” press release, May 6, 2015, https://www.faa.gov/news/press_releases/news_story.cfm?newsId=18756.

granted permits to oil companies ConocoPhillips and BP to test drones in those areas for conducting marine mammal and ice surveys necessary to meet environmental and safety rules prior to sea floor drilling.³⁶

Agriculture

Some observers believe that agriculture will be one of the first industries to utilize UAVs widely because flights over farm fields pose low risk to aircraft in flight or people and property on the ground. Drones have potential applications in precision agriculture, which involves the use of detailed data on soils, crops, nutrients, pests, moisture, and yield to increase farm productivity. Cameras aboard drones, for example, might provide infrared imagery that could identify the precise locations of weed emergence or insect infestations, enabling farmers to respond in a targeted fashion rather than treating acreage unnecessarily. The American Farm Bureau has forecast that farmers using drone services to monitor their crops could see a return on investment of \$12 per acre for corn, \$2.60 per acre for soybeans, and \$2.30 per acre for wheat.³⁷ Eventually, farmers might use UAVs for targeted application of herbicides and pesticides.

Real Estate

Real estate brokers already use UAV photography to replace more expensive images formerly captured by helicopters, although at present such a commercial use of UAS is generally prohibited by FAA. In addition to images of residential real estate, UAVs likely will be used to capture the scale and details of large commercial parcels such as office parks, malls, and undeveloped land. UAVs could potentially become a routine property maintenance tool, being used to inspect properties after storms or vandalism.

Utilities

Utilities are expected to utilize UAVs for inspection, surveying, and surveillance of the electrical system and pipelines. Utilities, especially, see the value of UAVs in organizing repairs after natural disasters, when roads may be impassable. UAVs also offer a way to monitor transmission lines, towers, and substations, often located in remote areas. The Edison Electric Institute, a utility trade group, suggests UAVs could improve worker safety, as scaffolding and ropes now used to inspect generating facilities could be largely replaced with remotely controlled UAVs.³⁸

Construction

The initial uses of UAVs in construction are likely to involve inspection work and mapping. More accurate topographical mapping could lead to more accurate project designs, reducing the number of expensive changes made in the field during the construction process. Worker safety would be improved by removing some of the high-elevation inspections now done with lifts or scaffolding, such as inspecting caulking joints in a tall building's envelope. The Associated General Contractors of America suggests that UAVs could document the progress of projects, providing a

³⁶ Federal Aviation Administration, "UAS in the Arctic," press release, August 18, 2015.

³⁷ American Farm Bureau Federation and Measure/Informa Economics, *Fact Sheet: Quantifying the Benefits of Drones in Precision Agriculture*, July 21, 2015.

³⁸ Edison Electric Institute, *Unmanned Aircraft Systems (UAS)*.

visual record that could reduce later disputes between contractors and landowners, and could eventually be used to carry tools and equipment from one location to another.³⁹

Filmmaking

Some films made abroad have been shot in part with video cameras aboard UAVs, even as similar use of drones has not been permitted in the United States.⁴⁰ The Motion Picture Association of America (MPAA) received an exemption from FAA so drones may be used in U.S. film production as well, contending that the exemption will ensure more domestic film production. The industry argued that it was an appropriate industry in which to begin using UAVs because filming occurs in tightly controlled locations. Drones used for this purpose are generally owned and operated by specialized aerial photo and video production contractors.

Local Law Enforcement and Public Safety Agencies

It has been estimated that domestic law enforcement agencies may purchase as many as 20,000 UAS annually by 2025.⁴¹ Law enforcement agencies are buying drones for use in possibly dangerous situations such as executing high-risk warrants, responding to barricaded subjects, locating missing persons, or responding to natural disasters. Local news stories routinely feature reports about police departments' new drone purchases. In addition, first responders may find UAS helpful in learning earlier about details of a fire or in assessing a hazardous waste spill on a major highway.

Use of drones by local law enforcement and public safety agencies has been controversial in some places. The American Civil Liberties Union has raised questions about the compatibility of law enforcement use of UAS with the Fourth Amendment to the U.S. Constitution, which prohibits unreasonable search and seizure.⁴² In many places, local groups have also objected to proposed uses of drones, or called for guidelines limiting the ways in which they may be employed. Law enforcement and public safety use of UAS may grow more slowly than forecasts indicate until such concerns are addressed at the state or local level; 20 states have enacted privacy legislation pertaining to UAS flights.

Factors Affecting Growth Prospects

Three regulatory issues and a technology challenge are likely to affect the growth of a domestic UAS industry: FAA drone testing plans; final FAA regulations governing the industry; privacy concerns; and improvements in sense-and-avoid and airspace management technologies.

³⁹ Associated General Contractors of America, *Notice of Proposed Rulemaking on Operation and Certification of Small Unmanned Aircraft Systems*, Docket No. FAA-2015-0150, April 24, 2015, p.3.

⁴⁰ For example, in the 2012 James Bond film *Skyfall*, a motorcycle chase across Istanbul rooftops was filmed with UAVs. Jeremy Coward, "3 Cool Clips Filmed By Drone Technology," *Totally Unmanned*, September 16, 2014, pp. <http://www.totallyunmanned.com/2014/09/16/3-cool-clips-filmed-by-drone-technology/>.

⁴¹ Michelle Bond, "Drones give law enforcement a new edge, but also raise concerns," *Philadelphia Inquirer*, August 11, 2015, http://articles.philly.com/2015-08-11/news/65419438_1_drone-use-law-enforcement-agencies.

⁴² Neema Singh Guliani, *Unchecked Government Drones? Not Over My Backyard*, American Civil Liberties Union, March 24, 2015, <https://www.aclu.org/blog/unchecked-government-drones-not-over-my-backyard>.

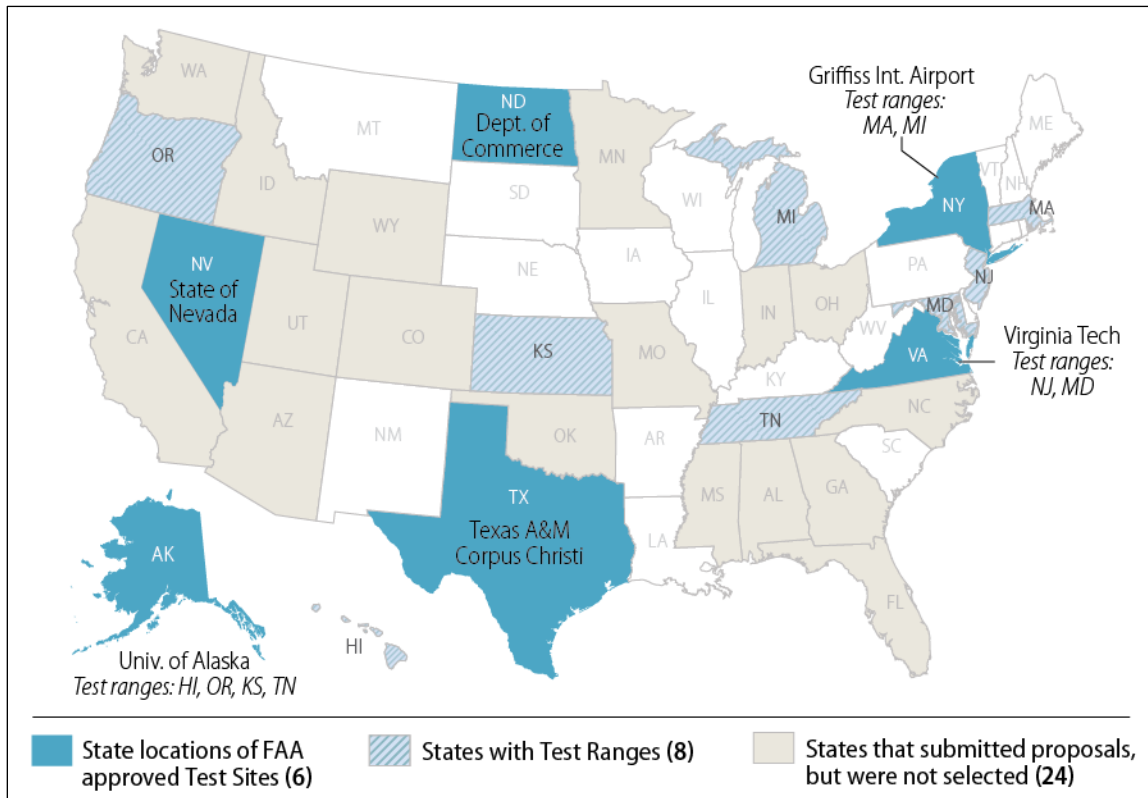
FAA Testing Plans

The FAA Modernization and Reform Act of 2012 directed FAA to select six sites to study how UAS could be integrated into the national airspace system.⁴³

The six sites, which receive no federal funding, were announced in December 2013 (see **Figure 3**). Some 25 states bid to host them,⁴⁴ often under the presumption that a test site would bring additional investment and employment. For example, Nevada Governor Brian Sandoval said, “It could mean billions of dollars in new investment, thousands of technical jobs for our state. It [would] make us an anchor tenant in a new and growing industry.”⁴⁵

A recent report by the Government Accountability Office (GAO) suggested that the site operators are unclear about the type of research they are to conduct. Nonetheless, despite problems in attracting UAS industry participation, the sites conducted 195 test flights in their first year.⁴⁶ The research conducted by the test sites will continue until 2017, but if FAA does not glean useful data from these tests, regulations permitting UAS activities may be delayed or limited in scope.

Figure 3. FAA’s UAS Research and Test Sites



Source: Federal Aviation Administration, Unmanned Aircraft Systems Office.

⁴³Federal Aviation Administration, “FAA Selects Unmanned Aircraft Systems Research and Test Sites,” press release, December 30, 2013, https://www.faa.gov/news/press_releases/news_story.cfm?newsid=15576.

⁴⁴ Only 24 proposals were made because Indiana and Ohio made a joint proposal.

⁴⁵ Reid Wilson, “FAA Picks six states for drone testing,” *Washington Post*, December 30, 2013.

⁴⁶ U.S. Government Accountability Office, *Unmanned Aerial Systems: FAA Continues Progress toward Integration into the National Airspace*, GAO-15-610, July 2015.

The test site sponsors and their research goals are the following:

- The *University of Alaska* is conducting UAS research in seven climatic zones, including locations in Hawaii and Oregon, and will develop standards for unmanned aircraft categories, safety, state monitoring, and navigation.
- The *state of Nevada* is concentrating on UAS standards and operations, operator standards, and certification requirements. The research will also evaluate the evolution of air traffic control procedures as UAS are integrated into the civil environment, and how these aircraft will be integrated with FAA's satellite-based Next Generation Air Transportation System, which is under development.
- *New York's Griffiss International Airport* is focusing on developing UAS test and evaluation processes under FAA safety oversight, and sense-and-avoid capabilities for UAS. Its sites in New York, Massachusetts, and Michigan will research the complexities of integrating UAS into the congested northeastern airspace.
- The *North Dakota Department of Commerce* is developing UAS airworthiness essential data to validate types of UAS technology.
- *Texas A&M University—Corpus Christi* is developing safety requirements for UAS vehicles and operations, with a goal of protocols and procedures for airworthiness testing.
- *Virginia Polytechnic Institute and State University (Virginia Tech)* is conducting UAS failure mode testing and identifying and evaluating operational and technical risk areas, using locations in Virginia and New Jersey.

Final Federal Drone Regulations

In February 2015, FAA issued a notice of proposed rulemaking as a step toward regulations that will spell out safety rules for nonrecreational UAS under 55 pounds. The notice proposes to limit flights to daylight hours and visual-line-of-sight operations. FAA also proposes to require a single operator for each drone, which could limit the commercial viability of some potential uses of UAS. The notice also specifies height restrictions, operator certification requirements, optional use of a visual observer, aircraft registration and marking, and operational limits. Final rules may not be issued by FAA until late 2016 or early 2017.

GAO has found that a number of other countries are moving ahead with final regulations pertaining to commercial use of UAS, including Australia, Canada, France, and the United Kingdom.⁴⁷ This has introduced a competitive dimension that is luring some U.S. companies to conduct research abroad. Amazon, for example, tested a package delivery drone in Canada,⁴⁸ while Google is doing something similar in Australia.⁴⁹

⁴⁷ GAO-15-610, pp. 29-30. Canada's and Australia's UAS regulations have been in place for more than a decade.

⁴⁸ Ed Pilkington, "Amazon tests delivery drones at secret Canada site after US frustration," *The Guardian*, March 30, 2015, <http://www.theguardian.com/technology/2015/mar/30/amazon-tests-drones-secret-site-canada-us-faa>.

⁴⁹ Konstantin Kakaes, "Why Is America Losing the Commercial Drone Wars?," *washingtonmonthly.com*, August 2015.

Privacy Concerns

Although several bills addressing privacy have been introduced in Congress, the FAA Modernization and Reform Act included no language concerning the privacy implications of UAS flights, and Congress has subsequently enacted no new laws on the subject. FAA did not include privacy principles in its proposed rule on small UAS. President Obama has issued a memorandum directing federal agencies to look at privacy guidelines with regard to UAS.⁵⁰ There are two principal privacy issues associated with commercial use of UAS: defining what privacy means in the context of aerial systems and selecting a government entity to oversee such issues. Progress in addressing these issues may affect the rate at which the commercial UAS industry develops.⁵¹

Sense-and-Avoid and Airspace Management Technology

FAA is understandably concerned about UAS that may crash into buildings, other aircraft, or people and objects below a flying drone. To address those concerns, proposed rules would require the operator to maintain a line of sight with the aircraft. This “see-and-avoid” restriction—cited in FAA’s proposed UAS regulations as “one of the fundamental principles for collision avoidance”⁵²—would limit the range of UAS and prevent the deployment of more sophisticated UAS that could operate over longer distances.

“Sense-and-avoid” technologies under development could overcome the current limitations through use of radar and electronic systems. A technology called automatic dependent surveillance-broadcast (or ADS-B), to be required on airliners by 2020, offers sense-and-avoid capabilities, but it is currently too large and expensive for UAS. Google and a Bellevue, WA, company are separately working on small, lightweight versions of ADS-B and radar scanning, two sense-and-avoid technologies that would be more appropriate for drone use. Such technologies could allow UAVs to fly in congested airspace, potentially broadening their commercial applications.

As part of the overall integration of UAS into the national airspace, it will be necessary to establish the technology and infrastructure for a UAS traffic management system for low-altitude airspace. NASA is leading research, development, testing, and implementation of the system.⁵³

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⁵⁰ White House, “Presidential Memorandum: Promoting Economic Competitiveness While Safeguarding Privacy, Civil Rights, and Civil Liberties in Domestic Use of Unmanned Aircraft Systems,” press release, February 15, 2015, <https://www.whitehouse.gov/the-press-office/2015/02/15/presidential-memorandum-promoting-economic-competitiveness-while-safegua>.

⁵¹ For more information on UAS privacy issues, see CRS Report R43965, *Domestic Drones and Privacy: A Primer*, by (name redacted).

⁵² Federal Aviation Administration, “Notice of Proposed Rulemaking, Operation and Certification of Small Unmanned Aircraft Systems,” 80 FR 9543 *Federal Register*, February 23, 2015.

⁵³ NASA, *NASA UTM 2015: The Next Era of Aviation*, <http://utm.arc.nasa.gov/index.shtml>.

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