UAV (Drones) UNIT PLAN

Compelling Question	**To what extent have Unmanned Aerial Vehicles (UAVs) been used to benefit humanity?**
Standards and Practices	*C3 Historical Thinking Standards* – D2.Civ.13.9-12. Evaluate public policies in terms of intended and unintended outcomes, and related consequences. *C3 Historical Thinking Standards* – D2.His.1.9-12. Evaluate how historical events and developments were shaped by unique circumstances of time and place as well as broader historical contexts. *C3 Historical Thinking Standards* – D2.His.2.9-12. Analyze change and continuity in historical eras. *C3 Historical Thinking Standards* – D4.1.9-12. Construct arguments using precise and knowledgeable claims, with evidence from multiple sources, while acknowledging counterclaims and evidentiary weaknesses. *Common Core Content Standards* – CCSS.ELA-LITERACY.WHST.9-10.1.B Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form and in a manner, that anticipates the audience's knowledge level and concerns.
Staging the Question	What are UAVs and how have they been used throughout history?

Supporting Question 1	**Supporting Question 2**	**Supporting Question 3**	**Supporting Question 4**
What is a UAV (and UAS) and what are its component technologies?	What are the historical origins of UAV-related technologies?	How have UAVs been used in military and non-military applications throughout history?	How might UAVs be used in military and non-military applications in the near and distant future?
Formative Performance Task	**Formative Performance Task**	**Formative Performance Task**	**Formative Performance Task**
Design an ad for a modern UAV and label its component technologies.	Create a "family tree" for a modern UAV (UAS). Trace the roots of its related technologies.	Develop a timeline showing specific UAVs from throughout history.	Create a mock company or non-profit organization that uses UAVs to accomplish its mission. Detail your mission and

			illustrate exactly how you will use the technology to accomplish it.
Featured Sources	**Featured Sources**	**Featured Sources**	**Featured Sources**
1A. FAA. "Fact Sheet – Unmanned Aircraft Systems (UAS)." September 19, 2014. Accessed March 25, 2017. https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=18297. 1B. Brock, David C. "How William Shockley's Robot Dream Helped Launch Silicon Valley." *IEEE Spectrum:* Technology, Engineering, and Science News. November 29, 2013. Accessed July 23, 2017. http://spectrum.ieee.org/at-work/innovation/how-william-shockleys-robot-dream-helped-launch-silicon-valley 1C. Mineses, Eric Larson & Christopher. "Not All Drones Are Created Equal." Mashable. November 21, 2014. Accessed May 14, 2017. http://mashable.com/2014/11/21/drone-infographic/?utm_cid=mash-com-pin-link&crlt.pid=camp.d1UXkSAQun65#zD7Ic8cMFkqG. 1D. Perlman, Alan. "Infographic: How Do	2A. Chevedden, Paul E. "The Hybrid Trebuchet: The Halfway Step to the Counterweight Trebuchet." *On the Social Origins of Medieval Institutions* (1998): 179-222. 2B. Darack, Ed. "A Brief History of Unmanned Aircraft." *Air & Space Magazine*. May 17, 2011. Accessed March 25, 2017. http://www.airspacemag.com/photos/a-brief-history-of-unmanned-aircraft-174072843/. 2C. Keane, John F., and Stephen S. Carr. "A Brief History of Early Unmanned Aircraft." *Johns Hopkins APL Technical Digest* 32, no. 3 (2013): 558-571. https://pdfs.semanticscholar.org/ed38/531575cf6fce272fd3d88ebe06f9775b021f.pdf. 2D. Winter, Frank H. *Prelude to the Space Age: The Rocket Societies, 1924-1940*. Washington D.C.: Smithsonian Institution Pr. in Komm., 1984. Accessed April 6, 2017. https://archive.org/details/preludetospaceag00wint. 2E. Naughton, Russell.	3A. Keane, John F., and Stephen S. Carr. "A Brief History of Early Unmanned Aircraft." *Johns Hopkins APL Technical Digest* 32, no. 3 (2013): 558-571. https://pdfs.semanticscholar.org/ed38/531575cf6fce272fd3d88ebe06f9775b021f.pdf. 3B. Rogers, J. David, PhD. "Japanese Vengeance Balloon Bombs of World War II." Accessed May 06, 2017. http://web.mst.edu/~rogersda/forensic_geology/Japenese%20vengenance%20bombs%20new.htm. 3C. Terwilliger, Brent, Dennis Vincenzi, and David Ison. "Unmanned Aerial Systems: Collaborative Innovation to Support Emergency Response." *Journal of Unmanned Vehicle Systems* 3, no. 2 (February 2015): 31-34. Accessed May 7, 2017. doi:10.1139/juvs-2015-0004. 3D. Blom, John David. *Unmanned Aerial Vehicles: A Historical Perspective*. Fort Leavenworth, KS: Combat Studies Institute Press, 2010. 3D. "Research Guides:	4A. Ackerman, Evan. "Swarms of Disposable Drones Will Make Critical Deliveries and Then Vanish." *IEEE Spectrum:* Technology, Engineering, and Science News. February 01, 2017. Accessed March 25, 2017. http://spectrum.ieee.org/automaton/robotics/drones/otherlab-apsara-aerial-delivery-system. 4B. Terwilliger, Brent, Dennis Vincenzi, and David Ison. "Unmanned Aerial Systems: Collaborative Innovation to Support Emergency Response." *Journal of Unmanned Vehicle Systems* 3, no. 2 (February 2015): 31-34. Accessed May 7, 2017. doi:10.1139/juvs-2015-0004. 4C. Campana, Stefano. "Drones in Archaeology. State-of-the-art and Future Perspectives." *Archaeological Prospection*, 2017. Accessed May 13, 2017. doi:10.1002/arp.1569. 4D. Morrison, Alan. "A Look at Drones as a Data Service (infographic)." Next in Tech. February 06, 2017. Accessed May 14, 2017. http://usblogs.pwc.com/e

Drones Work?" UAV Coach. September 14, 2016. Accessed July 22, 2017. https://uavcoach.com/infographic-drones-work/	"RPAV: Remote Piloted Aerial Vehicles." Hargrave -- Aviation and Aeromodelling: Interdependent Evolutions and Histories. August 3, 2007. Accessed July 22, 2017. http://www.ctie.monash.edu.au/hargrave/rpav_radioplane.html 2F. O'Malley, Dave. "The Mother of All Drones." Vintage Wings of Canada. 2013. Accessed July 22, 2017. http://www.vintagewings.ca/VintageNews/Stories/tabid/116/articleType/ArticleView/articleId/484/The-Mother-of-All-Drones.aspx	Government Resources: Defense, Military, and Security: Drones (Military)." University Libraries -- University of Louisville. Accessed May 14, 2017. http://library.louisville.edu/ekstrom/gov_defense/dronesmil 3F: *Drones from the Civil war to Today (04:43min)*	merging-technology/a-look-at-drones-as-a-data-service-infographic/.

Summative Performance Task	**Argument**	Write a thesis essay that directly addresses the compelling question using specific claims and relevant evidence from historical sources to support your claims while acknowledging competing views.
	Extension	Debate whether UAVs have been primarily a benefit or a detriment to humanity.
Taking Informed Action	**UNDERSTAND:** Research one future use of UAVs being developed currently. **ASSESS:** To what extent will this future application of UAVs benefit humanity. **ACTION:** Based on your assessment of its future impact on humanity, develop a marketing campaign to either promote or oppose this intended application of UAVs.	

TO THE TEACHER

All *REACH* Instructional Units are intended to be "classroomE ready." Each unit begins with a *Unit Plan* in the form of a *C3 Inquiry Design Model*. The *Unit Plan* includes learning objectives, content standards, formative and summative tasks, links to primary and secondary resources, and a warm-up activity.

Units are organized around a *Compelling Question* designed to inspire curiosity and promote discussion among students. To that end, we have also included a brief student introduction to the topic entitled, *Staging the Question*. Once students have been introduced to the topic, any number of *Formative Performance Tasks* may be completed using the included *Document Excerpts* (teachers may elect instead to utilize full-text documents linked within the *Featured Sources* section). *Document Excerpts* are print-ready in single-sheet format and keyed to the citations in the *Featured Sources* section of the *Unit Plan*. Teachers should select the *Formative Performance Tasks* and accompanying *Sources* that best suit their own instructional needs – content requirements, performance goals, student readiness, and time constraints. Upon the completion of each unit, students should be adequately prepared to complete the *Summative Performance Task* and *Taking Informed Action* sections of the *Unit Plan*.

To further assist the teacher, we have included a more thorough *Background Information* section. This document is intended to serve as professional reading prior to implementing the unit. Teachers may also wish to read the full-length primary and secondary sources from which the shorter excerpts were taken.

In this unit, we have also included a *Glossary of Terms*. It is located at the end of the Inquiry Unit.

STAGING THE QUESTION

Semi-autonomous and autonomous aerial vehicles or *UAVs* (Unmanned Aerial Vehicles) are part of a very long history that is directly connected to the histories of piloted flight, ballistics, and information processing. Early progress in UAV research was certainly toward military use, but more recently, the technologies were adapted to civilian and commercial activities, as well as to humanitarian and research programs.

Beginning in antiquity, people experimented with a variety of aerial machines, including mechanical wings to allow a person to glide through the air, flying automata driven by compressed air or springs, vertical lift machines such as helicopters, lighter-than-air craft such as hot air balloons, and manned airplanes. They also engineered catapults of varying types that could hurl projectiles through the air at enemies from a distance, demonstrating their understanding of such physical principles as lift, torsion, mechanical advantage, drag and thrust.

Over time, aeronautics development diverged into piloted and unpiloted aircraft. Later work with radar, radio control, telephony and computing allowed for the idea of remote-controlled and autonomous aircraft that could deliver anything from bombs to information and packages, or could survey and report on activities from above the earth. The technical innovations that came out of these pursuits led to modern UAV designs.

While the term “drone” was first used in 1936 to refer to unpiloted flying targets used for anti-aircraft practice, today government military agencies prefer the term, unpiloted aerial *systems*(UAS), to acknowledge that those UAVs could not get off the ground or complete their missions without the onboard sensors and computers or remote human pilots and unrecoverable munitions that make up those systems. The U.S. Federal Aviation Agency (FAA) describes UAS as:

> an unmanned aircraft and the equipment necessary for the safe and efficient operation of that aircraft. An unmanned aircraft is a component of a UAS. It is defined by statute as an aircraft that is operated without the possibility of direct human intervention from within or on the aircraft (Public Law 112-95, Section 331(8).

The design of UAVs in use today grew out of the improvements in mechanical control, computing, and satellite digital technologies. However, many of the concepts on which drones are based developed long before computers were widely available. Contraptions that were supposed to allow a person to fly or glide through the air are described in ancient myths. The earliest actual flying machines we have any record of were small bird-shaped automata. Catapults are perhaps the first evidence we have of machines designed to rain airborne weapons on their enemies. A number of catapult designs were developed in both Europe and China during the Middle Ages. During the 1840s, Europeans began using balloons in warfare. Though the balloons were manned, they supported the idea of air reconnaissance for which modern UAVs are often used. More modern UAVs were developed for use by numerous countries in every military conflict from the First World War to the present conflicts. Commercial use of drones is expanding quickly, and the same technologies that have been incorporated into military drones are now being used to provide life-saving and educational support as well.

PRINT DOCUMENTS

Document 1A (Excerpted[1])

Unmanned aircraft systems (UAS) come in a variety of shapes and sizes and serve diverse purposes. They may have a wingspan as large as a jet airliner or smaller than a radioE controlled model airplane. Because they are inherently different from manned aircraft, introducing UAS into the nation's airspace is challenging for both the FAA and aviation community. UAS must be integrated into the busiest, most complex airspace in the world — one that is evolving from groundE based navigation aids to a GPSE based system in NextGen. And because UAS technology also continues to evolve, the agency's rules and policies must be flexible enough to accommodate that progress.

Integration of UAS has to be safe, efficient and timely. Safety is the FAA's primary mission, the agency is committed to reducing delays and increasing system reliability. This new technology has significant potential safety and economic benefits to help achieve these goals.

The FAA is taking an incremental approach to safe UAS integration as the agency acquires a better understanding of operational issues such as training requirements, operational specifications, and technology considerations. [The FAA is constantly updating its progress and updates may be found here https://www.faa.gov/uas/]

Civil UAS Operations

In February 2015, the Department of Transportation and the FAA released a proposed set of regulations that will pave the way for small UAS — those under 55 pounds — to enter the mainstream of U.S. civil aviation. The rule would allow routine use of small UAS in today's aviation system, and is flexible enough to accommodate future technological innovations.

The proposal offers safety rules addressing nonE recreational small UAS operations and for model aircraft operations that do not meet the criteria in Section 336 of Public Law 112E 95. The rule would limit small UAS to daylight flights and visualE lineE ofE sight operations. The proposed rule also addresses issues such as height restrictions, operator certification, optional use of a visual observer, aircraft registration and marking, and operational limits. The proposed rule also includes extensive discussion of a possible "micro" classification for UAS under 4.4 pounds. The FAA is asking the public to comment on whether it should include this option as part of a final rule.

Private sector manufacturers and technology developers currently can obtain a Special Airworthiness Certificate in the experimental category to conduct research and development, crew training, market surveys, and flight demonstrations. Experimental certificates preclude carrying people or property for compensation or hire and typically include operating limitations such as altitude and geographical area. Commercial firms also may fly a UAS that has an FAA Restricted Category Type Certificate. The agency issues these certificates to UAS models previously flown by the military. They allow limited operations, such as wildlife conservation flights, aerial surveying, and oil/gas pipeline patrols. As of October 2014, the FAA had approved operations using two certificated UAS.

SOURCE: Excerpted from "Fact Sheet – Unmanned Aircraft Systems (UAS)." FAA. September 19, 2014. Accessed March 25, 2017. https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=18297.

Since June 2014, the agency has received petitions for exemptions under Section 333 of Public Law 112E 95 to permit nonE recreational UAS operations before the small UAS rule is finalized. Under that section of the law, the Secretary of Transportation can determine whether certain airworthiness requirements are necessary to authorize specific UAS to fly safely in narrowlyE defined, controlled, lowE risk situations. Commercial entities ask for relief from airworthiness certification requirements as allowed under Section 333, in addition to relief from regulations that address general flight rules, pilot certificate requirements, manuals, and maintenance and equipment mandates.

Model Aircraft

On June 23, 2014, the FAA issued an interpretation of Public Law 112E 95 providing clear guidance to model operators on the "do's and don'ts" of flying safely in accordance with the Act.

In the document, the FAA restates the law's definition of "model aircraft," including requirements that they not interfere with manned aircraft, be flown within sight of the operator, and be operated only for hobby or recreational purposes. The agency also explains that model aircraft operators flying within five miles of an airport must notify the airport operator and air traffic control tower.

The FAA reaffirms that the law's model aircraft provisions apply only to hobby or recreation operations and do not authorize the use of model aircraft for nonE recreational operations.

Government (Public) UAS Operations

A "Certificate of Waiver or Authorization" (COA) is available to government entities that want to fly a UAS in civil airspace. Common uses include law enforcement, firefighting, border patrol, disaster relief, search and rescue, military training and other government operational missions.

Applicants must submit their COA request through an online system. The FAA then evaluates the proposed operation to see if it can be conducted safely. If granted, the COA allows an operator to use a defined block of airspace, and includes special provisions unique to the proposed operation. For instance, a COA may require flying only under Visual Flight Rules (VFR) and/or only during daylight hours.

Today, the average time to obtain an authorization for nonE emergency operations is less than 60 days, and the renewal period is two years. The agency has expedited procedures to grant oneE time COAs for timeE sensitive emergency missions such as disaster relief and humanitarian efforts — sometimes in just a few hours.

Most COAs require coordination with an appropriate air traffic control facility and may require a transponder on the UAS to operate in certain types of airspace. Because UAS technology cannot yet comply with "see and avoid" rules that apply to all aircraft, a visual observer or an accompanying "chase plane" must maintain visual contact with the UAS and serve as its "eyes" when operating outside airspace restricted from other users.

[1]SOURCE: Excerpted from "Fact Sheet – Unmanned Aircraft Systems (UAS)." FAA. September 19, 2014. Accessed March 25, 2017. https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=18297.

Document 1B

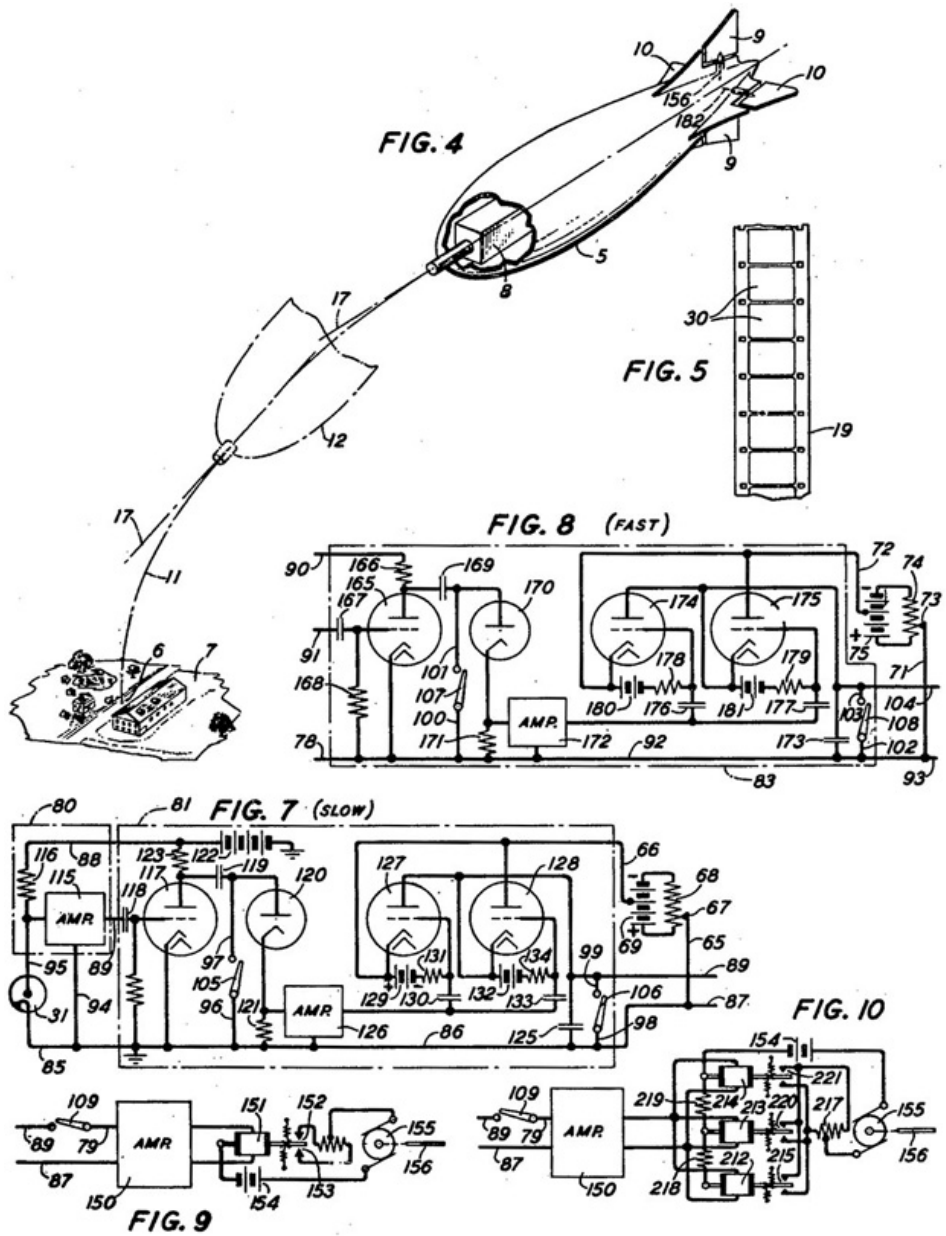
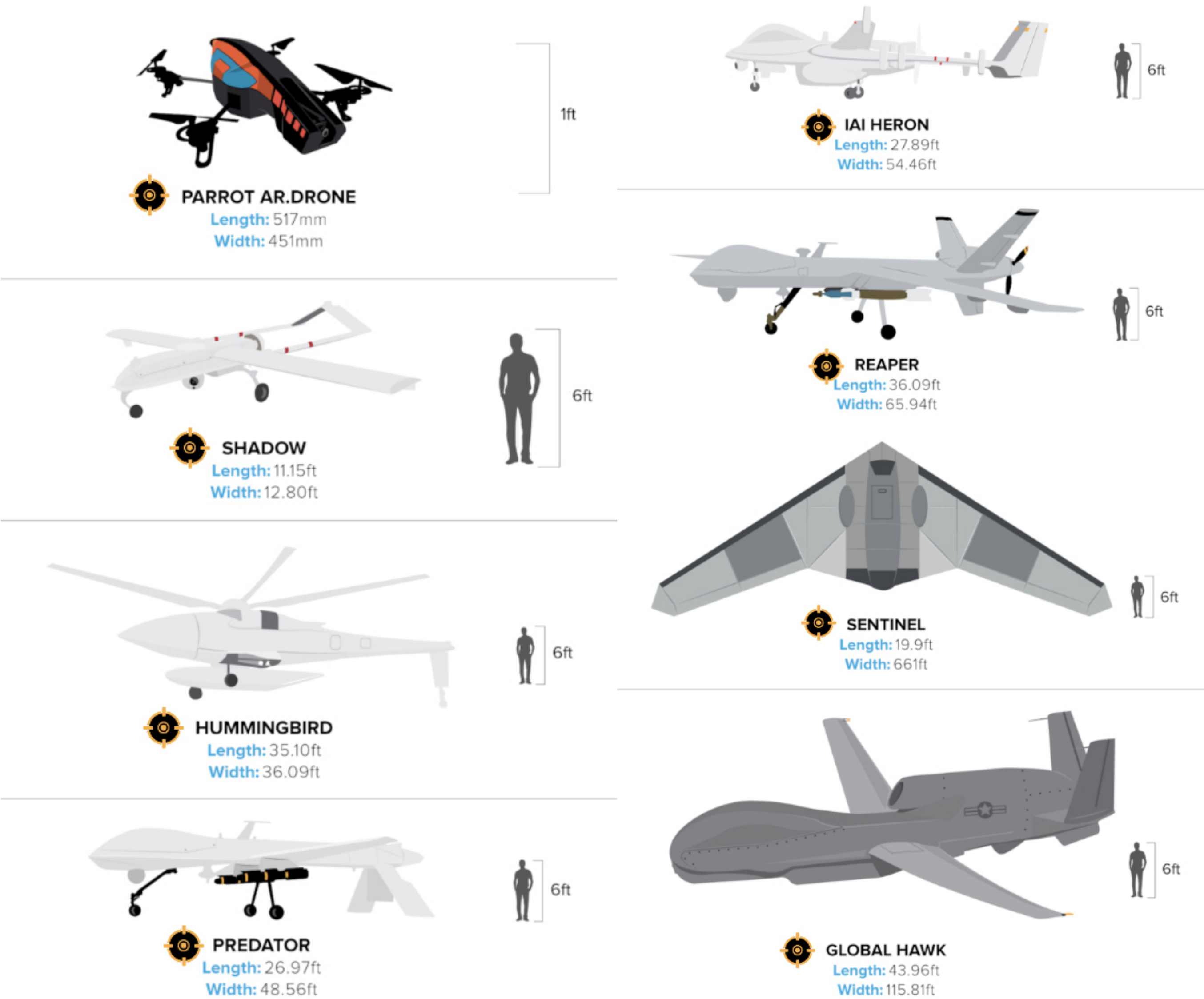


Photo: U.S. Patent & Trademark Office

SMART BOMB: In 1948, the same year he conceived the junction transistor, William Shockley filed a patent application for a "radiant energy control system"—basically a feedback control system that used a visual sensor. [This diagram shows a camera-guided missile.] Shockley outlined various uses for this system, including the self-guided bomb shown here. His application was quickly met with a patent secrecy order and remained under wraps for a decade.

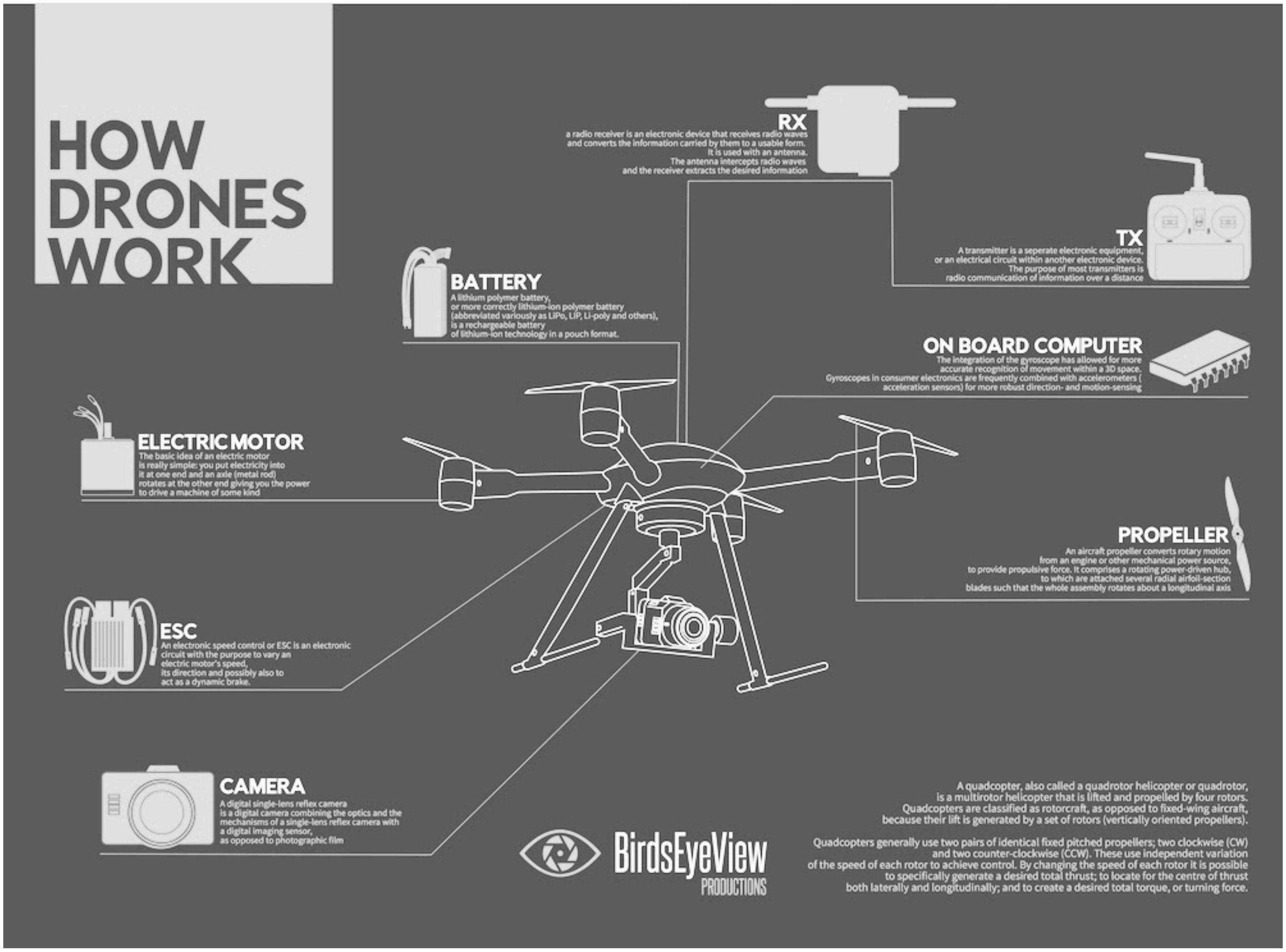
SOURCE: Excerpted from Brock, David C. "How William Shockley's Robot Dream Helped Launch Silicon Valley." IEEE Spectrum: Technology, Engineering, and Science News. November 29, 2013. Accessed July 23, 2017. http://spectrum.ieee.org/at-work/innovation/how-william-shockleys-robot-dream-helped-launch-silicon-valley

Document 1C



SOURCE: Excerpted from Mineses, Eric Larson & Christopher. "Not all drones are created equal." Mashable. November 21, 2014. Accessed May 14, 2017. http://mashable.com/2014/11/21/drone-infographic/?utm_cid=mash-com-pin-link&crlt.pid=camp.d1UXkSAQun65#zD7Ic8cMFkqG.

THE COMPONENTS OF A DRONE



The Transmitter (TX)

The transmitter enables the user to control the aircraft from a distance, using 2.4 gigahertz spread spectrum radio signals.

The Receiver (RX)

Receivers are electric devices with built in antennas that intercept the radio signals from the transmitters, and convert them into alternating current pulses. The receiver then produces information and sends it to the Flight Control Board.

Flight Control Board

After the transmitter is switched on, and the main power source – the LiPo battery – is plugged in, the receiver starts communicating with the transmitter. From this moment, the receiver will send every signal to the onboard computer. The sensors on the computer will make sure the aircraft is stable, even under windy conditions, which makes controlling the aircraft easier – even for beginners. As the transmitter sends signals to the aircraft, the onboard computer sends signals to the electric speed

SOURCE: Excerpted from Perlman, Alan. "Infographic: How Do Drones Work?" UAV Coach. September 14, 2016. Accessed July 22, 2017. https://uavcoach.com/infographicp dronesp work/

IEEE REACH

controllers. The e controllers can control the amount of voltage received by the motors, in order to control the speed of each propeller. This system allows the quadcopter to maneuver.

The battery (lithium polymer battery)

The LiPo battery is rechargeable and lightweight, capable of delivering high discharge rates to provide enough power to the brushless electric motors.

Electronic speed controller

The electronic speed controller is connected to the LiPo battery and controls the rotational speed of the motor by adjusting electric current (Amp) to ensure the motors are running smoothly and efficiently. The controller has a built in governor, which keeps the motor's RPM (rotation per minute) at a steady level, in every flight condition.

The electric motor

On the outside of the motor, there are magnets attached to the inner wall, called the rotor (the spinning part). There are also permanent magnets on the inside of the motor, called the stator. As the electricity runs through these magnets, it creates an electromagnetic field that attracts and repels the magnets in the stator. The constant change of polarity keeps the motor spinning.

The propeller (props)

The propeller converts the motion into lifting power. Because of the special shape of the blades, the air pressure is uneven on two sides while they are in motion, what creates lifting power. The principle can be easily modelled by Newton's third motion law and Bernoulli's principle.

Control surface

The flight computer can individually control the speed of each motor. The propellers can create an even lifting power in the four points of the model, making it lean towards a specific direction. For example, if the two propellers on the right side drop RPM, the lifting power will be bigger on the left side, therefore the right side will start descending in a quick motion and the model will start drifting to the right. The onboard computer will increase RPM when the drifting speed reaches the limit, and position the model back into a stable hovering position even if the user takes his hand off the controls – his is what makes quadcopters easy to fly.

[1]SOURCE: Excerpted from Perlman, Alan. "Infographic: How Do Drones Work?" UAV Coach. September 14, 2016. Accessed July 22, 2017. https://uavcoach.com/infographicp dronesp work/

Document 2A – The hybrid trebuchet: the halfway step to the counterweight trebuchet (Excerpted[1])

The trebuchet was far more powerful than earlier forms of artillery. Those who witnessed a display of its destructive capabilities for the first time were stunned by its effectiveness. When the Avaro-Slavs laid siege of Thessalonica in 597, the archbishop of the city was awe-struck by the devastation wrought by a battery of fifty traction trebuchets. His eyewitness account of the artillery bombardment contains the first detailed description of the traction trebuchet in an historical work. It is also the earliest unambiguous reference to the use of the traction trebuchet in the Mediterranean region:

“These [trebuchets] were tetragonal and rested on broader bases, tapering to narrower extremities. Attached to them were thick cylinders well clad in iron at the ends, and there were nailed to them timbers like beams from a large house. These timbers had the slings from the back side and from the front strong ropes, by which, pulling down and releasing the sling, they propel the stones up high and with a loud noise. And on being fired they sent up many great stones so that neither earth nor human constructions could bear the impacts. They also covered those tetragonal trebuchets with boards on three sides only, so that those inside firing them might not be wounded with arrows by those on the walls. And since one of these, with its boards, had been burned to a char by a flaming arrow, they returned, carrying away the machines. On the following day they again brought these trebuchets covered with freshly skinned hides and with the boards, and placing them closer to the walls, shooting, they hurled mountains and hills against us. For what else might one term these extremely large stones.”

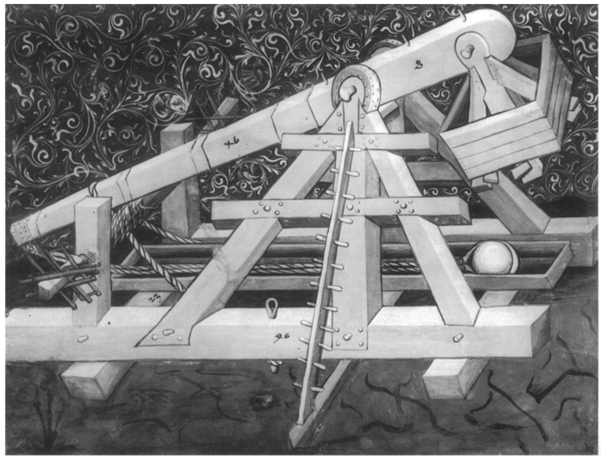
The most powerful Chinese traction trebuchet had a beam of 28 chi in length (8.6 m). This beam, made up of seven wooden (or perhaps bamboo) spars lashed together with rope or bound with metal bands, was mounted on top of a trestle frame that stood 21 chi in height (6.5 m). Attached to the butt-end of the beam were 125 pulling ropes that were hauled down by a crew of 250 men. The machine was capable of throwing a stone-shot weighing between 90 and 100 catties (between 53.7 and 59.7 kg) a distance of more than 50 pu (77 m). As impressive as this performance was, the hybrid trebuchet far surpassed the traction machine in launch capabilities.

The transition from the traction to the counterweight trebuchet took considerable time, due to the very success of the traction machine itself, the conservatism in engineering design that prevailed in the pre-modern era, and the difficulties involved in harnessing gravity power. The idea of adding additional weight to the butt-end of the beam of a traction machine to give it more power does not appear to require great inventiveness. The butt-end itself was weighted with a framework for holding the pulling ropes, and by experiment artillerists probably learned that a weighted butt-end enhanced the power of the machine. Even Ibn Urunbugha’s illustration of the small pole-framed traction trebuchet known as the ‘arradah’ is shown with a weight on the butt-end of the beam. “The fixed counterweight was such a simple idea,” declared Joseph Needham, “that its development only towards the end of the 12th century seems surprisingly late, especially as the ancient water-raising machine, prototype of all phao [trebuchets], had always had it.” An opposing point of view has been offered by Donald Hill:

“At first sight, it may seem surprising that the counterweight trebuchet was not developed, as an effective engine of war, before the end of the twelfth century. After all, not only did military engineers have the example of the traction trebuchet as a spur to their inventiveness, but they could also have been inspired by watching the action of the shaduf – the counterweighted irrigation device. The traction trebuchet, however, is a simpler machine, while the shaduf does not operate at high velocity. What is in fact surprising, when one comes to consider the dynamics of the counterweight trebuchet, is that it ever

SOURCE: Excerpted from Chevedden, Paul E. "The hybrid trebuchet: the halfway step to the counterweight trebuchet." On the Social Origins of Medieval Institutions (1998): 179-222.

became a useful engine of war at all. The engineer, Muslim or Christian, who constructed the first effective machine of this type deserves our unqualified respect."



Even though the use of gravitational force seems simple, it took great inventiveness to proceed along a different design path and much practical skill, technical training, and experimentation to produce an effective gravity-assisted machine. There was nothing inevitable about the appearance of the hybrid or the counterweight trebuchet. The long interval of time between the emergence of these forms of artillery suggests that these machines were the product of a succession of innovations. The high performance standards achieved by the traction trebuchet could even have discouraged efforts to improve the efficiency of the machine. The story of Columbus's egg may have much to tell us about the invention of the hybrid machine. Someone had to demonstrate how to accomplish the feat first before others would imitate the achievement. But human inventiveness was not the only ingredient required for the development of the hybrid trebuchet. A proper social, political, technological, and economic environment had to be created that would allow such changes to occur. Such an environment was present in South-West Asia and the Mediterranean during the period of the Islamic conquest movements.

The hybrid machine represents a critical step in the development of the trebuchet. For the first time the force of gravity was used to radically amplify the muscular force of the pulling crew of the machine in order to assist in the discharge of the projectile. The next leap forward in trebuchet design came when gravity power completely replaced the pulling crew. This innovation was prepared by many centuries of utilization of gravitational force made possible by the hybrid machine. Thus, the hybrid machine played an important role in the development of the counterweight trebuchet, the most powerful form of pre-gunpowder artillery invented.

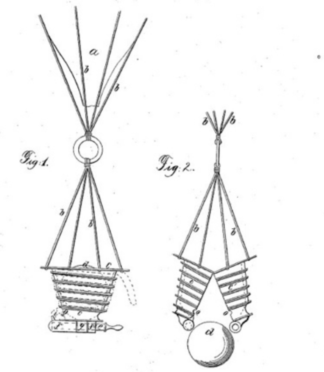
Despite more than a century and a half of research devoted to the trebuchet, the hybrid trebuchet has escaped scholarly notice. This machine was probably developed in the realms of Islam by the early part of the eighth century under the impetus of the conquest movements. It can now be shown that although China invented the trebuchet, it was the Islamic civilization that vastly improved the performance of this machine. The most powerful hybrid trebuchet could launch stone-shot more than three times heavier than that discharged by the most powerful Chinese traction trebuchet.

[1]SOURCE: Excerpted from Chevedden, Paul E. "The hybrid trebuchet: the halfway step to the counterweight trebuchet." *On the Social Origins of Medieval Institutions* (1998): 179p 222.

Document 2B (Excerpted[1])

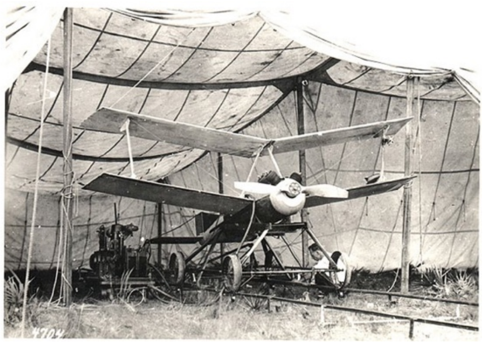
Bomb-Dropping Balloons

The Union and Confederate armies both used balloons for spying on the enemy during the U.S. Civil War, with pilot-observers onboard. At least one person—Charles Perley of New York City—imagined that they could also be used to deliver weapons. His patent dated February 24, 1863 calls for a "divided basket" which would open like a clamshell when a timed fuse expired, thereby releasing a bomb. "A balloon can be made to pass over any object, and…any-sized bomb or missile of destruction can be carried up over the place to be destroyed," he wrote.



(US Patent Office)

Kettering Bug



(NASM)

The Kettering Aerial Torpedo, later called the "Kettering Bug," was a small biplane powered by a De Palma 4-cylinder engine and guided by gyroscopes, a barometer, and a mechanical "computer." It flew in 1918 and had a range of up to 75 miles. The onboard computer counted engine revolutions (to gauge distance), then powered down the engine and jettisoned the torpedo's wings at a pre-determined distance (calculated before launch based on prevailing wind speed and direction). At that point the fuselage would crash into its intended target with an explosive payload onboard. The Bug was never used in actual combat.

Assembly Worker Marilyn Monroe

British-born actor Reginald Denny, who had served in the Royal Flying Corps during World War I, developed a fascination with radio-controlled aircraft in the 1930s. He and his partners formed the Radioplane Company and created the "Radioplane OQ-2," the first mass-produced UAV, at their southern California-based facility. Eventually the company rolled out nearly 15,000 airplanes for the U.S. Army and Navy, who used the Radioplanes as targets for anti-aircraft training.

(U.S. Army/David Conover for Yank, the Army Weekly)

While Denny enjoyed a long Hollywood career, appearing in films like Alfred Hitchcock's *Rebecca*, one of Radioplane's humble employees went on to greater stardom. An actor friend of Denny's, U.S. Army Air Forces Captain Ronald Reagan, sent a photographer to Radioplane in June 1945 to shoot female assembly workers for *Yank, the Army Weekly* magazine. The photographer, David Conover, focused on one worker in particular, Norma Jeane Dougherty, and asked her to pose for other shoots, which led to a modeling contract, a film career, and a name change—to Marilyn Monroe.

SOURCE: Excerpted from Darack, Ed. "A Brief History of Unmanned Aircraft." Air & Space Magazine. May 17, 2011. Accessed March 25, 2017. http://www.airspacemag.com/photos/apbriefphistorypofp unmannedpaircraftp174072843/.

Fu-Go Balloons

The first truly intercontinental weapon system, Japan's "Fu-Go" balloons were designed to cause widespread forest fires and damage to North American cities, civilians, and croplands during World War II. The hydrogen-filled balloons measured 30 feet in diameter. Each carried a payload of 32 paper sandbags, two incendiary devices, one small bomb, and an altitude regulation mechanism.


(NASM)

Launched from Japan, the balloons would rise to roughly 30,000 feet, where they would hitch a ride on the jet stream and travel at speeds of up to 120 miles per hour eastward. As hydrogen leaked out slowly, the balloon descended. At 25,000 feet, the altitude regulation system would drop one of the sand bags, causing the balloon to rise back to 35,000 feet. This continued until just the incendiary devices and bomb remained; then they too were dropped on the last dips to 25,000 feet. The Japanese launched up to 9,300 of these balloons, but only 300 actually reached North America. They caused six deaths: a woman and five students who happened upon one of the unexploded bombs during a church picnic in Oregon.

Operation Aphrodite

The United States attempted to weaponize unpiloted bombers during World War II, using specially modified B-17 Flying Fortresses and other airplanes loaded with explosives. In Operation Aphrodite, the U.S. Army Air Forces installed radio-controlled actuators to each aircraft's flight controls, along with two television cameras (one looking out the nose of the craft, and one aimed at its instrument panel). Two pilots set out in the drone B-17s. At an altitude of 10,000 feet, they armed the explosives, passed radio control to another B-17 (the "mothership"), then bailed out using parachutes. Personnel on the mothership (which was fitted with television receivers and radio control equipment) would then guide the drone to German V-2 launch sites. That was the plan, anyway. None of the B-17s (or B-24s or PB4Y-1s also used as makeshift UAVs) ever made it to their intended targets, and a number of crew—including Joseph Kennedy Jr. (pictured)—died during these attempts.


(U.S. Navy)

V-1 Buzz Bomb


(NASM)

Perhaps the best-known unmanned vehicle of World War II was the German Fieseler Fi 103, also called the V-1 "Buzz Bomb" ("V-1" stood for Vergeltungswaffe Eins, or "vengeance weapon one"). Meant to kill British civilians—per Adolf Hitler's order for a weapon to be used against "non-military targets"—the V-1 was powered by a pulsejet engine that made a distinctive buzz. It carried a 2,000-pound warhead approximately 150 miles, and had a sophisticated guidance system consisting of gyroscopes, barometers, and an anemometer, which was used to calculate distance flown. Once over the target, the guidance system put the V-1 into a steep dive. The Germans launched roughly 20,000 V-1s at Allied targets, primarily in London and Antwerp, Belgium. The Buzz Bombs proved devastating, killing more than 10,000 civilians and injuring nearly 28,000.

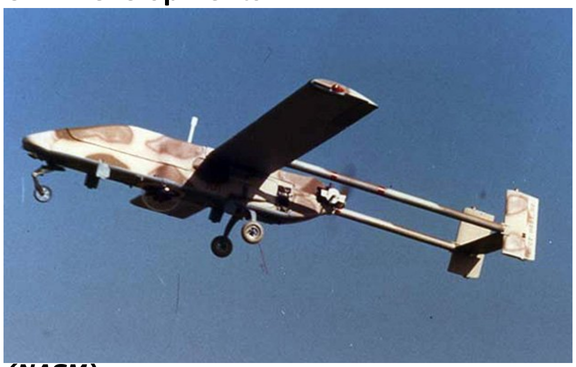
SOURCE: Excerpted from Darack, Ed. "A Brief History of Unmanned Aircraft." Air & Space Magazine. May 17, 2011. Accessed March 25, 2017. [http://www.airspacemag.com/photos/apbriefphistorypofp unmannedpaircraftp174072843/](http://www.airspacemag.com/photos/apbriefphistorypofpunmannedpaircraftp174072843/).

First Reconnaissance Drone

Reginald Denny's Radioplane Company, which was acquired in 1952 by Northrop Aircraft Incorporated, led the way in post-World War II UAV development. While most of the drones designed and produced during this period were used for target practice, 1955 saw the U.S. Army's first reconnaissance drone, the Northrop Radioplane RP-71 Falconer (designated the SD-1 by the Army), based on a target vehicle design. Launched by two rockets and recovered by parachute, the Falconer carried a still film camera and could transmit crude video.

(USAF)

UAV Developments



(NASM)

A second-generation turbojet-powered Firebee, built by Ryan Aeronautical Company and developed from a target drone initially developed for the U.S. Air Force, led to the AQM-34, which ushered in modern unmanned reconnaissance aircraft. From the mid-1960s to the mid-1970s, the AQM-34 flew tens of thousands of missions over North Vietnam, parts of China, and even the Soviet Union, obviating the risk posed by manned reconnaissance flights.

In the 1970s, Israel began to modify existing UAVs and develop new designs. One of the most ingenious Israeli uses of UAVs came during the Yom Kippur War of October 1973, when a "swarm" of Northrop Chukar unmanned craft was sent toward the Golan Heights. The Syrian military was tricked into thinking a massive air attack was under way against its potent surface-to-air missile (SAM) batteries, and launched dozens of SAMs against the incoming aircraft, substantially depleting their air defenses. In subsequent years, Israel took the global lead in certain types of UAVs, particularly in the 1980s with the development of lighter, smaller unmanned aircraft like the RQ-2 Pioneer (pictured). Along with its sibling, the IAI RQ-5 Hunter, the Pioneer flew extensively in the 1991 Gulf War.

RQ-1 Predator

The RQ-1 Predator, probably the best-known modern UAV, made its first test flight in 1994. Produced by General Atomics Aeronautical Systems—based on a design by Abraham Karem, a former engineering officer for the Israeli Air Force—it was designed for "long loiter" reconnaissance work. The RQ-1 has evolved, and today its variants patrol the U.S.-Mexico border, collect air samples for scientific research, and unleash Hellfire air-to-ground missiles on military targets.

(USAF Photo: Senior Airman Julianne Showalter)

(Department of Defense)

RQ-4 Global Hawk

Soaring even higher than the Predator—which the military considers a medium altitude UAV—the Northrop Grumman RQ-4 Global Hawk is a high-altitude, long endurance aircraft with performance and sensor capabilities so impressive it's scary. Born out of a 1995 DARPA (Defense Advanced Research Projects Agency) request, the Global Hawk can fly more than 32 hours at a stretch and loiter at altitudes as high as 65,000 feet, with a suite of sensors that can see through clouds, dense fog, haze, and dust storms. Thanks to a data transmission rate dozens of times faster than a T1 line, operators can view very high resolution imagery of wide swaths of the ground below.

Non-Military Use

Despite the historic focus on military uses, UAV designers see an ever-expanding non-military role for their vehicles as airframe designs, control systems, and onboard sensors become more reliable, smaller, lighter, longer-lasting, safer, and cheaper.

(NASA)

In 2007, an Aerosonde UAV took off from the NASA Wallops Flight Facility in Virginia and headed into Hurricane Noel, a Category 1 storm churning up the eastern coast of the United States. During its 17 hour, 27 minute flight into Noel, the Aerosonde flew as low as 300 feet above sea level, far lower than a piloted airplane would dare travel inside a hurricane eyewall. Last year, NASA used a Global Hawk to take this image of Tropical Storm Frank over the Pacific Ocean. Other non-military UAV uses include crop monitoring, search and rescue, fire spotting, mineral exploration, aerial photography and ground mapping. And those are only the ones we've thought of already.

[1]SOURCE: Excerpted from Darack, Ed. "A Brief History of Unmanned Aircraft." Air & Space Magazine. May 17, 2011. Accessed March 25, 2017. http://www.airspacemag.com/photos/apbriefphistorypofp unmannedpaircraftp174072843/.

Document 2C (Excerpted[1])

Like many weapon systems, UAVs thrive when the need is apparent; when there is no need, they fall into disfavor. Numerous obstacles have hindered UAV development. Oftentimes, technologies simply were not mature enough for the UAVs to become operational. Other times, lack of service cooperation led to failure. For example, the U.S. Army Air Corps funded Project Aphrodite (using BE-17s as flying bombs) in WWII, while the Navy's WWII Project Anvil was very similar but used PB4Ys (the Navy's designation for the BE-24). If the services had coordinated efforts, perhaps the overall effort would have been successful. Additionally, competing weapons systems made it difficult for UAVs to get funding. And of course, it was sometimes difficult to sell pilotless aircraft to senior service leaders, who were often pilots….

WWI: Efforts in the Development of the Aerial Torpedo and Kettering Bug

In 1911, just 8 years after the advent of manned flight, Elmer Sperry, inventor of the gyroscope, became intrigued with the application of radio control to aircraft. Sperry succeeded in obtaining Navy financial support and assistance and, between 31 August and 4 October 1913, oversaw 58 flight tests conducted by Lieutenant P. N. L. Bellinger at Hammondsport, New York, in which the application of the gyroscope to stabilized flight proved successful. In 1915, Sperry and Dr. Peter Cooper Hewitt (best known for his work in radio and contributions to the development of the vacuum tube) were appointed members to the Aeronautical Committee of the Naval Consulting Board, established by Secretary of the Navy Josephus Daniels on 7 October 1915 and led by Thomas A. Edison to advise Daniels on scientific and technical matters.

By this time, Europe was embroiled in war, and the utility of unmanned aircraft was becoming apparent. Conditions on the European battlefields were ideal for such a system: enemy anti-aircraft weapons were heavily concentrated, Germany had air superiority in certain sectors, and there was an extremely static battlefield situation over 470 miles of front. Heavy British air losses led to a research program at the Ordnance College of Woolwich, United Kingdom, in remotely controlled pilotless aircraft designed to glide into the target and explode on impact. A parallel program was begun by the Royal Aircraft Factory that included aircraft manufacturers such as the Sopwith Aviation Company and de Havilland. None saw action during the war.

By 1916, Carl Norden (developer of the famed Norden bombsight of WWII) joined the Sperry/Hewitt team and developed the concept of an aerial torpedo. After America's entry into WWI on 6 April 1917, they convinced the Navy to fund their research. Eight days later, the Naval Consulting Board recommended to Secretary Daniels that $50,000 be granted to Sperry's team to carry out experimental work on aerial torpedoes. The fact that the Western Electric Company was working on radio devices encouraged Sperry to investigate the use of radio control in the aerial torpedo problem. However, after several tests, it was determined that the radio technology was too immature, and follow-on tests concentrated on maintaining course and measuring distance to the target.

SOURCE: Excerpted from Keane, John F., and Stephen S. Carr. "A brief history of early unmanned aircraft." Johns Hopkins APL Technical Digest 32, no. 3 (2013): 558-571.

On 10 November 1917, Glenn Curtiss, inventor of the flying boat, delivered an airframe designed to carry 1,000 pounds of ordnance a distance of 50 miles at 90 mph to the Sperry Flying Field at Copiague, Long Island, New York. A successful demonstration of the Navy's aerial torpedo was conducted 11 days later. Meanwhile, Rear admiral Ralph Earle, U.S. Navy Chief of the Bureau of Ordnance, had submitted his ideas on how the aerial torpedo might best be used to win the war and suggested that it might be most effective in defeating the UE-boat menace. Earle suggested that aerial torpedoes could be carried on ships stationed off shore from the German submarine bases in Wilhelmshaven, Cuxhaven, and Flanders and used to destroy submarines, shipyard facilities, etc. Earle directed Lieutenant T. S. Wilkinson, U.S. Navy, to proceed to the Sperry Flying Field to observe and report on tests being conducted there. On 6 March 1918, the Curtiss-Sperry aerial torpedo made its longest successful flight, flying a distance of 1000 yards. Experiments with pilotless flight continued, and on 17 October 1918, a pilotless N-9 aircraft was successfully launched; it flew its prescribed course but failed to land at a preset range of 14,500 yards and crashed at sea. More than 100 tests were conducted by the Navy before the Armistice was signed on 11 November 1918 and, thus, like its British counterparts, the aerial torpedo never saw wartime service.

The Army was not to be left behind. After witnessing the Navy's aerial torpedo test on 21 November 1917, Major General George O. Squier, Chief Signal Officer of the Army, determined that a parallel effort by the Army should be undertaken at McCook Field, Dayton, Ohio. The U.S. Army aircraft board asked Charles Kettering to design an unmanned "flying bomb" that could hit a target at a range of 50 miles. Kettering's design eventually acquired the name "Kettering Bug" and had Orville Wright as an airframe consultant and Childe H. Wills of the Ford Motor Company as engine consultant on the project.

Launching the 530-pound "Bug" was accomplished using a dolly-and-track system, similar to the method used by the Wright Brothers when they made their first powered flights. Once launched, a small onboard gyroscope guided the aircraft to its destination at an airspeed of about 120 mph. Control was achieved through a pneumatic/vacuum system, electric system, and an aneroid barometer/altimeter.

To ensure that the Bug hit its target, a mechanical system was devised that would track the distance the aircraft flew. Before takeoff, technicians plotted the plane's intended trajectory and forecasted the en route winds. Using this information, technicians also predicted the number of engine revolutions needed for the Bug to reach its destination. As the aircraft neared the end of its flight and the estimated number of revolutions had elapsed, the engine was mechanically turned off and the wings jettisoned. The Bug then began a ballistic trajectory into the target, with the impact detonating the explosive payload. The prototype Bug was completed near the end of WWI, and the Army ordered 25 Bugs on 25 January 1918. Flight tests began in September 1918, with the first successful flight on 22 October 1918. Unfortunately, the Bug failed in its testing, having made only eight successful test flights of 36, yielding a 22% success rate. In a fate like those of its Navy and British counterparts, the war ended before the "Bug" could enter combat. If the Army (Kettering Bug) and Navy (aerial torpedo) had worked jointly on these two concurrent efforts, perhaps an operational system could have been fielded before the Armistice.

[1]SOURCE: Excerpted from Keane, John F., and Stephen S. Carr. "A brief history of early unmanned aircraft." Johns Hopkins APL Technical Digest 32, no. 3 (2013): 558---571.

Document 2D (Excerpted[1])

The Society for Space Ship Travel, or *Verien fur Raumschiffahrt* — the VfR, and afterwards more popularly called the German Rocket Society — was born on July 5, 1927. It met in the parlor of the Goldnen Zepter (Golden Scepter) tavern on Schmeidebrucke22 in the German industrial town of Breslau (now Wroclaw, Poland)….

The connection of the military with the VfR—and other pre-war German rocket societies—was to be of profound importance to the development of the modern liquidE propellant rocket. The key link in this connection was Karl Emil Becker, a Doctor-Engineer in the Artillery. His interest in rocketry pre-dated the founding of the VfR. He had studied ballistics under Professor Carl Julius Cranz at the *Technischen Hochschule* in Berlin and contributed to the 1926 edition of Cranz's famous *Lehrbuch der Ballistik* (Textbook of Ballistics) which contains a lengthy section on rockets. Becker himself may have written this part. Here was analyzed the solid fuel aerial torpedo of the late 19th century Swedish ordnance officer, Wilhelm Unge, and the 1919 paper of Robert H. Goddard. Liquid propellants were treated in a discussion of Hermann Oberth's 1923 space ships.

With the creation of the VfR in 1927 there emerged in Germany and elsewhere a great swell of publicity—much of it sensationalistic rather than scientific—which Becker and other military men could not fail to notice. By 1929 this publicity grew to such proportions, generated especially by the Valier-von Opel stunts, that Becker took direct action to start Army involvement in rockets. As a colonel and chief of the Heeres Waffenampt (Army Weapons Board) of the Ballistiche und Munitionsabteilung (Ballistic and Munitions Department), he ordered Captain Dr. Engineer D'Aubigny von Engelbrunner Horstig (usually referred to as Captain von Horstig) to thoroughly examine the literature to determine military potential of the liquid fuel rocket.

Much has been made of the reason for the German Army's interest in the potential of the rocket as a weapon in 1929-1930. The Versailles Treaty, which severely restricted Germany's armaments, conspicuously left out rockets. That the Versailles Treaty was honored even before Hitler's assumption of power, however, is a myth. Moments after the ink had dried upon the treaty, certain elements within the German arms industry and the military surreptitiously sought ways to contravene the armaments clause.... There is ample evidence to show that the Versailles Treaty's silence on rockets was a factor in the early military development of the weapon. But what is not stated is the underlying motive: Germany's general move toward rearmament, and more importantly, the inevitability of the liquid fuel rocket's military development. The rhetoric of Adolf Hitler perhaps was also a factor which urged the military towards seeking a new, more powerful weapon. His constant theme was vengeance over the Versailles Treaty and the forging of a new more powerful Army. "We will have arms again!" he had written in Mein Kampf in 1923. Whether out of vengeance, feelings of military impotency created by the restricting clauses of the Versailles Treaty, or a Germanic fascination with new weaponry, the military was determined to exploit the rocket….

…On 17 December 1930 a crucial meeting took place in which Becker and Dornberger were present and presided by Colonel Karlewski. This was the real start of the Army's rocket program as Karlewski approved the allotment of the equivalent sum of $50,000 per year for the rocket program; an additional $50,000 was approved the following year….

SOURCE: Excerpted from Winter, Frank H. Prelude to the space age: the rocket societies, 1924X 1940. Washington/D.C.: Smithsonian Institution Pr. in Komm., 1984. Accessed May 6, 2017. https://archive.org/details/preludetospaceag00wint.

The alcohol fuel was fed by compressed nitrogen and the motor cooled by a water-filled jacket. According to Dornberger: "I remember the great disappointment in August 1932, during a demonstration at Kummersdorf, when a rocket of this type built by the Raketenflugplatz group, after rising vertically for 100-odd feet (30.4 meters) sharply swerved into a horizontal course and crashed in a nearby forest."…

During his visits to the Raketenflugplatz and at the test at Kummersdorf, Dornberger was "struck" by the energy, shrewdness, and "astonishing theoretical knowledge" of von Braun. [More on Wernher von Braun can be found in the glossary] "It seemed to me," he also noted, "that he grasped the problems and that his chief concern was to lay bare the difficulties." Becker provided von Braun with a research grant to simultaneously pursue his rocketry work and continue his education in physics at the University of Berlin (Friedrich-Wilhelms-Universitat); his rocket research was now conducted in secrecy at Kummersdorf….

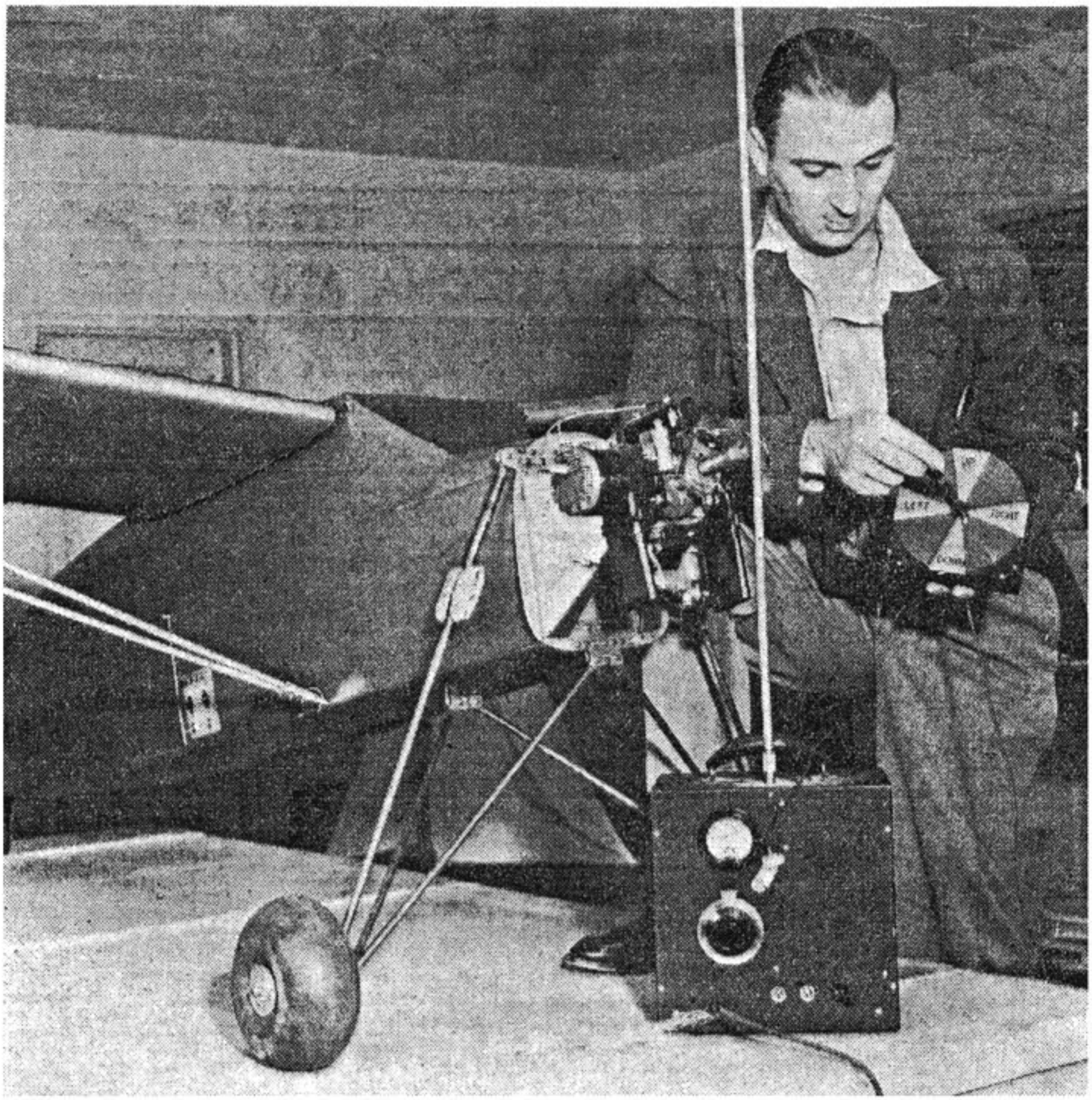
The question of "morality" has often been asked of von Braun and his VfR colleagues, in committing themselves to the design and construction of what became one of the war's most awesome weapons. Von Braun very simply wished to build bigger rockets with space travel always in mind. "I was sure Reinickendorf [the site of Raketenflugplatz] was utterly inadequate even to commence the vast experimental program which must be the precursor of success," he wrote. "It seemed that the funds and facilities of the Army were the only practical approach to space travel." Von Braun's explanation is entirely plausible, especially considering the financial straits of the Society during its final days. From the personal standpoint when he was hired by the Army late in 1932, he thought of nothing but rockets and wished to pursue his education as far as possible, preferably along the lines of his avocation. The Army obliged. He consequently attained his doctorate in physics in 1934 at Army expense, his thesis covering theoretical and experimental aspects of liquid propellant rocket engines. There was also during the pre-Hitler time no inkling where the work would lead. "It is, perhaps, apropos," he said, "that at that time none of us thought of the havoc which rockets would eventually wreck as weapons of war." Gerdde Beeck, an illustrator at Peenemunde, was so infected by the space travel talk of the old VfR and other space travel society members, that he was induced to render his own version of the Woman on the Moon on the side of an experimental V-2.

[1]SOURCE: Excerpted from Winter, Frank H. *Prelude to the space age: the rocket societies, 1924X 1940*. Washington/D.C.: Smithsonian Institution Pr. in Komm., 1984. Accessed May 6, 2017. https://archive.org/details/preludetospaceag00wint.

Los Angeles Times

JANUARY 28, 1938.— FRIDAY MORNING.

AIRSHIP DESIGNED TO BE SHOT DOWN



Paul Whittier, co-builder of the radio-controlled model airplane to be tested Tuesday by Coast Artillerymen, the plane and his ground control equipment. Times photo

[1]SOURCE: Excerpted from Naughton, Russell. "RPAV: Remote Piloted Aerial Vehicles." Hargrave p p Aviation and Aeromodelling: Interdependent Evolutions and Histories. August 3, 2007. Accessed July 22, 2017. http://www.ctie.monash.edu.au/hargrave/rpav_radioplane.html

ARMY TO TEST MODEL ROBOT PLANE AS ARTILLERY TARGET

With elaborate range-finding equipment, a unit of the Sixty-third Coast Artillery under Lieut.-Col. Claude M. Thiele will go to Muroc Dry Lake next Tuesday to test its markmanship against a radio-controlled model airplane.

If successful, trial flights of the miniature craft will pave the way for general use of such machines to train anti-aircraft and coast artillerymen.

RADIO CONTROLLED

Paul Whittier, veteran National Guard airman, and Reginald Denny, actor-model-maker, constructed the gasoline-powered plane, climaxing two years of intense experimentation before they were successful in building a delicate radio mechanism which permits control of the model aloft.

The craft's wing span is twelve feet. From tail to propellor, it measures eight and one-half feet.

IMPULSES CONTROLLED

Once the model's three-horsepower engine pulls it skyward, the radio controls go into action. In the fuselage of the plane, the builders have installed a three-tube receiving set, which relays impulses to tiny electric motors. These operate the tail rudder and elevators.

Ground equipment consists of a shortwave sending set and a control box, with contact points which modulate the wavelengths of the radio impulses. These send the model up, down, left or right.

DEVELOPMENT PLANNED

Eventually, said Whittier, who served as chief engineer of the project since its inception in 1935, they hope to gyrate the small craft in intricate loops, falling leaves, and spins.

Earlier flight tests have indicated that the Whittier-Denny model will travel sixty miles an hour. Its tiny engine will haul its forty-two pounds to an altitude of 9000 feet—far enough to put the plane out of sight of the naked eye.

COFFEE CUP IDEA

Two years ago, over the coffee cups, Denny broached the idea of making such a ship for anti-aircraft artillery use. Practice procedure for the Army today demands the day-and-night service of an observation plane and a skilled pilot. This costs the government $300 an hour.

The model, proven successful, will permit coast artillerists to attain their range-finding for a very small sum.

RATIO PLANNED

Its design aims at producing a miniature whose speed-size ratio corresponds exactly to full-sized ships. Thus, as the models become old, they will probably be used directly as flying targets for the artillerists.

On a production basis, Whittier said, the craft will fetch $600. This experimental model, however, represents a $2000 investment.

ALL-DAY TEST

Col. Thiele announced he will take height-finders, speed determiners and other equipment to Muroc Dry Lake for an all-day test Tuesday.

He admitted freely that perfection of such a model will provide the Army with something it has sought for years.

[1]SOURCE: Excerpted from Naughton, Russell. "RPAV: Remote Piloted Aerial Vehicles." Hargrave p p Aviation and Aeromodelling: Interdependent Evolutions and Histories. August 3, 2007. Accessed July 22, 2017. http://www.ctie.monash.edu.au/hargrave/rpav_radioplane.html

The de Havilland Queen Bee K4227, one of the first 10 production models (Number 7), at the Royal Aircraft Establishment at Farnborough. We can clearly see the ram air turbine mounted on the port side of the fuselage aft of the engine, which powered the pump that provided compressed air to the remote control system housed in the space where the instructor pilot would have sat. These views give us a good idea of how the early aircraft were configured for pilotless flight. Tonneau [canvas] covers help streamline the cockpits, which were still required to do factory test flights and delivery to launch sites. It is believed that these early production models were painted overall in silver. Photo: Royal Air Force

The Queen Bee represented a major step forward on many fronts, not the least of which was radio-control. One of its immediate, if disappointing, benefits was that it revealed shortfalls in the skills and efficacy of Royal Navy anti-aircraft gunners and systems. It was not uncommon for a Queen Bee to parade up and down in front of an entire warship squadron for over an hour while they pounded away at it, only to be commanded to land without a scratch. There is even an account of the King witnessing a demonstration of Royal Navy gunnery prowess using the Queen Bee, during which the gunners were unable to hit it. One high-ranking officer was seen to turn to his subordinate and whisper "For ***** sake, tell the operator to dial SPIN", at which point the Queen Bee dove into the sea, seemingly the victim of the gunners. The Royal Navy, British Army and Royal Air Force would utilize the Queen Bee to great extent to improve gunnery results, but the Navy soon turned to new technologies such as radar range finding and primitive computers to make warship anti-aircraft weapons the equal of modern dive and torpedo bombers….

The Queen Bee was certainly the first truly successful pilotless aircraft with nearly 400 being manufactured over several years. The Queen Bee's ability to fly without a pilot was indeed high technology at the time and it was demonstrated for dignitaries on many occasions. In 1936, Admiral William Harrison Standley, the US Navy's representative at the London Naval Conference, was witness to

[1]**SOURCE: Excerpted from O'Malley, Dave. "The Mother of All Drones." Vintage Wings of Canada. 2013. Accessed July 22, 2017. http://www.vintagewings.ca/VintageNews/Stories/tabid/116/articleType/ArticleView/articleId/484/Thep Motherp ofp Allp Drones.aspx**

a demonstration of the Queen Bee during a live-firing exercise. Upon his return to the United States, he set in motion revitalized American research into remotely flown aircraft like the Queen Bee, which could be used as a training device in the same manner.

Shortly thereafter, the Navy's Bureau of Aeronautics (BuAer) tasked Lieutenant Commander Delmar Fahrney to lead a project to develop the system. Within months, two Curtiss N2C-2 Fledgling and two Stearman training biplanes were equipped with similar equipment to the Queen Bee. Soon, the word "drone" began appearing in documents related to the American project. According to accounts, Fahrney himself coined the term drone as a deliberate nod to the de Havilland Queen Bee.

It is not known for sure if the drone naming is fact, but it is likely. Certainly, it is an appropriate name, conjuring armies of identical, mindless animals whose sole purpose is to do the bidding of a Queen Bee mother. Regardless of the source of the new name, it stuck like honey to a picnic blanket! Before the arrival of the Queen Bee, there were certainly other attempts at birthing the remotely flown aircraft, but they were largely aborted, miscarried, stillborn or short-lived. The Queen Bee produced nearly 400 offspring and generations upon generations of evermore capable aircraft flown by operators who stand off a world away. Today, drones can do almost anything from delivering pizza to occupying the nightmares of terrorists everywhere. Any one of us can own one. They range in size from mere inches to 150-foot wingspans. They can fly for days on end and for thousands of miles. They present complex moral conundrums about the sanitized delivery of death, about who is a combatant, and many more….

[1]SOURCE: Excerpted from O'Malley, Dave. "The Mother of All Drones." Vintage Wings of Canada. 2013. Accessed July 22, 2017.
http://www.vintagewings.ca/VintageNews/Stories/tabid/116/articleType/ArticleView/articleId/484/The-Mother-of-All-Drones.aspx

Document 3A (Excerpted[1])

The Vietnam War was America's first "war" that saw extensive use of UAVs. A total of 3435 operational reconnaissance UAV missions were flown between 1964 and 1975.[1] Approximately one-third of these missions were various versions of the Lightning Bug, which was the workhorse of Vietnam-era UAVs. Between 1967 and 1971, 138 missions were launched from DC-130 aircraft and flown via remote control in hostile territory. Many were recovered via the MARS (midair retrieval system), which was a specially equipped H-53 helicopter that caught the drone while in its parachute descent.

Operation Chicken was the operation in which the Lighting Bug UAV was introduced to many of the same tactics used by manned aircraft to escape MiG (Mikoyan and Gurevich—a former Soviet, and now Russian corporation) aircraft intercepts, air-to-air missile intercepts, and surface-to-air missile intercepts, thus introducing us to the age of artificial intelligence.

Because of the extent of enemy anti-aircraft fire in Vietnam, UAVs were often used as unmanned intelligence gathering platforms, taking photos from low and high altitude (IMINT, or imagery intelligence) that were used for strike planning and battle damage assessment. As the Vietnam War wore on, the Lightning Bugs were modified with larger engines that allowed them to carry heavier payloads. These UAVs could now perform signals intelligence missions in addition to their IMINT roles. Late in the Vietnam War, UAVs also performed psychological operations via leaflet drops.

In 1965, the U.S. Air Force established a requirement for a long-range recon-UAV. Ryan developed the model 154, Compass Arrow, designed to fly at 78,000 feet; it was also designed with minimal heat and radar signature, thus becoming the first UAV to use stealth technologies. Like its cousin the Lightning Bug, Compass Arrow was launched from a DC-130, was recovered via MARS, and had electronic countermeasures to improve its survivability. The program failed to move forward because of various political, financial, and technical problems. So while the Lightning Bug was an enormous success, both as a drone and a recon-UAV, Compass Arrow was a failure and possibly led to the lack of UAV acceptance at that time by many in the aviation business.

But with the success of the Lightning Bug, the modern UCAV was born. After 4 years of research and development, Ryan Aeronautical took its Lightning Bug design and showed that it could strike and destroy a ship from a distance of about 100 miles. In 1971, the Lightning Bug (model BQM/SSM) flew a perfect demonstration, slamming into the side of the ex-USS John C. Butler (DE-339) [a US Destroyer Escort]. But the BQM/SSM was competing against the more versatile Harpoon weapon system, which was all-weather and could be employed from a variety of platforms. Hence, the Navy chose Harpoon and canceled the BQM/SSM effort.

Like the BQM/SSM, the BGM-34A was developed because of hostilities. Israel was concerned about Soviet-made anti-aircraft artillery emplacements along the Suez Canal. In 1971, Teledyne-Ryan Aeronautical (TRA) developed a UCAV that could deliver air -to-surface munitions. TRA again used the Lightning Bug as the basic frame and then used pieces from other UAVs to develop the final BGM-34A product. In less than a year, TRA had developed a UCAV that was used to fire a powered, guided air-to-surface missile against a simulated target. American military thinkers had the idea of using these UCAVs on the first wave to soften a target then to finish off the target with manned aircraft. The Israelis agreed and used the BGM-34A against Egyptian missile sites and armored vehicles in the October 1973 Yom Kippur War and again in 1982 against Syrian missile emplacements in the Bekaa Valley. These Israeli

UCAVs certainly saved the lives of Israeli pilots. Americans never used this UCAV in Vietnam because it could not perform better than manned technology. After the Vietnam conflict, a few improvements were made to the BGM (such as models 34B and C), but generally speaking, interest in UAVs in general waned and further expenditures on recon-UAVs were put on hold. Additionally, UAVs had to compete with new high-speed missile systems, long-range bombers, and cruise missiles. So, with drastic budget cuts, UAV development basically ceased for about a decade.

In the late 1970s, the U.S. Army began a major UAV acquisition effort known as Aquila. It was originally estimated to cost $123 million for a 4-year development cycle, followed by $440 million for the production of 780 vehicles. Its original mission was to be a small propeller-driven, man-portable UAV that provided ground commanders with real-time battlefield intelligence. As development continued, requirements grew and the UAV's small size could no longer handle the avionics and payload items the Army wanted, such as autopilot, sensors to locate the enemy in all conditions, laser designators for artillery projectiles, and abilities to survive against Soviet anti-aircraft artillery. The Army abandoned the program in 1987 because of cost, schedule, and technical difficulties (and after $1 billion in expenditures).

[1]SOURCE: Excerpted from Keane, John F., and Stephen S. Carr. "A brief history of early unmanned aircraft." *Johns Hopkins APL Technical Digest* 32, no. 3 (2013): 558-571.

Document 3B (Excerpted[1])

During the Second World War the Japanese conceived the idea of fashioning incendiary bombs and attaching these to balloons which were released with easterly wintertime jet stream winds above 30,000 feet to float 5,000 miles across the north Pacific. The idea was to have these devices explode over the forested regions of the Pacific Northwest and initiate large forest fires that would hopefully divert U.S. manpower from warfighting in the Pacific theater to combating fires at home.

The balloons were crafted from mulberry paper, glued together with potato flour and filled with expansive hydrogen. They were 33 feet in diameter and could lift approximately 1,000 pounds, but the deadly portion of their cargo was a 33-lb anti-personnel fragmentation bomb, attached to a 64–foot long fuse that was intended to burn for 82 minutes before detonating. The Japanese programmed the balloons to release hydrogen if they ascended to over 38,000 feet and to drop pairs of sand filled ballast bags if the balloon dropped below 30,000 feet, using an onboard altimeter. Three-dozen sand-filled ballast bags were hung from a 4-spoke aluminum wheel that was suspended beneath the balloon, along with the bomb. Each ballast bag weighed between 3 and 7 pounds. The bags were programmed to be released in pairs on opposing sides of the wheel so the balloon would not be tipped to one side or another, releasing any of the precious hydrogen. In this way the balloons would rise in the daylight heat each day of the crossing and fall each evening, till their ballast bags were depleted, at which time the balloon and its deadly contents would descend upon whatever lay beneath it.

The first balloons were launched on November 3, 1944 and began landing in the United States on November 5th (off San Pedro, California) and by the following day (November 6th) were landing as far away as Thermopolis, Wyoming. 285 confirmed landings/sightings were made over a wide area, stretching from the Aleutian Islands, Canada and across the width and breadth of the continental United States: as far south as Nogales, Arizona (on the Mexican border) and easterly, to Farmington, Michigan (10 miles from Detroit). Most of the ballast bags were released in the trip across the north Pacific, but a few balloons crashed without exploding and some of the ballast bags were recovered. All of the bags contained the same type of dark colored sand.

The U.S. government muzzled the media about making any mention of the balloons in fear that whoever was producing them might be encouraged to send more. On March 5, 1945 a minister's wife and five Sunday School students on a fishing trip were killed by one of the grounded balloons near Bly, Oregon while attempting to pull it through the forest, back to their camp. These were the only casualties of the balloon bombs during the war and the victim's relatives were provided with a special death benefit after the war ended (in March 1946). The American public was made aware of the balloons after these tragic deaths, but word of their detonation never filtered back to the Japanese.

The Military Geology Unit (MGU) of the U.S. Geological Survey was tasked with investigating the small handfuls of sand occasionally recovered from the various crash sites. Before they were engaged in solving the case, federal investigators believed that the balloons were either being fashioned in POW camps along the west coast or possibly being released from Japanese submarines off our coast. On initial examination the MGU quickly eliminated North America as a source of the sand. The sand contained over 100 species of tiny microscopic diatoms, a mixture of fossil and recent species. There are 25,000 recognized species of diatoms. The fossil diatoms were all found to be of Pliocene age, between 5.3 and 1.6 Ma (million years before present).

[1]SOURCE: Excerpted from Rogers, J. David, PhD. "Japanese Vengenance Balloon Bombs of World War II." Accessed May 06, 2017. http://web.mst.edu/~rogersda/forensic_geology/Japenese%20vengenance%20bombs%20new.htm.

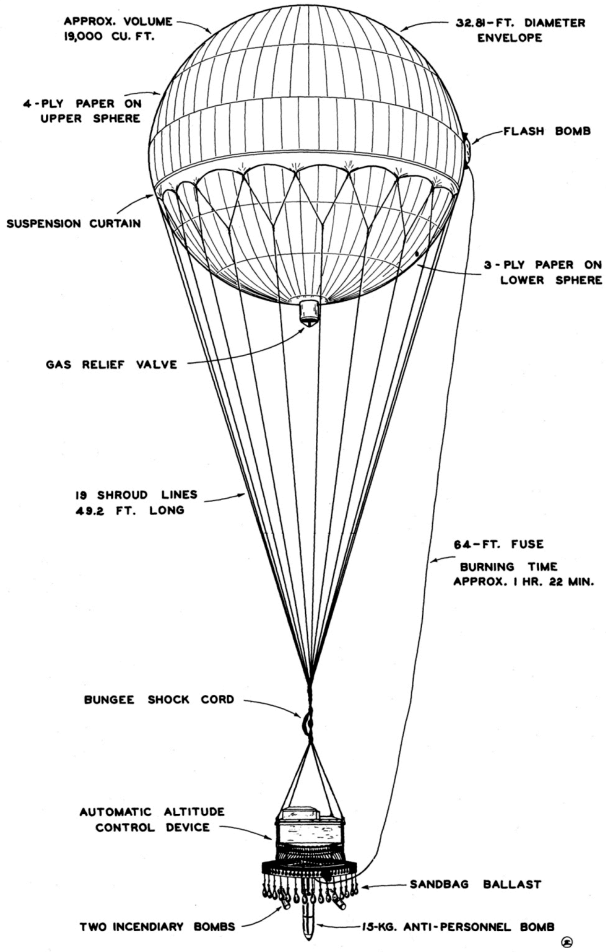
It was immediately clear that the ballast sand had come from a beach, but where? Further examination revealed that the sand was devoid of any coral, but contained small mollusk fragments. In Japan coral grows along the coast of the main island of Honshu as far north as Tokyo Bay, near the 35th Parallel. They also found foraminifera (known as "forams"), tiny skeletons of microscopic organisms that feed on the ocean bottom. Some of the foram species identified had only been previously described in Japanese geologic papers dealing with beaches north of Tokyo on the eastern shore of Honshu.

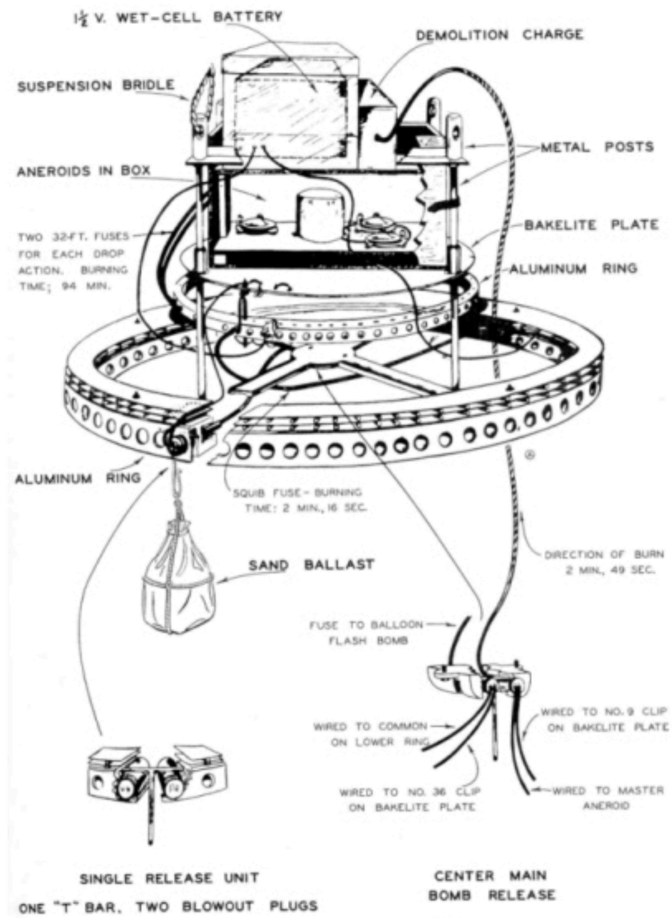
The individual sand grains were found to be of granitic origin, but with an unusual set of trace, or associated, minerals. 52% of those trace minerals were hypersthene, a heavy mineral. Another mineral called augite was also found in abundance, but was known to be of volcanic origin. Two other heavy minerals, hornblende and garnet, were varieties thought to be associated with metamorphic source rocks. By now the MGU geologists had narrowed the source area to the northerly thousand miles of Japan's eastern coasts. Further detailed study of pre-war Japanese geologic studies allowed them to narrow the source area by 80%. They determined that the sand samples likely came from either of two locations: a northerly site along the great beach at Shiogama, close to Sentai, Japan; and/or the Ninety-nine League Beach at Ichinomiya, Japan.

The work of the MGU conclusively identified northeastern coastal Japan as the source area for the sand ballast, and the likely point of launching. Once these locations were revealed detailed photo reconnaissance were made of the areas in early 1945 and the photo interpreters succeeded in identifying two of the three plants producing hydrogen for the project in vicinity of Ichinomiya. These plants were conclusively destroyed by American B-29 bombers based in the Mariannas Islands in April 1945, putting an end to the vengeance bomb project.

Although only 285 of the 9,000 bomb-laden balloons the Japanese launched were documented to have reached North America, experts believe that probably close to 1,000 made it across the Pacific. The Japanese government withdrew further funding for the project around the same time (April 1945) allied bombers destroyed the hydrogen plants, due to lack of conclusive evidence that they were reaching America and exploding. After the war, intelligence debriefings of those responsible for the launchings revealed that the balloons had been launched from three sites: Ichinomiya (close to Tokyo) and two other sites 10 miles apart and about 100 miles up the coast of Honshu, in the direction of Shiogama. The MGU hadn't identified the two northerly launch sites because the only sand samples they were provided with had come from Ichinomiya. Forensic geology became a permanent part of the Federal Bureau of Investigation and continues to help solve difficult mysteries to the present.

[1]SOURCE: Excerpted from Rogers, J. David, PhD. "Japanese Vengenance Balloon Bombs of World War II." Accessed May 06, 2017.
http://web.mst.edu/~rogersda/forensic_geology/Japenese%20vengenance%20bombs%20new.htm.





Automatic altitude-control device.

[1]**SOURCE: Excerpted from Rogers, J. David, PhD. "Japanese Vengenance Balloon Bombs of World War II." Accessed May 06, 2017. http://web.mst.edu/~rogersda/forensic_geology/Japenese%20vengenance%20bombs%20new.htm.**

The role and usage of UAS has grown significantly in the U.S. since their adoption as aerodynamic models, test beds, and aerial munitions in the early years of aviation (i.e., 1890s to 1918). Eventually, after the baseline technology was advanced, the roles of UAS were expanded to include use as aerial targets, weapons delivery platforms, communications relays, target designators, and ISR gathering assets. While the application of UAS has steadily increased over the years, the full extent of reliability and functionality was not realized until the 1990s. During operations Desert Shield and Desert Storm, U.S. forces flew a significant number of missions using UAS, which represented the first wide-scale use of this technology. These aircraft ranged in size from the group one sized FQM-151A Pointer, launched by hand, up to the group three RQ-2 Pioneer, requiring specialized support equipment for launch and recovery.

The use of UAS in military conflicts of the 1990s supported the capture of time sensitive intelligence and data that could be used by military leadership in their decision-making process, without subjecting a manned aviator to the risk of flying in an operational theater. Information could be obtained faster, from dangerous environments, with less risk to valuable assets and pilots. The result of this wide-scale use of UAS demonstrated their value, leading to the investment of funding to further develop and refine the associated technology and operational processes.

Advancement in the underlying and related technology, coupled with need, has led to the identification of wider application and utility of UAS. As the increased or improved capabilities associated with new technologies or the boundaries of existing technologies are discerned, the utility and capability of UAS also increase. While the majority of historical UAS application has stemmed from military/tactical uses, the technology has migrated to the civilian and commercial sectors. The resulting benefits of such migration include the ability to provide increased security, productivity, and efficiency, enhanced mobility and response, and improved access to perform disaster assessment, infrastructure inspection, and environmental protection.

The application of UAS for the sake of saving lives and assessing damage has been advocated by numerous government organizations and researchers. While there have been several high-profile cases where UAS have been used in disaster relief in other countries, emergency responders in the U.S. have been hesitant to use them in such cases due to regulatory and legislative restrictions. There are however, some examples of historical and current usage domestically. Also, UAS stakeholders have provided examples of missed cases in which UAS could have dramatically assisted in emergency events.

California Wild Fires. On multiple occasions in the past, the State of California has utilized UAS in attempts to monitor and fight wildfires. In 2011, a UAS was used to map fire activity and damage. As recently as 2013, a Predator UAS from the 163rd Wing of the California Air National Guard was used to provide real-time imagery to firefighters in order to assist in planning and direction of assets in a 301-square mile fire within Yosemite National Park. Of course, military platforms do not face the restrictions with which operations that smaller, non-military UAS users must conform. In fact, other California UAS operators have been cautious to launch their platforms even in face of threatening fires because of FAA restrictions.

PostT Hurricane Uses. Two UASs from the University of South Florida were deployed following the landfall of hurricane Katrina in storm damaged communities in Mississippi. A fourE footE long fixed wing platform

SOURCE: Excerpted from Terwilliger, Brent, Dennis Vincenzi, and David Ison. "Unmanned aerial systems: collaborative innovation to support emergency response." Journal of Unmanned Vehicle Systems 3, no. 2 (February 2015): 31---34. Accessed May 7, 2017. doi:10.1139/juvs---2015---0004.

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was used to provide an overview of damage. A helicopter UAS was used to zoom in on a smaller scale, looking at rooftops and within windows. This permitted first responders to confirm there were no survivors in the area threated by the Pearl River flood waters. This allowed rescuers to more effectively deploy assets to other locations. Three days following the landfall of hurricane Wilma, a micro UAS was coupled with an unmanned water surface vehicle to assess damage to seawalls, piers and to identify submerged debris.

Washington Landslide. In March of 2014, a massive landslide occurred burying a community near Arlington, Washington. In addition to the devastation brought by the slide, debris blocked a river potentially making things worse with the threat of massive flooding. To assess the damage, the status of the river, and to look for survivors a small UAS was deployed. The system was able to provide real-time data to rescue personnel through video feed and by taking photographs.

Boston Bombing. Although there are many cases in which UAS use for disaster relief could have been helpful, one of those receiving a tremendous amount of media attention was the bombing of the Boston Marathon in 2013. According to Clark, "Police, lawmakers and advocates are questioning whether police drones could have found the suspects faster." Numerous experts and law enforcement personnel believe that the manhunt for those responsible would have been more timely and organized with the inclusion of UAS. Moreover, if UAS were able to monitor such events, they may act as a deterrent and, in the worst case, assist in identifying guilty parties.

[1]SOURCE: Excerpted from Terwilliger, Brent, Dennis Vincenzi, and David Ison. "Unmanned aerial systems: collaborative innovation to support emergency response." ***Journal of Unmanned Vehicle Systems*** **3, no. 2 (February 2015): 31-34. Accessed May 7, 2017. doi:10.1139/juvs-2015-0004.**

Document 3D (Excerpted[1])

The invasion of Afghanistan in 2001 marked the beginning of the Long War. In March 2003, Operation Iraqi Freedom opened a second front in this war. During these two wars, UAVs performed far more missions, in type and quantity, and received far more attention than any previous conflict. Procurement of existing and development of new systems expanded exponentially. The limited wars in Bosnia and Kosovo demonstrated that UAVs had finally reached their potential. The Long War provided the stimulus to fully exploit these new tools. Existing systems such as the Predator and Hunter, underwent further modifications to expand their capabilities and prolong their operational life. New systems, such as the Raven and Shadow, moved quickly from initial development to large-scale production in a relatively short period of time. The growth of UAVs has provided commanders at all echelons with a better understanding of battle space and improved command and control. However, the rapid pace of the expansion raised several issues about the future of UAVs, including the long-term costs for logistical support and maintenance, concerns about the bandwidth required to support current and future UAV operations, and the proper balance of manned and unmanned vehicles within the services….

Global Hawk

The Air Force's Global Hawk UAV flew at the strategic level providing ISR missions for an extended period high above that achieved by the Predators, Reapers, and Sky Warriors. The Global Hawk transitioned from an ACTD [Advanced Concept Technology Demonstration] production to an operational program in 2001. The first operational production model was deployed to Central Command in 2006. Prior to this period, residual aircraft from the ACTD program flew missions in both Iraq and Afghanistan. By March 2005, the new system had flown over 4,000 hours of combat operations. A more advanced 'B' model performed its first flight in March 2007. Like the Predator, operators in Europe and the United States usually controlled Global Hawk while in theater. Because Global Hawk is a relatively new system, control from the United States has allowed for more rapid adjustments and improvements to the control system than was possible if the vehicle had been controlled in theater. If an operator experienced a problem or simply could not develop a target, he could call a developer on his cell phone and talk to him about how to fix the system. In one case a hard drive in the control system overheated. The intelligence operator assumed the mission was not recoverable and started to leave the control center. An engineer diagnosed the problem, and the mission commander sent someone to the post exchange to buy a fan. This $15 fix cooled the drive and allowed the mission to continue successfully.

Predator and Variants

Of all the UAVs supporting American forces in Iraq and Afghanistan, none received as much attention as the Predator system. During the 1990s, the USAF designated the Predator as the RQ-1. The Air Force had used 'Q' to designate unmanned aircraft as early as World War II. The 'R' stood for reconnaissance. As early as 2001, the Air Force used a Predator aircraft to launch a Hellfire air-to-ground missile against an enemy target. This new capability prompted a change in designation from RQ-1 to MQ-1, the 'M' represented the Predator's new multi-mission capability…. In Kosovo Predators flew equipped with laser designators. The armed models used this designator to mark targets for their onboard Hellfire missiles. Both the CIA and the Air Force operated Predators using this new capability in the first six months of Operation Enduring Freedom.

In September 2008, the Air Force had an inventory of 110 Predators. During the surge that year in Iraq, Predators provided over 13,000 hours of video to the troops on the ground each month. At one point, the Air Force conducted 24 simultaneous combat air patrol missions, with each one providing coverage around the clock. This operation intensity was possible through the development of "split remote control." In this model, take-off and landing was directed by line-of-sight control in theater. Once airborne, operators in the continental US assumed control of the vehicle. This method, which increased the number of operators available, nearly tripled the number of operational Air Force's Predators at any given time, from 30 percent to 85 percent of the inventory.

Simultaneously with the expansion of the Air Force's Predator, operational availability was the Army's purpose for its own endurance UAV. Army efforts focused on the General Atomics Sky Warrior, initially known as the Improved GNAT-Extended Range (I-GNAT-ER). The vehicle itself closely resembled the Predator, but powered a diesel (instead of aviation gasoline) engine. The first Warriors were deployed to Iraq in 2004. A newer version, known as Sky Warrior, entered service in 2008. Sky Warrior possessed a superior weapons payload to the Predator or Warrior, and was capable of carrying four Hellfire missiles. Initial plans called for a system of 12 vehicles to be assigned to each divisional aviation brigade, further divided into 3 platoons. Each deployed system also included five ground control stations. In addition to its own lethal payload, the Warrior (and later Sky Warrior) acquired targets for the hunter-killer teams of OH-58 and AH-64 helicopters. Before Warrior, these teams functioned basically as they had in Vietnam: the OH-58 sought out targets and the helicopter gunship engaged it. Now, manned helicopters remained on strip alert until Warrior acquired a target. Also, because it was organic within the division, the operation team was in sync with the operations and activities of the ground forces that the vehicle supported. In one case, a Warrior imagery analyst detected insurgents placing an IED on a road several miles ahead of an approaching convoy. Because the operator knew where the convoy was headed, he warned the convoy commander. The commander stopped his vehicles, the Warrior lased the target, and a team of Apache and Kiowa helicopters engaged both the IED and the insurgents. An operator and analyst working from the continental United States would have identified the IED being set and directed other units to destroy it, but the analyst might not have known to warn the approaching convoy and save US Soldiers lives.

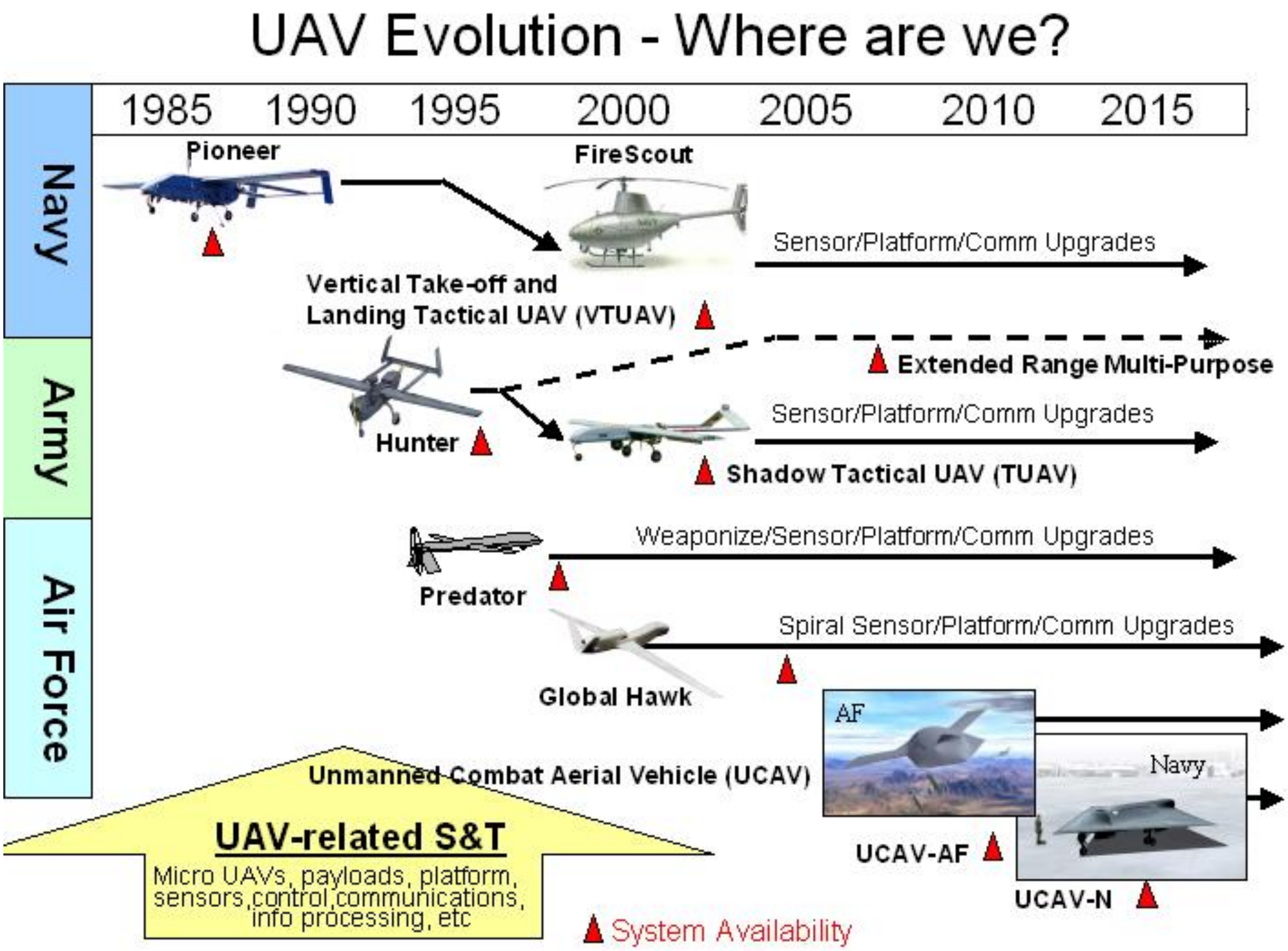
Short Range Systems – Hunter, Pioneer, and Shadow

During the Long War, three UAV systems performed the short range ISR mission. Two of these programs possessed operational experience in previous conflicts: Hunter and Pioneer. The third system, Shadow, debuted during the Long War….

The Army used the One System Ground Control Station (GCS), designed by AAI for the Shadow system. Interoperability and commonality increased due to its ability to work with multiple platforms. From 2001 through 2005, the GCS was able to control modified Pioneer, Warrior, and Hunter UAVs, each of which had previously used its own GCS…. As more units received the One System GCS, it was easier for an Army unit working adjacent to a Marine unit to "borrow" a Marine UAV and vice versa. In addition to providing a rapid response to quickly developing situations, this interoperability also decreased the amount of mission overlap that occurred when each service needed to deploy its own UAV.

[1]SOURCE: Excerpted from Blom, John David. *Unmanned Aerial Vehicles: A Historical Perspective*. Fort Leavenworth, KS: Combat Studies Institute Press, 2010.

Document 3D



SOURCE: Excerpted from "Research Guides: Government Resources: Defense, Military, and Security: Drones (Military)." University Libraries -- University of Louisville. Accessed May 14, 2017.
http://library.louisville.edu/ekstrom/gov_defense/dronesmil

Document 4A (Excerpted[1])

Delivery drones still face an uncertain future, but there's at least one scenario where they make a lot of sense: Flying robots can be ideal for bringing small, high value, time-sensitive goods to people in low-infrastructure areas. As specific a situation as that sounds like, it's an enormous opportunity, and has the potential to make a huge difference in rural areas and disaster relief missions with deliveries of food and medical supplies, for example.

One challenge with that, however, is that while drones are cheap to operate, the up-front investment is significant, especially if you need to make a lot of deliveries quickly, like right after an earthquake. With this sort of thing in mind, DARPA has funded several companies under its ICARUS (Inbound, Controlled, Air-Releasable, Unrecoverable Systems) program to create cheap, disposable drones that are designed to deliver a thing to a place and then be forgotten about. One of the companies receiving DARPA funding is San Francisco research firm Otherlab, which does weird robotics-y stuff with creative materials, among other things, and they've come up with a design for a drone they're calling APSARA: Aerial Platform Supporting Autonomous Resupply/ Actions.

Otherlab's APSARA drones are made almost entirely of cardboard, with some packing tape mixed in. They're about a meter in size and don't have propellers: They are designed to be launched from other aircraft and glide, using some very basic hardware (GPS, an autopilot, some small servos, and a disposable battery) to steer themselves. Otherlab says the drones can travel distances of up 150 kilometers, and land within 10 meters of their target. And once they deliver their 1-kilogram payloads, you're supposed to just forget about them—they'll degrade and disappear on their own. At the moment only the cardboard airframe is degradable—Otherlab used low-cost conventional electronic components for the hardware—but DARPA is funding a separate program called Vanishing Programmable Resources (VAPR), to develop electronics capable of "physically disappearing in a controlled, triggerable manner."

"We knew it had to disappear," says Mikell Taylor, team lead at Otherlab's Everfly (and Automaton alum). "That pointed us to a fairly limited range of materials." She explained that Otherlab does a lot of rapid prototyping using cardboard with very precise curves and shapes, and that capability helped hugely with the design of the APSARA drones. "It's like the IKEA of drones: It comes as a flat-pack thing with a bunch of sheets of cardboard that's been laser cut and scored, and you can fold it up when you're ready to go," she says. "It's easy to assemble, you just tape it together."

Taylor told us that the assembly process usually takes about 30 minutes per drone. It's very straightforward, and could be made even easier by pre-printing instructions on the drones themselves. The goal is to make the design simple enough that it requires no skill or experience to construct.

Once you've got the drone put together, launching it is (to be fair) a bit of a hassle. As a glider, the APSARA drones require that you give them a substantial amount of starting altitude. Otherlab envisions dumping a couple hundred of them out the back of a C-17 transport aircraft at 35,000 feet, which is where they get their 150 km maximum range, but you don't necessarily need to go up that high.

SOURCE: Excerpted from Ackerman, Evan. "Swarms of Disposable Drones Will Make Critical Deliveries and Then Vanish." IEEE Spectrum: Technology, Engineering, and Science News. February 01, 2017. Accessed March 25, 2017. https://spectrum.ieee.org/automaton/robotics/drones/otherlab-apsara-aerial-delivery-system.

The drones are very efficient, with an excellent glide ratio; it's simply that the higher you drop them from, the farther they'll be able to go.

Otherlab has experimented with a variety of landing techniques, but for now, they've settled on a spiral down to a controlled crash landing. Remember, the drones are designed to be disposable, so "crash" is perfectly acceptable—as long as the payload arrives safely, a landing that's more crashy really just means that the drone is getting a head start on disposing of itself. Of course, "dispose of" can mean a lot of different things. DARPA's looking for drones that can essentially cease to exist within hours or days, and, at least for the paper components, Otherlab might be able to do that using special cardboard that's been impregnated with mushroom spores. Or maybe you want the material of the drone to be useable to the person receiving the delivery somehow. This is all part of what's so interesting about DARPA's ICARUS program: There are all kinds of different ways of tweaking the design to make drones that are both disposable and useful at the same time.

Otherlab also had to keep costs at a minimum so that the drones are so cheap that you don't have to worry about not getting them back. How cheap? Taylor wouldn't comment specifically on price, except to say that it's "really, really cheap," to the point where in most use cases, users won't care if they lose all of them. And this is the key—the change in mindset that comes with being able to just not care if your drones never come back, which lets you focus on the deliveries, as opposed to recovering your delivery assets, as Taylor explains:

> *"I think that's why there's been so much excitement about this: If you look at the way goods are delivered by air right now, whether you're a humanitarian agency, the military, or whoever, all the logistics of delivering has to budget for really high losses, because stuff goes wrong. If you have the delivery mechanism be this cheap, it opens up a lot of opportunity to get more stuff to people who need it more effectively."*

Otherlab's grant under DARPA's ICARUS program has concluded, but the company is looking at a few different potential sources for funding. Taylor tells us that there's been a substantial amount of interest in this project, and we can't wait to see what happens with it.

[1]SOURCE: Excerpted from Ackerman, Evan. "Swarms of Disposable Drones Will Make Critical Deliveries and Then Vanish." IEEE Spectrum*: Technology, Engineering, and Science News*. February 01, 2017. Accessed March 25, 2017. https://spectrum.ieee.org/automaton/robotics/drones/otherlab-apsara-aerial-delivery-system

Document 4B (Excerpted[1])

[NOTE: some of the regulations cited in this document have changed since it was printed. Current information regarding government control of UAVs can be found on the FAA website.]

The primary restriction to UAS operations for any non-personal (hobby) or larger platforms comes from the FAA. Currently, any other type of UAS operation – academic, law enforcement, commercial, disaster relief – is limited by FAA mandates. If an individual wants to operate a non-personal UAS, they must apply for a Certificate of Authorization (COA) with which the FAA has not been reliably forthcoming. As of March 2014, only public agencies are eligible to apply for a COA. Alternatively, a user can apply for a special airworthiness certificate but these provide limited scope of use. Thus it is impossible for first responders to "legally" utilize UAS in their efforts except in the case of a sponsoring military agency. Yet this means that disaster responders have limited flexibility about quickly and effectively dealing with time sensitive events.

Additional state and local legislation has surfaced to limit UAS usage. As of 2014, 43 states had considered or passed UAS-restrictive legislation. More than 70% of the passed legislation allow provisions for UAS use in exigent circumstances such as emergency response. Additionally, more than 80% of those passed permitted UASs when a warrant was issued. Many municipalities have also brought forth constraints to UAS. Charlottesville, Virginia has a "drone-free zone" and a moratorium on the purchase of UAS by the city. Other cities and counties have adopted restrictions on weaponized UAS, UAS prohibitions, and limits to purchases of UAS by government or law enforcement. However, many of these motions have exemptions for UAS being flown for exigent circumstances.

More resistance to UAS adoption stems from privacy concerns. When the City of Seattle attempted to add UAS to their police force, protesters forced the Chief of Police to abandon the pursuit indefinitely. There has been a significant amount of public concern voiced about UAS data collection, even if unintentional, during their use even in disaster relief or other virtuous tasks. This has prompted legislators and local representatives to pursue the aforementioned legislative actions. Also, prominent groups such as the American Civil Liberties Union (ACLU) and Code Pink have been vocal about privacy protection from UAS. Even the FAA has faced pressure about addressing the privacy issue, which they then included privacy protection language in the recently released test site plan which will allow UAS testing for their integration into the National Airspace System.

Uses of UAS for the civilian sector are numerous and the list is growing daily. The trend in military UAS applications is to replace manned missions that are typically classified as "dull, dirty and dangerous. The terms "dull, dirty and dangerous" not only describe a significant part of warfare activity, but can also be applied to many tasks where UAS technology can be most useful, including but not limited to things such as pipeline monitoring, agricultural and crop-dusting applications, wildfire aerial assessment, and disaster response and relief efforts.

UAS technology is uniquely suited for ISR operations due to a wide variety of sensors and payloads available for military and civilian use. Sensors are usually designed to collect information or data from the aircraft or environment, whereas payloads are usually designed to leave the aircraft. Examples of sensors may be video cameras, infrared cameras, multispectral cameras, or aircraft sensors (altitude, airspeed, temperature, etc.), whereas examples of payloads may be crop-dusting pesticides, water for fighting fires, or as is the case with military applications, armament. However, payloads can also refer to

SOURCE: Excerpted from Terwilliger, Brent, Dennis Vincenzi, and David Ison. "Unmanned aerial systems: collaborative innovation to support emergency response." Journal of Unmanned Vehicle Systems 3, no. 2 (February 2015): 31---34. Accessed May 7, 2017. doi:10.1139/juvs---2015---0004.

a collection of sensors combined into one unit such as a suite of sensors (infrared cameras, high resolution video cameras, etc.). Today, the term sensor and payload are often used interchangeably.

One of the most redeeming features of a UAS used in disaster response and recovery efforts is the ability of the UAS to transmit information from sensors and payloads back to the ground control station (GCS) for processing. The ability of the UASs to fulfill their missions depends in large part upon the communications link between the UAS and the GCS. These two factors allow UAS units (UAS and GCS) to enter an affected area quickly while leaving the human component behind in a safe location to process information and coordinate response and recovery activities. Sending the UAS into the hazardous area to perform the missions related to damage assessment and search for stranded individuals in need of assistance can be performed much sooner than normally possible if the technology were not present and available. This allows enhanced situation awareness for rescue and response personnel and pinpoint focusing of resources where needed instead of blanket coverage and inefficient rescue operations.

There are several significant concerns and challenges that may restrict the operation and application of UAS to support disaster recovery and response. These concerns and challenges include gaining access to airspace, ensuring safety and privacy, and optimizing data capture and analysis. Until these issues are better understood, with possible methods to mitigate identified, the potential of UAS to support disaster recovery and response efforts may not be fully achievable. A few recent research topics associated with UAS technology exhibit potential applicability and benefit to resolve some of these issues. These subjects include unmanned system teaming, improved algorithms, adaptive training, and improved automation. Further exploring these avenues of research may provide additional capabilities and performance to better support the future execution of UAS disaster recovery and response missions.

The adoption of UAS in disaster and recovery efforts shows excellent promise to assist first responders to support in the most comprehensive possible ways. By giving these individuals difficult to attain or presently unavailable data, first responders can apply UAS to expedite their efforts in order to save property and lives in a safe, efficient, and effective manner.

Unfortunately, the current regulatory environment hampers their use. It is critical that UAS stakeholders continue their efforts to attempt to provide regulating agencies and legislators the extremely beneficial attributes of UAS in the ability to provide critical data to disaster and recovery efforts. Examples such as the Boston Marathon bombing point to missed opportunities that could have benefitted from the inclusion of UASs.

Once the regulatory issues are resolved and the FAA provides a framework for reasonable use of UAS, such should allow for constructive and beneficent UAS operations such as those that assist first response efforts. The potential of UAS to help in disaster and recovery efforts cannot be underestimated and theoretically can revolutionize the data collection and observation capabilities in situations currently handicapped by the lack thereof. UAS have the capability to transform the way disaster relief is handled – let us hope that the obstacles are removed so that rescue personnel can leverage their abilities to save lives.

[1]SOURCE: Excerpted from Terwilliger, Brent, Dennis Vincenzi, and David Ison. "Unmanned aerial systems: collaborative innovation to support emergency response." ***Journal of Unmanned Vehicle Systems*** **3, no. 2 (February 2015): 31p 34. Accessed May 7, 2017. doi:10.1139/juvsp 2015p 0004.**

Document 4C (Excerpted[1])

Although UAV systems of various kinds have been available for less than a decade, and are still very much in an experimental stage, archaeologist and applied scientists have already identified numerous archaeological applications in which aerial platforms of this kind could play an important and innovative role. The scale of the detail in which UAVs operate has always been somewhat problematic – relatively restricted in comparison with traditional systems based on conventional air photography or aerial photogrammetry but relatively large by contrast with terrestrial detection systems such as total station survey, global navigation satellite system (GNSS) and ground-based laser scanning. In a sense, however, drones offer the opportunity to fill a gap in the effective range and detail of low-altitude survey, with an effective coverage of between about 20 and 200 m flying altitude and the capacity to acquire data for landscape areas ranging from less than a hectare to as much as 300 hectares per day.

The geometric resolution that can be obtained is unprecedented, allowing the acquisition of images of excellent quality for both aerial photograph interpretation and 3D modelling. A further aspect, of great interest, lies in the capacity of the UAV to take to the air at short notice, almost anywhere and at almost any time of day and year, increasing what might be termed the 'temporal resolution' of the instrument. This facility, compared with the difficulties involved in the hire of traditional light aircraft from perhaps distant airfields, introduces completely new opportunities for high resolution survey, exploration and landscape monitoring, in some cases also providing access to areas or features that are inaccessible from the ground. These characteristics open up new scenarios not only for the monitoring of individual site or monuments but also for archaeological conservation more generally in response to the many activities and development proposals that daily threaten the cultural heritage. The opportunity to develop highly accurate 3D models of monuments and archaeological sites, even including those of very significant size (as at Paestum) offers new perspectives for World Heritage recording and conservation. In the case of environmental or other dramatic events and disasters UAV-based data collection will make it possible to create digital 3D representations of the actual environmental conditions in the affected locality, assisting rescue or reconstruction work and serving as agents for memory preservation. It should be emphasized that these are complex issues that require specific analysis. The risk factors are not limited to war scenarios and terrorist attacks. A more incisive role can be attributed to other factors, including, intensive agriculture, new construction work, industrial activities and infrastructure developments as well as natural erosion and systematic looting, for instance. Another significant aspect is the cost of the equipment. In recent years, these initial costs have been in sharp decline, although the purchase of a professional-grade system equipped with high-quality sensors and offering high reliability and good tolerance of variable environmental conditions still requires a significant financial investment. That said, the survey speed and data quality are so high that they will quickly prove cost-effective in the balance between resources invested and results achieved. Following appropriate training, and acquisition of the necessary permits, most currently available UAV systems are relatively easy to use. The fact that the survey work can in many cases be carried out effectively and safely by just a single person is another factor in the balance between initial capital investment and subsequent operating costs.

However, there are still several important problems to be overcome, though most of them are already some way towards solution. Drones are in most cases significantly weather dependent and are especially affected by strong or gusty winds. In many instances the lifting capacity needs to be improved, as does the tolerance of non-ideal weather conditions and the relatively poor on-board 'intelligence' of many of the available platforms – few drones yet have any significant capacity to respond independently to

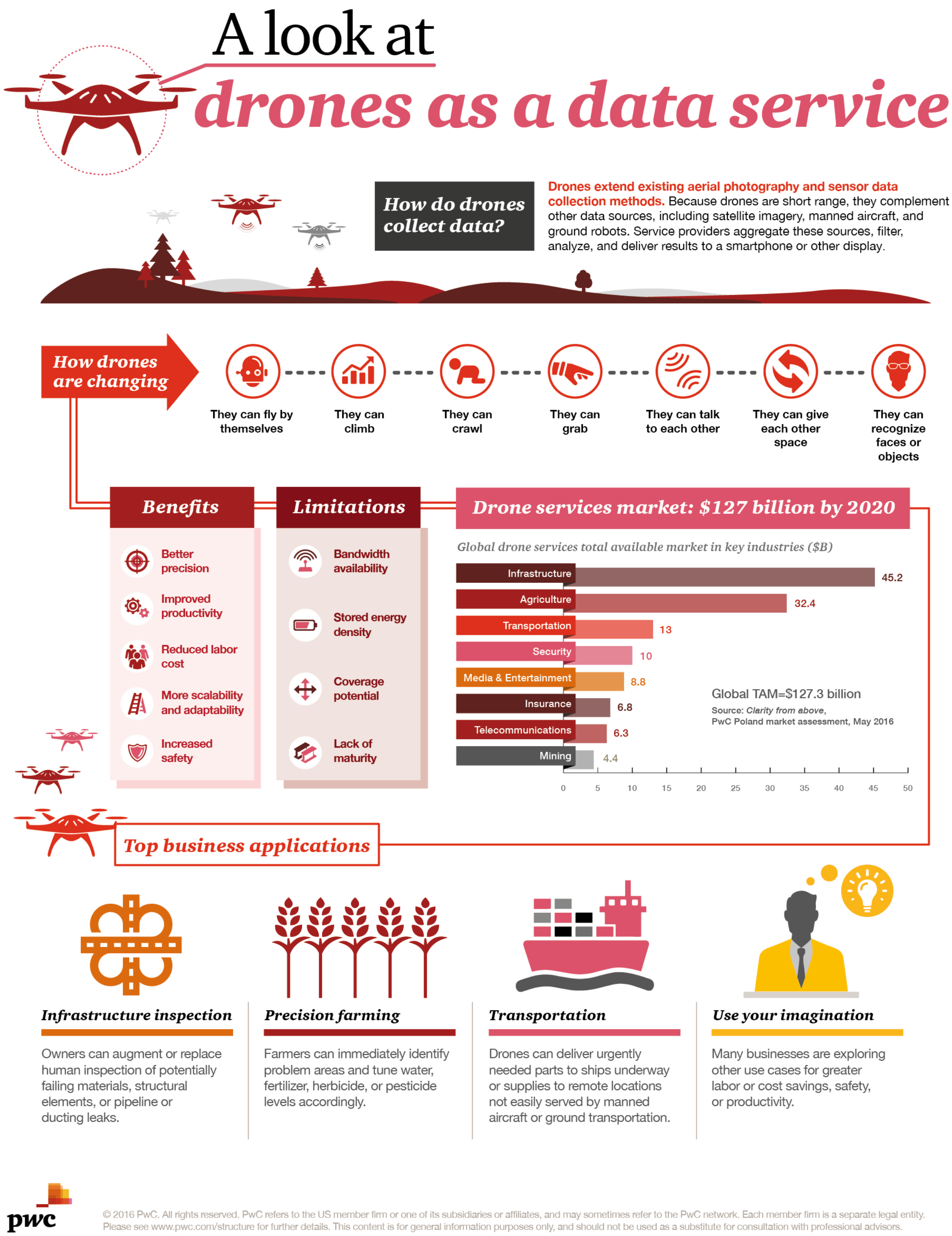
SOURCE: Excerpted from Campana, Stefano. "Drones in Archaeology. Statep ofp thep art and Future Perspectives." Archaeological Prospection, 2017. Accessed May 13, 2017. doi:10.1002/arp.1569.

variable wind conditions or the presence of stationary or moving obstacles that lie outside the direct sight-line of the pilot. In these senses autonomy and reliability, both of which vary greatly with the type and capital cost of the UAV, represent key considerations for potential users, especially in the initial phases of research design. Reliability must also be a factor which is directly related to the search for safety of operation: serious accidents are thankfully rare but they do occur and any form of unreliability could become a contributory factor in future events of this kind. In addition to responsible behavior and the observance of professional ethics, meticulous attention must also be paid to the regulations in force at the time and place of operation – the regulations, unfortunately, can be quite uneven and inconsistent between one country or context and another.

Ultimately the major methodological novelty of UAVs, beyond mere technical innovation, lies in their capacity to provide archaeologists with the opportunity to exercise direct and independent control over all aspects of the survey process: the platform, the sensors and the subsequent processing of the collected data. This capacity to control the process will give the researcher the freedom to develop applications and programs of work that are directly related to the framing and answering of specifically archaeological questions, without having to deal (apart from the regulatory framework) with any non-archaeological intermediary. This kind of challenge has been a constant in the history of archaeology; the advent of drones and their increasing capacity to carry varying kinds of sensors, represents a major breakthrough that could in important respects revolutionize the future potential of archaeological survey, interpretation and problem-solving.

[1]SOURCE: Excerpted from Campana, Stefano. "Drones in Archaeology. Statep ofp thep art and Future Perspectives." *Archaeological Prospection*, 2017. Accessed May 13, 2017. doi:10.1002/ arp.1569.

Document 4D



SOURCE: Excerpted from Morrison, Alan. "A look at drones as a data service (infographic)." Next In Tech. February 06, 2017. Accessed May 14, 2017. http://usblogs.pwc.com/emerging-technology/a-look-at-drones-as-a-data-service-infographic/.

IEEE REACH

GLOSSARY OF TERMS

3D modelling – process of developing a mathematical representation of any surface

AAI – a Maryland-based aerospace and defense development and manufacturing corporation

air-to-surface munitions – weapons designed to be launched from aircraft at land and sea targets

altimeter – instrument designed to measure altitude

altitude – height above sea level

anemometer – an instrument for measuring wind speed

aneroid barometer/altimeter – an instrument that measures atmospheric air pressure for determining altitude

assets – "tools" employed for one's own advantage

B-17 Flying Fortresses – bomber aircraft used in WWII

Becker and Dornberger – Karl Becker and Walter Dornberger were Nazi military officers assigned to work together on the V2 Rocket development program

Colonel Karlewski – Nazi ordnance officer who led the first meeting with Becker and Dornberger that helped to secure the commission to build the V2 Rocket

Columbus's egg – a reference to a story about Columbus and his detractors. According to the story, some competing navigators criticized Columbus for his "discovery" of America, saying that anyone could have done it – the achievement took no great skill. Columbus' response was to challenge his detractors to stand an egg on its end without any props. Of course, they all failed. Then, according to the story, Columbus cracked the egg and stood it up on its now flattened end, thus demonstrating that any feat may seem simple once you know how to do it. The achievement is in discovering the solution for the first time. (This story has also been attributed to Filippo Brunelleschi.)

countermeasures – military tactics designed to respond to specific offensive measures

counterweight trebuchet – evolutionary culmination of the hybrid trebuchet that finally eliminated the need for ropes and pullers altogether. Momentum was entirely controlled by a counterweight behind the fulcrum. Various designs of this weapon include fixed or hinged counterweights, as well as multiple means of holding and releasing the stone.

DARPA – Defense Advanced Research Projects Agency

disaster assessment – a determination of the losses incurred as a result of a disaster divisional aviation brigade – a multi-squadron unit of aircraft

electric system – a system that uses electricity to do work

Gerd de Beek - Gerd Wilhelm de Beek was a graphic artist at Peenemunde (site of Nazi army research center that became the home of V2 rocket development) who illustrated the progress of the V2 rocket program.

global navigation satellite system (GNSS) – a satellite navigation system with global coverage

ground control stations – land- or sea-based control center for UAVs

ground-based laser scanning – technology used for improved photogrammetry

gyroscope – a device consisting of a wheel that rotates rapidly about an axis. Because the plane of rotation of the wheel is unaffected by the movement of the base on which the axis is mounted, the device is often used to stabilize vessels in navigation.

Harpoon weapon system – US-designed anti-ship missile system that uses radar to track its target

hectare – metric unit of square measure equal to 10,000 square meters

Hellfire air-to-ground missile – originally developed as an anti-armor weapon, it has become the most widely used missile among allies of the US

hybrid trebuchet – a traction trebuchet with some weight added behind the fulcrum to assist the pullers and increase the effective throwing distance

IED – improvised explosive device

IMINT – Imagery Intelligence is concerned with gathering intelligence via satellite and aerial photography

in theater – within an active war zone

infrastructure inspection – an examination of the roads, bridges, tunnels, etc. that comprise the nation's infrastructure

insurgents – anti-governmental rebels

intercepts – missiles designed to destroy other missiles before they reach their targets

Interoperability – the ability of equipment or groups to operate in conjunction with each other

ISR – intelligence, surveillance, and reconnaissance lased – marked with a laser

leaflet drop – military tactic consisting of dropping printed propaganda from aircraft.

long-range recon – reconnaissance conducted deep within enemy territory.

mechanical “computer” – a “computer” consisting of mechanical rather than electronic components. The most common example is an adding machine.

MiG – series of Russian fighter jets produced by the Mikoyan-I-Gurevich Design Bureau and used since WWII.

NextGen – Next Generation Air Transportation System. An improved air traffic control system with more automation for added safety, developed under the U.S. Federal Aviation Administration (FAA).

phao – Chinese term for “trebuchet.”

photogrammetry – the use of photography to measure distance between objects.

platoons – small military unit usually consisting of 40-50 soldiers.

pneumatic/vacuum system – in fluid mechanics, a system that employs compressed air driven into a controlled space such as a balloon or pipe.

propellant – something that causes something else to move, for example, a gas that expands to push liquid.

rearmament – the process of rebuilding a country’s military.

reconnaissance – military observation of a region to find enemy locations and assist in strategic planning

Reinickendorf - the site of Raketenflugplatz, the field used by Germany’s Society of Space Travel (VfR) for rocket testing.

Ryan – Ryan Aeronautical Company developed small drones including the Lightning Bug, the Firefly, and the Compass Arrow.

servo – a device that uses negative error-sensing feedback to automatically correct and control the action of a machine or a part of a machine such as a UAV.

shaduf – (water sweep) an irrigation device used by the ancient Egyptians that employed a counterweighted arm to lift the water from its source.

signals intelligence missions – concerned with gathering intelligence from enemy electronic signals.

survivability – ability to survive.

terrestrial – of the earth.

traction trebuchet – original trebuchet design that used several manned ropes to pull the catapult arm through its rotation.

trebuchet – medieval siege weapon developed from a basic catapult, a compound machine that includes a base and a throwing arm. The term derives from Old French.

UAS – Unmanned Aerial System that includes the unpiloted aircraft, the ground-based controller or command center, and the system of communications technologies connecting them, such as computers, visual sensors, and satellite communication.

UCAV – unmanned combat aerial vehicles or combat drones.

unmanned system teaming – process for allowing multiple unmanned systems to communicate.

unmanned water surface vehicle – a drone that functions on water.

Valier-von Opel stunts – rocket-powered ground tests conducted by Max Valier and Fritz von Opel.

von Braun – Wernher von Braun began his work as part of Germany's Verein für Raumschiffahrt, or Society for Space Travel (VfR). He led the Nazi team of scientists that developed the V2 rocket, and later led the American team of scientists that developed the Saturn V rocket to power the Apollo space missions.

weapons payload – the total amount of explosive carried by a missile.