



Chapter 15

HELICOPTERS, STOLs, VTOLs AND UAVs



Objectives

- Identify** at least two heavy-lift helicopters.
- Identify** at least two light-lift helicopters.
- Define** STOL and VSTOL.
- Define** UAV.

Vertical and short takeoff aircraft are known as V/STOL. The most common type of VSTOL aircraft is the helicopter. Since a helicopter can takeoff and land vertically it is also known as a VTOL aircraft.

Helicopters are used in civilian and military for transportation. In the military, they are also used for attack missions. Some drawbacks to helicopters over fixed wing aircraft are maintenance, vibration, and speed. Even, Igor Sikorsky admitted that. Advances in technology have reduced vibration.

The main historical advance that made helicopters more useful was the gas turbine engine. This enabled greater lifting loads and speed.

Most modern helicopters make extensive use of composites such as fiberglass and carbon epoxy. Helicopters for the US Army are usually named after Native American Tribes. The US Army is the lead service for helicopter research and development.

Helicopters

Military

While many designs have military uses, attack helicopters are almost entirely in the military domain, although there are some Cobras in private ownership. The main U.S. attack helicopters are the AH-1 *Cobra* and AH-64 *Apache*.

Attack

AH-1 Cobra. The *Cobra* was a development of the UH-1 *Iroquois* solely for the attack mission. Although the US Army retains some Cobras, they are being retired. Several other countries still operate them. The newest Cobra in the US inventory is the AH-1Z *Super Cobra*. It is a development of the earlier AH-1W. The AH-1Z has a four-bladed 680 rotor and a new cockpit. It is powered by two General



Electric T-700 engines each producing 1500 SHP. It is built by Bell Helicopter Textron, Inc.

AH-64 Apache. The AH-64 *Apache* was developed by Hughes Helicopters. The company was originally founded by Howard Hughes. The company was subsequently bought by McDonnell Douglas then Boeing. A version of the same engines that power the Super Cobra is used in the AH-64 *Apache*. The latest variant of the *Apache* is the AH-64D. The AH-64D has a millimeter wave radar that enhances its attack capabilities.

Both aircraft can carry an assortment of weapons ranging from the Hellfire missiles to the 2.75 in rockets. The AH-64 has a 30mm gun; the *Cobra* has a three-barreled 20mm cannon.



AH-64A Apache (Boeing Photo)

Transport

Transport helicopters by their nature can be military or civilian. There are three categories of transport or cargo helicopters. They are heavy lift, medium lift and light lift or utility. An example of heavy lift is the CH-53. An example of medium lift is the H-46 *Sea Knight*, and an example of utility is the UH-1 *Iroquois*.

Heavy-lift

Sikorsky H-53. The US helicopter with the heaviest lift capability is the CH-53E *Super Stallion*. It is built by Sikorsky Aircraft. It can vertically lift up to 32,000 lbs. It is powered by three 4380 SHP General Electric T-64 engines. Its seven-bladed main rotor has a diameter of 79 feet and its overall



Boeing CH-47 Chinook (EAA)

length is 99 feet. It is an outgrowth of the earlier CH-53D *Sea Stallion* which is still operated by the US Marines. The CH-53D has two engines each with 3200 SHP. The CH-53D has a six-bladed main rotor with a diameter of 72 feet. A replacement for CH-53E is currently under development, it is the CH-53K.

Boeing H-47. The heavy lift machine for the Army is the CH-47 *Chinook*. It is built by Boeing Helicopters. It comes in several variants. The CH-47D is the most common. These are being replaced by, and upgraded to, CH-47Fs. CH-47F may be cancelled. Special Operations uses both the MH-47E and MH-47G. They are powered by the Lycoming T-55.

Medium-lift

Boeing H-46. Medium lift is defined by the CH-46 *Sea Knight*. The CH-46 was built by Vertol, which later became Boeing Helicopters. It is a development of the earlier tandems designed by Frank Piasecki. It is powered by two General Electric T-58 engines of 1600 SHP each. It is 84 feet long. The CH-46 served with both the US Navy and the US Marine Corps. It has been replaced in the Navy by the MH-60S *Knighthawk* and is being replaced in the Marine Corps by the V-22 *Osprey*. The H-46 will remain in service until 2020.



Sikorsky H-3 Sea King. The Sikorsky H-3 has served in many roles for many services: antisubmarine warfare, search and rescue, and transport. The H-3 has largely been replaced by the H-60. In the Air Force the HH-3E was replaced by the MH-60. The HH-3E had been known as the “Jolly Green Giant” during the Vietnam war. In the Coast Guard, the HH-3F *Pelican* was replaced by the MH-60J. A few H-3s are still in use by the Navy as search and rescue and transport aircraft. Largely they have been replaced by the SH-60F, HH-60H and MH-60S. The VH-3D is one of the select few to fly the President and other dignitaries. When the President is aboard they are known as “Marine One” The VH-3 will eventually be replaced by the VH-71 *Kestrel* also known as the US 101. This is the US version of the European Helicopter Industries EH101 built by Great Britain (Westland) and Italy (Agusta).

Utility

Bell H-1. The most famous of all utility helicopters is the Bell UH-1 *Iroquois*. It is nicknamed the *Huey*. It is the most built helicopter of all time with production topping 16,000 machines.

It was originally designated the Bell XH-40. Then later, the HU-1; the name *Huey* comes from the HU-1 designation. It was Larry Bell’s most successful design. However, he died the same day the XH-40 first flew. The latest variant of the *Huey* is the UH-1Y which has the same rotor system, engines, and transmission as the AH-1Z.

Bell Jet Ranger. Another light utility helicopter is the Bell *Jet Ranger*. Although used in the civilian market, many variants are used by the military. They include the OH-58 *Kiowa* and TH-67 *Creek* for the Army and TH-57 *Sea Ranger* for the Navy. Both the TH-57 and TH-67 are used for training. The OH-58D is a scout, observation and light attack helicopter. They are all powered by various versions of the Allison/Rolls Royce C250 engine. The UH-70 is a new scout helicopter based on the Bell 407, similar to Bell *Jet Ranger* and designed to replace the cancelled RAH-66 *Commanche*. It is also known as the RAH-70 (Armed Reconnaissance Helicopter).

Another light helicopter is the H-6 *Cayuse*. The H-6 was originally built by the Hughes Helicopter Company. The helicopter company was acquired first by McDonnell Douglas then Boeing. It is used in several variants. The US Navy has the TH-6, the Army had the OH-6 and Special Operations has the MH-6. They are powered by a version of the same engine that powers the *Jet Ranger*.

UH-60. Although developed as a replacement for the UH-



UH-60A *Black Hawk*



1. The *Blackhawk* spans the space between utility and medium lift. First developed by Sikorsky as the UH-60 *Blackhawk*, versions are now in use by all services and many foreign countries. The US Army operates the UH-60 *Blackhawk*; the US Navy operates the SH-60B, SH-60F, MH-60R, HH-60H, MH-60S; the US Coast Guard operates the MH-60J, the US Marine Corps operates the VH-60N to transport the President and the US Air Force operates the MH-60G. All H-60



Coast Guard HH-60J

production variants use versions of the GE T-700 engine used in the *Apache*, *Super Cobra* and UH-1Y *Huey*.

UH-72. Many other new developments are underway. The UH-72A *Lakota* is a United States Army light utility helicopter that entered service in 2006, built by the American Eurocopter division of EADS North America. It is a military version of the Eurocopter EC 145 modified to the Light Utility Helicopter (LUH) requirements for the US Military. The UH-72 is being bought for the Army Guard to replace the UH-60. In June 2006, the US Army selected it as the winner of its LUH program with 300 aircraft planned. The fielding of the LUH is part of an ongoing Army-level effort to transform its aviation capability through the deliberate reinvestment of funds from the canceled RAH-66 *Comanche* program. The Army National Guard will receive the majority of the 322 new aircraft. Initial aircraft will be used for medical evacuation missions.

Civil

The civil market operates many similar machines to the transport helicopters operated by the military. In the heavy lift role, they operate the *Chinook* as the Boeing 234 and the Sikorsky S-64 *Skycrane*. The military S-64 was known as the CH-54. It is no longer in use by the US military. In the light lift role they operate the Bell 206, 406, 427. The civil variant of the H-60 is the Sikorsky S-70 a lighter machine known as the S-76 is also operated. Many older military machines are still operated such as the Bell 47 *Ranger* made famous in Korea by MASH units.

Bell 222. This aircraft utilizes the latest technology to produce a fast, quiet, long-range helicopter. The 222 is aimed at the executive aircraft market, as well as other commercial uses. It carries up to 10 passengers or 2,700 pounds of useful load. Its hoist is rated at 4,000 pounds. The twin 600-horsepower



turbine engines give the 222 a top speed of 180 mph and a range of about 400 miles.

McDonnell-Douglas 500D. The MD Helicopters MD 500 series is an American family of light utility civilian and military helicopters. The MD 500 originated as the Hughes 500, a civilian version of the US Army’s OH-6A *Cayuse/Loach*. The series currently includes the MD 500E, MD 520N, and MD 530F. The 500E replaced the 500D in 1982. The 500E had a pointed nose and greater head and leg room. The 530F was a more powerful version of the 500E. The MD 520N introduced a revolutionary advance in helicopter design as it dispensed with a conventional tail rotor in favor of the NOTAR system. The NOTAR no-tail-rotor is popular with law enforcement because of its very low noise levels.

Sikorsky S-76. Another helicopter, which was developed specifically for the civilian market, is the Sikorsky S-76. Much of the new technology developed for the UH-60A is used in the S-76. It is aimed at the executive aircraft market and is available in several plush interiors. The S-76 is powered by two 700-horsepower turbines that give it a maximum cruising speed of 160 to 170 mph and a range of up to 450 miles.

Sikorsky has used the latest in soundproofing and antinoise, antivibration technology to make the S-



Sikorsky S-76

76 one of the smoothest and quietest helicopters ever built. The S-76 is also designed as an instrument flight rules (IFR) helicopter, which allows it to fly in all but the worst types of weather. More than 800 have been ordered and 650 have been delivered to customers in 23 countries.

	<i>S-70B</i>	<i>S-76</i>
Crew	pilot, copilot + 12	pilot, copilot + 12
External lift	12,000 lbs	13,500 lbs
Max speed	193 mph	193 mph
Range	460 miles	460miles

Other Light Helicopters. There are three other US light helicopters, which we will discuss before looking at some foreign-made aircraft. The closest thing to helicopters for personal use are the small aircraft manufactured by Brantly-Hynes, Enstrom and Schweizer. All three of these aircraft utilize reciprocating engines rather than turbines. These are just about the only helicopters still being manufactured with piston engines.

The Brantly-Hynes H-2 is a two-place helicopter powered by a 180-horsepower reciprocating engine. The H-2 has a useful load of 670 pounds, cruises at about 100 mph and has a maximum range of 250 miles.



Enstrom Helicopter Corporation makes four models of small helicopters, all of which are three-place aircraft. They are all powered by 205-horsepower reciprocating engines and, in two of the models, the engines are turbocharged. The Enstrom 280C has a useful load of 850 pounds and cruises at about 100 mph. The range with maximum fuel is about 250 miles. Enstrom uses fiberglass and aluminum exclusively in its construction.

Schweizer Helicopter builds a civilian version of the small, reciprocating-engine helicopter that was developed by Hughes Aircraft for pilot training by the Army. This aircraft, designated the 300C, is a three-place aircraft that cruises at about 90 mph and can carry a useful load of 1,000 pounds for 200 miles.

Foreign-built Helicopters

Three foreign manufacturers are dominant in the manufacture of helicopters. They are Aerospatiale of France, Messerschmitt-Bolkow-Blohm (MBB) of Germany, and Agusta of Italy. Aerospatiale is far larger than the other two and sells many times the aircraft as MBB and Agusta combined.

Aerospatiale. This is the national aerospace industry of France, and it is currently producing 10 different models of helicopters. They range in size from the five-place *Gazelle* to the 22-place *Puma*.

The most popular Aerospatiale helicopters in the United States are the seven-place *Alouette III* and the *Puma*. A new helicopter, the SA 365N *Dauphin 2*, is also becoming popular, particularly with the oil platform people. The *Dauphin 2* is competitive with the Bell 222.

Agusta. This Italian company markets one helicopter, the 109A Mk II, which is imported into the United States by the Atlantic Aviation Corporation. The 109A Mk II is a light-haul, twin-turbine helicopter, which is being advertised as a high-technology competitor of the Bell 222 and the Sikorsky S-76. The 109A can carry up to eight people or 2,400 pounds of useful load. It cruises at about 175 mph and has a range of about 350 miles. There are about 30 of these helicopters imported into the United States each year.

MBB. Marketed by MBB Helicopter, Inc., the MBB BO 105 CBS light helicopter is imported from Germany. The BO 105 is a twin turbine-powered aircraft with a useful load of 2,300 pounds. It can lift 2,000 pounds with its external hoist. The range (300 miles) and speed (150 mph) are about the same as other light twin, turbine-powered helicopters. In addition to being used as an executive aircraft, the BO 105 is popular for use in supply of offshore oilrigs.

V/STOL Aircraft

V/STOL in all its forms encompasses many types of lifting and many operational techniques. Broadly they can be categorized as VTOL – Vertical Take off and landing, STOL Short takeoff and landing; with the components: VTO - Vertical Take off, STO- short take off, VL - Vertical landing, SL - Short landing. These can be combined to give you: STOVL -Short takeoff vertical landing, VTOSL Vertical takeoff Short landing Practicality limits most aircraft to STOVL.

There are differences of opinion as to whether STOL is worthwhile when the full Vertical Takeoff and Landing (VTOL) capability is another goal being pursued. Most agree, however, that the pursuit



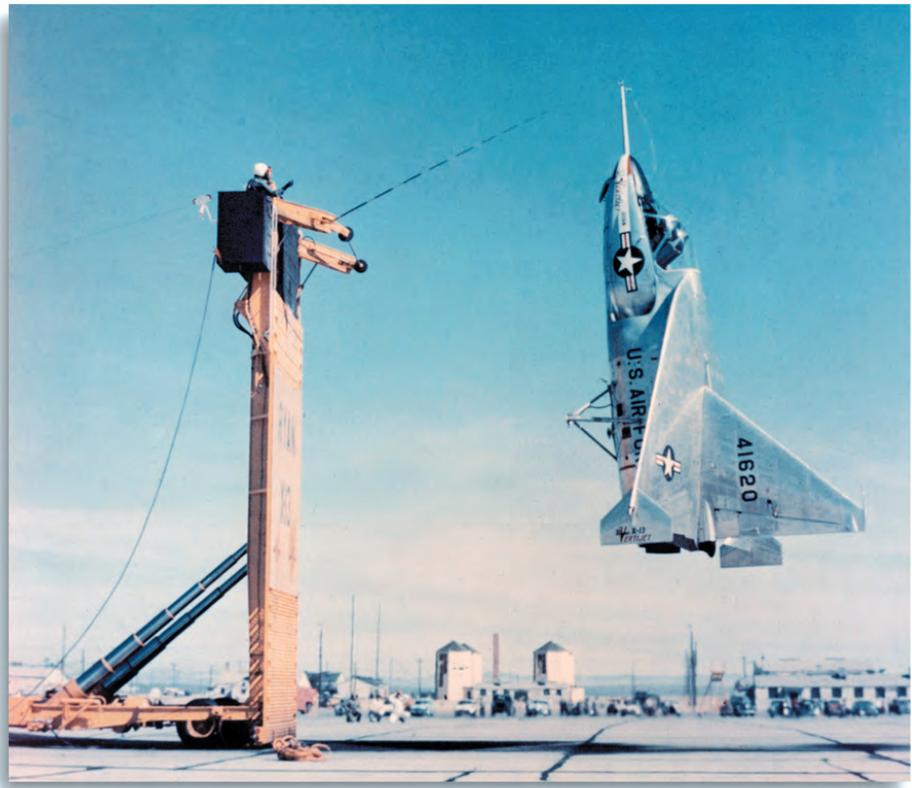
of STOL is a worthwhile effort and will not be made obsolete by VTOL progress for many years to come. As things look now, STOL can be more easily combined with better all-around aircraft economy and performance. Full VTOL capability demands more engine weight, more fuel consumption, and less payload.

In war, there will always be situations in which STOL is not good enough and only VTOL airplanes or helicopters can be used. An example is rescuing a downed flyer from a jungle or supplying troops in battle. In other military situations, however, advanced STOL capability would be highly useful. Higher-performance STOL airplanes could use short, unprepared landing strips, and could transport personnel and supplies over long distances faster than present-day helicopters. STOL attack or fighter planes could be dispersed over many small military bases rather than a few large ones.

Vertical/Short takeoff aircraft have been around for many years. Unfortunately not many military VSTOL aircraft have reached production. The exceptions are the AV-8 *Harrier* and V-22 *Osprey*. The third member of this family will be the V/STOL variant of the F-35 formerly known as the Joint Strike Fighter. The F-35 *Lightning II* will replace the F-16, F-18C, A-10, AV-8B, as well as the *Harrier* in other countries.

V-22 Osprey. The V-22 *Osprey* is an outgrowth of tiltrotor technology developed by Bell Helicopter in the XV-15 during the 1970s. It is a multimission V/STOL aircraft. The V-22 is produced as a joint venture between Bell and Boeing Helicopters with sub assemblies built in 48 states. As stated above, it is replacing the H-46. It has two 38-foot prop-rotors, meaning they can be used as helicopter rotors in hover or tilted forward and used as propellers. The V-22 has two Rolls Royce T-406 engines of 6000 SHP each. These engines and their associated transmissions are cross-shafted to each other meaning one engine can drive both rotors. The span across the two side by side prop rotors is 85 feet. The V-22 is 58 feet long. To date, nearly 100 have been built or are under construction.

AV-8 Harrier. The AV-8 *Harrier* was developed from the XV-6A *Kestrel*. Many versions are in service world wide. It came to attention when the British used it in the Falklands War in 1982. Although



The Ryan X-13 was an early experiment in VTOL technology.
(San Diego Aerospace Museum)



CV-22 Osprey



AV-8 Harrier (Boeing Photo)

some were lost to ground fire not a single one was lost in air-to-air combat. The US Marine Corps initially ordered the AV-8A *Harrier* then the AV-8B *Harrier II*. The AV-8B makes larger use of composites and has a larger wing. The British have continued to develop the *Harrier* into the GR9.



XV-6A

Compound Helicopters

These machines use lift compounding and or thrust compounding to achieve better performance than standard helicopters. The most recent compound is the X-49A *Speedhawk* modified by Piasecki Aircraft. It seeks to expand the capabilities of the Blackhawk helicopter. It first flew in June 2007.

Possibly the most famous compound was the AH-56 *Cheyenne*. It had both a tail rotor and pusher propeller. It was cancelled due to cost. The AH-56 was built by Lockheed aircraft and was an outgrowth of their earlier XH-51. Both aircraft had very stiff or rigid rotors. The AH-56 was powered by the General Electric T-64 engine similar to what was



A-49



AH-56

used in the H-53.

Compound helicopters can be heavy lift machines as well. The Soviets had the biggest one, the Mi-12, also known as the V-12, or *Homer* to NATO. The Mi-12 lifts 55,000 pounds of payload vertically, or 66,000 pounds with a short takeoff run, to a service ceiling of 11,500 feet.

The Mi-12 lifts more than 88,000 pounds of payload to altitudes around 7,000 feet. It is a four-engine, two-rotor aircraft with the counter-rotating rotors mounted on the ends of wings on each side rather than fore-and-aft like most helicopters. The high wings are braced with struts and the span over the rotors is 219 feet 10 inches.



Soviet Mi-12

Uninhabited Air Vehicles (UAVs)

Unmanned or uninhabited aerial vehicles have been around since WWI. They can range in size from the size of an insect to the largest of aircraft. Among the first was the Kettering “Doodle Bug”. Unmanned or remotely piloted vehicles continued on in to WWII. During Korea and Vietnam they were again used. Some examples were remotely piloted versions of manned vehicles. Some were dedicated designs developed specifically for unmanned use. The Israeli’s built the Pioneer that was used successfully.

During the 80’s UAVs began to emerge in earnest. Today they have grown in size to perform virtually any mission a manned platform can perform. They come in all classes; rotary and fixed wing.



Large

Helios. The largest UAV yet flown was the Helios operated by NASA. It had a 247 foot wing span. (that is larger than a C-5 or a B-36). It was lost in 2003. It set an altitude record of 96,863 feet.

RQ-4. The Northrop Grumman RQ-4 *Global Hawk* is powered by a Rolls-Royce/Allison F-137 turbofan. The airframe has prominent nose bulge houses a wideband SATCOM antenna. . The vehicle can reach an altitude of 65000 feet and has an endurance of 40 hours. It is about the size of a U-2.



The Helios Prootype flying wing is shown over the Pacific Ocean during its first test flight on solar power rom the U./S. Navy's Pacific Missile Range Facility in Hawaii (Boeing Photo)

Medium

In the medium size class is the General Atomics RQ-1 *Predator*. Recently an armed variant, the MQ-9 *Reaper* has also appeared. In the rotary wing world, the RQ-8A and RQ-8B *Firescout* operated by Army and Navy have appeared. They are base on the Hughes 269 manned helicopter. The *Eagle Eye* is a Tilt Rotor UAV presently being explored by the Coast Guard. The Northrop Grumman RQ-5



MQ-9 Reaper (Boeing Photo)

Hunter is a pusher-puller propeller-driven UAV similar in configuration to the Cessna 337 *Skymaster* but much smaller.



Small

Small UAVs are some times known as Tactical UAVs.

One of the first to appear was the RQ-2 *Pioneer*. It was developed by IAI in Israel; then further developed in the US. It has operated from land bases as well as ships. On ships it operated from the battleships and later from Navy LPD-type ships. LPDs are landing ships for personnel and include a well deck to operate landing craft or hovercraft. The *Pioneer* is presently operated by the US Marine Corps.



CL 327 (Boeing Photo)

The Canadair company fielded the CL 227, 327, and 427. These UAVs used a Williams gas turbine engine similar to the engine used in cruise missiles. It had two contrarotating rotors similar to a coaxial helicopter.

Another small UAV is the *Scan Eagle* built by the Insitu company and marketed by the Boeing Company. It weighs 44 lb and is powered by a modified 3W 28i engine. Versions of this engine are in use by the radio controlled airplane hobby industry. From the beginning a major hurdle for small UAVs has been their fuel. If used on a ship heavy fuels such as jet fuel (JP4, 5, 8 or jet A) or diesel are much preferred to gasoline. Boeing/Insitu appears to have solved this problem. They are presently testing a heavy fuel engine. The *Scan Eagle* used by the USAF, Marines, and Navy.

Other small UAVs are the *Manta* and RQ-7B *Shadow*. The *Shadow* is operated by the US Army. Yet even smaller UAVs are being fielded. They are known as micro UAVs. One of these is the Honeywell MAV.

A major challenge in the small UAV world is how the small vehicles react to air as a fluid. This science involves the use a term known as Reynolds number. UAVs contain every bit of technology that their larger manned cousins carry. UAVs are also used to research flight conditions which have not yet been attained by manned aircraft. Some examples are the X-36 and X-51.



Boeing X-36 Unmanned Tailless Agility Research Aircraft (*Boeing Photo*)



Key Terms and Concepts

- rotor system
- gearbox
- rotor hub
- rotor blades
- composite materials
- heavy-lift
- light-lift
- compound helicopters
- hybrid helicopters
- Short Takeoff and Landing (STOL)
- Vertical Takeoff and Landing (VTOL)
- Newton's 3rd Law of Motion
- Tilt-Rotor Research Aircraft (TRRA)
- Unmanned Air Vehicles (UAV)

? Test Your Knowledge ?

SELECT THE CORRECT ANSWER

1. The dividing line in the text for deciding whether a helicopter is heavy-lift or light-lift is a useful load of (4,000 / 5,000 / 6,000) pounds.
2. Generally speaking, (compound / hybrid) helicopters go further than (compound/hybrid) helicopters in combining the airplane and helicopter.
3. There is debate within the aerospace community whether (VTOL/STOL) will have much value after (VTOL / STOL) is fully developed.
4. UAVs have been in wide usage since the (Vietnam / Korean / Gulf) War.
5. The USAF standardized definition of STOL is an aircraft with the ability to clear a (50 / 100 / 200) foot obstacle within (1,000 / 1,500 / 2,000) feet of commencing takeoff role and to stop within (500 / 1000 / 1500) feet after passing over a (50/100/200) foot obstacle when landing.

MULTIPLE CHOICE

6. Which of the following was not a drawback to helicopters that has been improved or eliminated due to advancements in technology?
 - a. High maintenance
 - b. High noise levels
 - c. Controlability problems
 - d. Slow cruise speeds
 - e. Vibration



7. Which of the following is not a dominant foreign manufacturer of helicopters?
 - a. Schweizer
 - b. Aerospatiale
 - c. Messerschmitt-Bolkow-Blohm
 - d. Agusta
8. Which of the following is not a major US manufacturer of helicopters?
 - a. Lockheed
 - b. Boeing
 - c. Bell
 - d. Sikorsky

FILL IN THE BLANKS

9. The _____ is a _____ helicopter using a tilt-rotor designed developed for _____ US military.
10. By applying _____ (for every action there is an equal and opposite reaction), VTOL capability is achieved.
11. Using the main propulsion units for VTOL requires either _____ (like the AV-8) or _____ (like NASA TRRA).
12. UAV missions are classified as either _____ or _____, depending on whether or not the UAV is used to destroy a target.

TRUE OR FALSE

13. Although initially designed for military use, heavy lift helicopters are being used more frequently in the civilian market, mainly through military surplus sales.
14. The helicopter was first put into use after World War I.
15. Many helicopters are produced in both civilian and military versions.
16. A drawback to helicopters is their inability to accomplish a transoceanic flight.
17. In-flight aerial refueling has yet to be adapted for helicopters.