Radar

Radar (radio detecting and ranging) is often called the weapon that won World War II and the invention that changed the world. While these claims may be a little hyperbolic, there is no question that radar was a major development. It has certainly proven to be one of the most amazingly useful developments of the 20th century and is vital to aviation. It is also a clear example of a military technology that had important civilian uses.

To quote Scottish scientist Robert Watson-Watt, one of the early pioneers of radar technology, radar is “the art of detecting by means of radio echoes the presence of objects, determining their direction and ranges, recognizing their character and employing data thus obtained in the performance of military, naval, or other operations.” Radar is used for navigation, targeting, air traffic control, weather tracking, and a host of other purposes.

Radio, which was first developed in the late 1800s, allowed people to communicate over long distances without a physical connection such as a wire between the transmitter and the receiver. Radio worked by converting sound into electromagnetic energy that was then transmitted over a distance. When it was received, it could be converted back to sound waves. It did not take those who used radio long to realize that a lot of things could affect its performance. Weather conditions could reduce the transmission of radio waves, as could physical objects such as mountains between the transmitter and receiver.

Exactly who gets credit for “inventing” radar is a topic of some disagreement in historical circles, for many people started working on the subject in many places at roughly the same time, and many of their developments influenced each other. In 1934, researchers at the Naval Research Laboratory (NRL) in Washington, D.C., began work on bouncing radio signals off of objects after noticing that ships traveling down the Potomac River interfered with radio signals being transmitted across the river. Robert Watson-Watt had also heard of reports from the government post office, which was responsible for shortwave radio communications, that airplanes flying near post office receivers caused problems with reception of signals. He wrote a lengthy memo on how this phenomenon might be used to detect airplanes. In 1936, the U.S. Army Signal Corps’ laboratory for ground equipment at Fort Monmouth, New Jersey, also started a radar project. In 1934, Robert Page developed a pulse radar for the detection of aircraft.

The first radar in extensive operational use was the British Home Chain radar (often referred to as the CH radar), which entered service in 1937. The CH and other early radars operated in the "high frequency," or HF portion of the electromagnetic spectrum. But early radar developers recognized that radars that could operate at frequencies higher than HF could perform better. In 1936-37, military radar researchers in the United States developed several devices such as the resonant cavity circuit, the klystron electron tube, and the coaxial and waveguide transmission lines and components that allowed the generation of signals in the microwave region of the electromagnetic spectrum. (Microwaves operate at a higher frequency than 'high frequency.') This dramatically improved radar performance and was a major military development. The Americans secretly shared this information with their counterparts in the United Kingdom and this enabled the British to build better radars for detecting planes approaching the British Isles. Radar gave the British warning of approaching German planes during the Battle of Britain in 1940 and was instrumental in the outcome of the battle. Britain also developed airborne radar that helped pilots flying at night to detect aircraft in the darkness and bomber crews to locate targets at night.

The United States Army Air Forces soon established the Radiation Laboratory at the Massachusetts Institute of Technology, in Cambridge, Massachusetts. The "Rad Lab" as it became known, worked to develop numerous radar systems for various uses during the war. These included radar for aiming anti-aircraft guns, general search radars for detecting airplanes, shipborne radar, and airborne radars to be carried in airplanes and used for various purposes, from targeting other airplanes at night to "weather reconnaissance" to navigation.

The Germans also made important advances in radar, particularly with the Würzburg ground radar which entered service in 1940. They fielded numerous ground-based radars and also developed aerial and shipborne radars as well, although not nearly in as great numbers as the Americans or British. But as
the war progressed, German radar research stagnated, which is one reason why some people claim that radar won the war for the Allies.

After World War II, the Rad Lab closed and research on radar in the United States and Britain languished for several years. But although radar technology did not advance much in this period, its use certainly did. Many military radars were transferred to civilian use where they were used for Air Traffic Control (ATC) and Ground Controlled Approach (GCA) to airports.

Not until the Korean War did the U.S. Air Force recognize the need for more radar research. It created the Lincoln Laboratory near Boston to research the development of a continental air defense system for protecting the United States from bomber attack. Eventually, this led to the SAGE air defense system developed in the mid-1950s, as well as the Distant Early Warning Line ("DEW-Line") of radars located along the northern boundary of Canada and Alaska.

For years after World War II, the Soviet Union used U.S.-built radars it had received during the War. But Soviet engineers began to modify the radars and improve their range and performance. When the first American U-2 reconnaissance aircraft flew over the Soviet Union in the summer of 1956, the Americans expected that the Soviets would not be able to detect the aircraft using the old U.S. radars. But they were surprised when the Soviets tracked the plane for almost its entire flight. This prompted the Americans to seek ways to reduce the radar signature of the U-2.

During the 1950s, the quest was for higher and higher frequencies. Most radars used a rotating dish antenna for transmitting and receiving the signals. But by the 1950s and 1960s, researchers were exploring the possibilities of "phased-array" radars that had flat panel antennas. In these systems, the radar beam is pencil-thin and "steered" electronically. This eliminates the wasted time when a radar beam is sweeping across empty space. The most well known of these kinds of radar was the SPY-1 radar used as part of the U.S. Navy's Aegis weapons system on cruisers and destroyers starting in the 1980s.

During the 1950s and 1960s, smaller and more robust radars were developed for use in the nosecones of missiles such as the Falcon and Sparrow, allowing them to home in on the reflected energy, or "radar return," from an enemy aircraft. Flat panel antennas were also developed for airborne use.

By the 1970s, U.S. military aviation experts became concerned with "low observable" or "stealth" technology that would enable aircraft to evade radar. By designing aircraft with specific shapes and coating them in special materials, they dramatically reduced the amount of electromagnetic energy that the aircraft reflected back to the source. But these techniques do not work equally well against all frequencies, and some low-frequency radars can detect stealth aircraft, although they cannot pinpoint their location.

Improvements in electronics, particularly during the 1970s and 1980s, allowed radar systems to become smaller, lighter and more capable, and able to achieve even higher frequencies. But a major improvement in radar capabilities concerned the development of software for better processing of radar signals. One development was "Synthetic Aperture Radar" (SAR), which was first explored in the 1970s and later applied to many different types of radar. SAR electronically stores the radar returns over a period of time as the radar (mounted on an airplane or spacecraft) moves. It then combines them into a detailed image of the ground with picture-like quality. SAR has been used to map the earth from the Space Shuttle, to provide reconnaissance imagery, and to target precision weapons from aircraft such as the Boeing F-15E Strike Eagle.

The military has always pushed the boundaries of radar technology, while civilian needs for Air Traffic Control were far less demanding. However, by the 21st century, other technologies were beginning to supplement and in some ways replace radar. In particular, the Global Positioning System (GPS) and satellite communications links allow ground controllers to track aircraft without using radar at all. But radar is such an amazingly useful technology that it will always be used in aviation.

--Dwayne A. Day

Sources and further reading:


Blumtritt, Oskar, Petzold, Hartmut, and Aspray, William. Tracking the History of Radar,
weather radar in 1971. The radar dish is in the foreground. Triangular panels of protective fiberglass radar dome are in the background.

Three 34-meter (110-foot) diameter Beam Waveguide antennas located at the Goldstone Deep Space Communications Complex in the Mojave Desert in California. This is one of three complexes that make up NASA's Deep Space Network that provides radio communications for NASA's interplanetary spacecraft and is also used for radio astronomy and radar observations of the solar system and the universe.

A view of the Airborne Synthetic Aperature Radar (AIRSAR) antenna on the left rear fuselage of a NASA DC-8. The AIRSAR captures images of the ground from the side of the aircraft and can provide precision digital elevation mapping capabilities for a variety of studies.


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