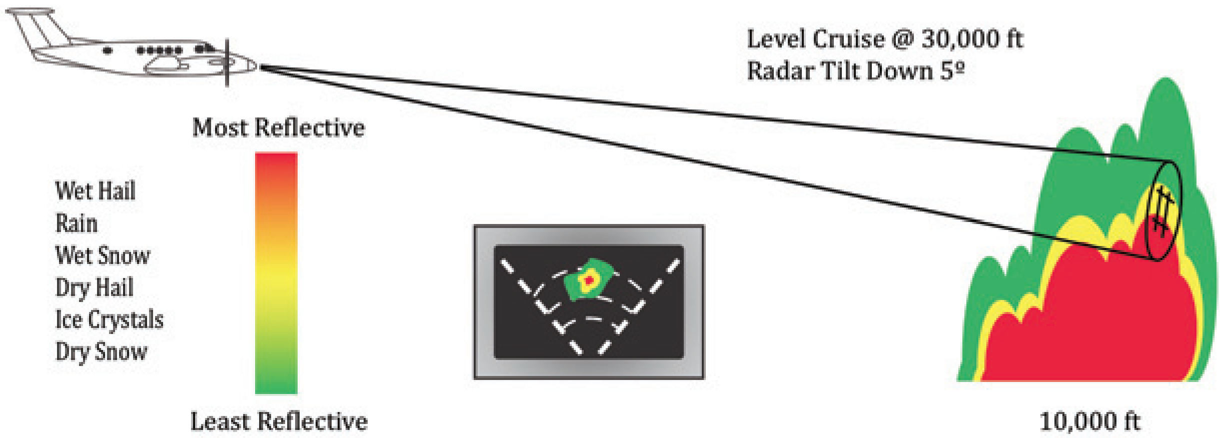

Airborne Weather Radar

Theory & Operation for More Effective Troubleshooting

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EDITOR'S NOTE:
Avionics News will present this white paper, authored by TexasGYRO, in multiple parts. This white paper presentation is for training purposes only. Its sole intent is to improve the maintenance technician's knowledge and understanding of airborne weather radar systems. Refer to manufacturer's most current technical data, maintenance and/or installation manuals or pilot's guides whenever performing maintenance on aircraft or aircraft components.

1. INTRODUCTION

► *White Paper Objectives*

Primary objectives will be:

1. Understand the history and theory of Airborne Weather Radar.
2. Understand how Weather Radar systems operate from the pilot's perspective.
3. Understand how to properly interpret the pilot's complaint, discrepancy or squawk.
4. Understand flight-line troubleshooting and repair of Airborne Weather Radar systems.
5. Understand Radar Stabilization, and how to perform a Radar Stabilization Alignment.

► *Reasons For Weather Radar*

Three common threats to aircraft are turbulence, hail and windshear at low altitude. All three of these are by-products of thunderstorms. Weather radar is a popular method of alerting the flight crew to the presence and location of thunderstorms.

An airborne weather radar is technically called a Weather AVOIDANCE Radar. The radar system will provide the pilot with the necessary weather information to avoid, not penetrate, severe and dangerous weather.

► *Safety*

Radar systems can be dangerous and life threatening if warnings and cautions are not followed. The manufacturers maintenance manuals contain numerous warnings and cautions which must be followed.

• **High Voltage**

High voltage and high currents exist in radar systems that can and will KILL you! Typical high voltage drive to the display is 12,500 volts.

The pulse transformer in the RT generates a 5,000 volt 5 Amp pulse to excite the magnetron. Use caution when covers are removed.

• **RF Radiation**

A microwave oven uses a magnetron to transmit high power RF radiation into a shielded enclosure to heat and cook. Most weather radar systems use this very same device to generate their high power RF signal. This RF radiation can damage the human body or ignite flammable liquids. When operating a Weather Radar system, always be aware of the following:

- Never transmit inside a closed hanger.
- Never transmit toward a fuel truck.
- Consider all radar systems to transmit in test, until confirmed otherwise.
- When operating the system on the bench, always attach a dummy load to the RT.

Transmitter power, proximity/distance and time/duration are all factors that affect the damage that RF radiation can do. Consult FAA Advisory Circular AC 20-68B (Radiation Safety) for additional information on RF exposure and permissible levels.

► *Magnets*

Magnetrons in the Receiver/Transmitter contain strong magnetic magnets. Use caution around radar indicators and computers. Magnets can magnetize and distort display colors and cause loss of data to computer disk drives.

2. HISTORY

► *Political*

The political climate at the end of World War II did not give much credit to Germany for technological advancements. Also, the destruction and division of post-war Germany made the discovery and credit

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for German radar advances difficult.

The well publicized scenario of British radar superiority at the beginning of World War II is quite simply not true. There is no doubt that Britain led the world in appreciating the strategic importance of radar, but German radar sets in the late 1930s and early 1940s were superior to British systems.

The technological promise of radar and it's realistic use are two vastly different matters. The German Luftwaffe had superior radar equipment, but never developed a realistic strategy for it's use. The Germans blindly placed their sole radar focus on offensive navigational systems. The British had a large, clumsy, "dead end" technology system in their Chain Home Radar System. However, they developed a Command and Control system, called the Filter Room that was vastly superior in concept and implementation. This Filter Room was the real hero in the defense of Britain.

The Filter Room was a command and control center that received radar data from each Chain Home station. Azimuth data was derived via triangulation, accuracy calibrations were performed and target information was then plotted on a large map. Friendly fighter radio traffic was monitored, and targets were thus identified as either friendly or hostile. With a clear picture of approaching threats, Filter Room commanders were able to match limited fighter resources to the greatest threat.

► *Early Radar Development*

Radar principles have been known since the turn of the century. In 1904, Christian Hülsmeyer, a German inventor was granted a British patent for a system using radio waves to remotely detect the presence of a metallic body, such as a ship. On the morning of May 10, 1904, he demonstrated that he could locate a ship from a distance of five kilometers. These modern concepts would be forgotten and not rediscovered for another 30 years.

In the mid 1930s, radar principles were well known and being actively developed by Japan, Germany, Russia, America and Britain; yet it was the British who had the most pressing need, and Nazi aggression caused the British to increase their defensive capability.

► *German Radar Development*

Dr. Rudolph Kühnold of the German Navy re-invented radar in 1933, while working on a project to detect underwater objects (eventually called Sonar) by bouncing sound waves off of objects. He theorized and created a system using radio waves that worked above the water. Kühnold did this with no knowledge of Christian Hülsmeyer's prior (1904) radar research. In 1934, Kühnold demonstrated to German officials the ability to spot ships more than seven miles away. During this demonstration he inadvertently detected a seaplane moving in front of the radar, discovering by accident the use of radar for aircraft detection.

Germany named this system the Freya, with the Luftwaffe receiving the first operational set in 1938. The name came from the Norse Goddess "Freyja." Freya would become the primary German early-warning radar, vastly superior to any British system at the time. Freya was a steerable and semi-mobile system operating at a frequency of 120MHz to 130MHz, PRF (Pulse Repetition Frequency) of 500Hz, PW (Pulse Width) of 3m (micro) seconds and peak power output of 15 to 20 kilowatts. It had a maximum range of 160 kilometers, yet it had difficulty accurately determining altitude.

► *British Radar Development*

In 1934, the British Ministry set up special task force under Sir Henry Tizard, called the "Tizard Commission" to investigate different and exotic defensive means. One such means was a "Death Ray" for which a special reward of £1,000 was offered to anyone who could successfully kill a sheep at 100 meters.

Robert Watson Watts, a British scientist was consulted by Sir Henry Tizard to determine if such a death ray was feasible. It was quickly determined to be impossible, but Watts theorized that RF Radiation could be used to detect aircraft.

Watts proposed the idea of radio detection, but before the British Ministry would commit the considerable funds necessary for development, they required a successful demonstration.

On the morning of Feb. 26, 1935, the 43 year old Watson Watts and an assistant drove a small van loaded with electronics to a country field near the British village of Daventry. There he monitored and adjusted his displays while a RAF Bomber flew back and forth between two nearby BBC radio towers. They were able to detect a disturbance in the RF from the towers and track the bomber at an unbelievable range of eight miles. What was not known until many years later was that the brilliant Watts had quietly instructed the RAF bomber captain to trail a long aerial wire behind the aircraft to enhance the chance of success.

On this very same day, Adolf Hitler appointed Reichsmarschall (Marshal of the Empire) Hermann Goering as head of the German Luftwaffe with the sole intent of creating an Air Force to destroy everything that stood in the path of the Nazi advance.

The German blitzkrieg of 1936 against Spain showed the world how air raids could rapidly destroy an enemy with very little warning. Being an island, Britain had plenty of warning of any impending surface attack. The German use of air attacks in the attacks on Spain proved the urgent need for a British defensive warning system and kicked the development of radar into overdrive.

Soon, 350-foot tall radar towers began to spring up along the eastern British coast. This became the Chain Home Radar System and was completed in 1938. Chain Home towers were 20 miles apart, had a range of 100 miles and used triangulation between towers to determine azimuth. They were not accurate in altitude detection, requiring constant calibration and adjustment by the Filter Room.

The Chain Home system was acceptable for daylight intercepts where the radar only had to get fighters to within a couple of miles to intercept the German bombers. At night, the fighters had to be guided to within about 500 yards to visually acquire the targets.

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Chain Home operated on a frequency of 22MHz. In good weather it could detect an aircraft at 10,000 feet 100 miles out. Later in the war the frequency was increased to 50MHz to avoid interference with other towers, noise and to prevent enemy jamming.

Because most British men were involved in the imminent war with Germany, these radar sites were staffed almost exclusively by women.

During the early days of operation, the Chain Home Radar System operators observed that weather systems would affect the performance of their radar. This was the first known indication that radar could be used for weather detection. It wasn't until 1941 that the military became serious about using radar for meteorological purposes.

During the Battle of Britain, Germany greatly outnumbered Britain in terms of aircraft. Britain's Chain Home Radar and Filter Room enabled them to marshal their precious few fighters to quality daylight intercepts of German Bombers. Germany had more than 3,000 aircraft compared to Britain's mere 600 fighters.

► German Actions on British Radar Stations

Some officers in the German high command had thoughts that the British towers held a military purpose. Hermann Goering outfitted the 776 foot Graf Zeppelin LZ130 with electronics monitoring equipment and flew three missions along the British coast from May to August of 1939. These were the world's first electronics surveillance missions. The British tracked the Graf Zeppelin on radar.

German scientists discounted the idea that a radar system could be operated in the HF band. Britain's system operated at 22MHz while the German systems operated at 120MHz. The Germans were searching this higher frequency band, thus detecting nothing. They concluded from this that the British had no operational radar and wrongly summarized that that this was some type of "aircraft landing aid" system.

During the summer of 1940, Hermann Goering was poised to unleash massive air raids on Britain. General Wolfgang Martini, Luftwaffe Head of Signals, believed that the towers dotting the eastern shores of Great Britain were more than just "aircraft landing aids". Martini convinced Goering to bomb these towers. On Sunday, Aug. 8, 1940, the Luftwaffe attacked the Chain Home towers. These towers were difficult to bomb from the air and of all the stations attacked, only one tower was damaged. Goering was so focused in his belief that the British had no working radar system he never attacked the towers again. This was one of many major blunders he committed as the head of the German Luftwaffe.

► Need for Airborne Systems

The accuracy of the land based Chain Home Radar System was acceptable to guide the fighters sufficiently close to for daylight intercepts, however, not nearly close enough to visually acquire the target at night. Chain Home was not mobile and did nothing to detect German U-boats on the surface.

An airborne system was desperately needed to overcome these shortcomings of the Chain Home system.

The transmitters and antennas of the Chain Home System would never fit in any aircraft. A smaller device, as well as a system operating on a shorter wavelength (higher frequency) was urgently needed.

Two British scientists invented the magnetron, a small high power short wavelength transmission device. This incredible invention changed everything in radar technology.

► American Radar Development

In August 1940, Winston Churchill commissioned Sir Henry Tizard to go to America, taking with him the ultra top secret magnetron and many more military technology secrets. The mission's purpose was to enlist America's aid in manufacturing military equipment and the sharing of certain military secrets.

This and many other military secrets were given to America cart blanche, no strings attached. Britain wanted the Americans to share the technology of the Norden Bomb-Sight to use on their own bombers. However, America was not yet at war and Franklin Delano Roosevelt, fearing that British bombers would be shot down over enemy territory, denied their request for the Norden Bomb-Sight.

The magnetron advanced the American radar development by two years.

Soon after the Tizard mission, America opened the Radiation Laboratory (commonly called the Rad Lab) at Massachusetts Institute of Technology (MIT). Under the guidance of Vannevar Bush, America's top physicists and scientists were recruited for a crash program to expedite the development of radar systems.

The Rad Lab developed radar systems at an incredible pace. By the end of World War II, more than 150 different models of radar systems were designed for use in aircraft, submarine, battleship and costal defense. The American industrial might built more than one million radar sets for military use by both the American and British forces.

Dismissing valuable radar data played a disastrous role at Pearl Harbor. The U.S. Army had deployed five mobile radar sets, each with a range of 150 miles, on the island of Oahu, Hawaii. On Dec. 7, 1941, one of these sets detected multiple targets while conducting training operations. The operators on duty detected incoming aircraft and relayed this information up the chain of command. The lieutenant on duty, having heard a vague rumor of incoming American bombers due around this time, wrongly dismissed the report as irrelevant.

This disaster alerted the American military to the importance of radar and significantly sped up it's deployment.

A radar navigational system called "Eagle" guided the B-29, Enola Gay to Japan on the morning of Aug. 6, 1945, where she dropped Little Boy, the first atomic weapon used in war. At 8:15 a.m., four separate radar altimeters detonated Little Boy above Hiroshima. Three days later, a similar system was used over Nagasaki, thus ending Japan's will to fight, and the war in the Pacific. ❑

Part 2 of this white paper will appear in the April edition of Avionics News.