PANAMA IN WORLD WAR 2: THE INTRODUCTION OF RADAR

Much has been written about the failure of radar, in place if not fully operational, to warn of the Japanese attack on Pearl Harbor in December 1941. However, lesser known is that such radar was already installed and operating in the Panama Canal Zone, with sets at each end of the Canal, with the first having arrived a year earlier, in December 1940. In fact, the first example of a fixed-site long-range radar was deployed in the Canal Zone in October 1940, and was the US Army's first operational radar station.

When the defences of the Canal were being planned, an attack by naval forces was the primary concern – to damage or destroy the locks and other facilities. Some sort of landing of troops was also anticipated. However, by the time World War 1 came to an end in 1918 attack from the air had become a potential threat, and as early as 1915 a War Department Board of Review had recommended, for the Canal Zone as well as the Continental US and other possessions, 3-inch (76.2 mm) anti-aircraft guns,[1] as well as a considerable increase in ammunition,[2] with additional fire control stations and searchlights.

Pre-war, the US Army, like other armies, used sound location devices, including the so-called "Big Ears" mobile detector units. In the Canal Zone, these were operated by the Coast Artillery Corps. These were the first practical means of detecting aircraft at a distance and used horns, with larger horns increasing the range of detection. One pair of horns funnelled sound into the earphones of the azimuth operator; the other pair was used by the elevation operator.[3]

[1] However, there were only eight 3-inch guns in place by May 1918, due to the needs of the Western Front, although a handful more would be received later that year; and in 1920, no less than 36 were allocated to the Canal Zone defences.

[2] Ammunition storage would be increased considerable in the lead up to World War 2, as it was recognised that the Canal Zone might have to defend itself for some time before reinforcement or resupply could be affected. Nevertheless, as late as 1941 there were concerns over ammunition shortages for the 90 mm anti-aircraft cannon.

[3] It is recorded that sound locators are said to have detected the Japanese attack on Corregidor in the Philippines in December 1941.

Between the war, not only did aircraft themselves become more capable, with greater range and increased bombloads, but the development of the aircraft carrier meant that a potential enemy could bring his air forces to bear in that way. No longer would the relative remoteness of the Canal Zone mean that an aerial attack would have to be mounted from one of the neighbouring countries – none of which at the time has either the capability or intent. It would be the late 1950s before a potential enemy had bombers of sufficient range to seriously threaten the Canal – but, of course, by then missiles and nuclear weapons presented an even greater danger.

Even by the late 1930s, the range of land-based bombers was not sufficiently great to believe that any would-be enemy (Japan and Germany being the obvious contenders) would be able to use those to disable or destroy the Canal. The fear of an enemy using airfields in neighbouring countries to mount a surprise attack remained.[4] Aside from sabotage, it was the fear of a carrier-based attack that most exercised defence planners, and pre-war fleet exercises, which chiefly centred on the Canal region, appeared to show that such an attack had a good chance of success (if the carriers could get within range to launch without detection).

So, amid the raising international tensions of the late 1930s, sabotage and air attack were the greatest concern. There was also recognition that the air defences of the Canal Zone were lacking. The Canal Zone was a small trip of land, roughly 360 square miles (930 km), with all its defences, including its detection devices (at the time, sound locators) and aircraft within that small area – the latter based at two main airfields, one at either end of the Canal, though with a number of temporary, or "emergency", landing fields available in Panama itself.

[4] This was one reason why the SCADTA airline in Colombia, founded by an Austrian and employing many German aircraft types and German personnel, would eventually be acquired by Pan American Airways. SCADTA - *Sociedad Colombo-Alemana De Transportes Aereos* - was founded in 1921 by Peter Paul von Bauer, an Austrian, who in World War 1 had been a pilot in the Imperial German Army's air force (the *Deutsche Luftstreitkräfte***).** It was bought out by Pan American World Airways in 1941, Pan American having already acquired 80% of the airline.

A mobile anti-aircraft "Big Ears" sound locator unit of the Coast Artillery Corps, with a searchlight, in 1932

Anti-aircraft gun defences were considered insufficient, and even then, short of ammunition, with no barrage balloons or smoke generators. On the other hand, the fighter strength was boosted by the arrival of large numbers of the more effective P-36 Hawks in 1939 – replacing the large obsolete P-26A Peashooters - and then the much better P-40 from 1940.

However, except for aerial patrols by Army bombers or Navy flying-boats, or patrolling warships, there was no means of any long-range detection of an incoming attack.[5] Closer in, one could rely on human observers on the ground, or standing patrols of fighters. The latter was inefficient and wasteful of pilots and equipment, and neither would provide sufficient warning to allow a "scramble" to reach a suitable interception altitude in time. As at Pearl Harbor, if the defenders only knew of the attack when the bombs actually began to fall, it would be difficult, or impossible, to mount any sort of defence. Even if defending fighters were not caught and destroyed on the ground, without early warning, the best that they might be able to do would be to inflict losses on a departing force – *after* it had wrecked the Canal.[6]

[5] The Pacific approaches were seen as the more vulnerable. Not only was Japan a more realistic threat, and had the aircraft carriers capable of mounting a devastating attack, but that approach also lacked the screen of islands through which any force entering via the Caribbean would have to pass.

[6] In 1931, a US Army Air Corps (USAAC) exercise in Ohio saw defending fighters obtain little success against attacking bombers reported on by a net of ground observers. However, some success was obtained in a subsequent exercise in 1933, using a system of observers combined with filter centres, improved plotting techniques and command and control

As would be shown by the experience of the RAF in the Battle of Britain, an effective radar system, providing early warning, combined with efficient and coordinated command and control, could make the difference between victory and defeat.

Between the wars, US Army policy was for its fighters to be point-defence interceptors, able to defend key population and industrial centres of the Continental US (or those near the seacoasts), and the overseas possessions in the Philippines, Hawaii and Panama. For this role, they were to have excellent climb rates from take-off, a decent armament, a good low-to-medium altitude performance, and the range and endurance to carry out its role.

For the Continental US, until at least the late 1930s, there was little chance of large numbers of enemy strategic bombers reaching targets with or without an escort, and the only fighters encountered by defenders might be those flown from aircraft carriers. Given the relative remoteness of the Canal Zone, this assumption seemed even more correct.

By mid-1941, an integrated air defence system had begun to take shape in the US, with fighters recognised as the principal defence against air attack, with an effective air warning system seen as being key to successful interception.[7]

What in 1930 had become the US Signal Corps Laboratories had been experimenting at its facility in New Jersey with some detection concepts as early as the late 1920s, although the Army had initially focused primarily on infra-red detection systems (which was a popular idea at the time). In 1935, work turned to radar, as was happening in other countries, such as Germany and Britain.[8] Although hampered by a lack of funds and personnel, the Laboratories were able to provide a practical demonstration in a successful test in 1936, following which a hand-built prototype was

[7] *The American Aircraft Warning Service Takes Shape* by Randall DeGering (Air University Press, 2018): https://www.jstor.org/stable/pdf/resrep19549.10.pdf

[8] https://www.antoineonline.com/Product.aspx?productCode=0009781156651797

completed in 1937. This was the prototype of what became the SCR-268 (Signal Corps Radio, Model 268)[9] short-range, searchlight-controlling radar.[10]

It has been said of radar pre-war that the US Army "*simply did not have the funds or manpower . . . to fool with it*", but it has also been suggested that a better explanation was simply the absence through pre-war years of any urgent sense of need for such a device. In contrast, Britain, with potential enemies much closer, had pressed ahead with their radar development programme from 1934, with the result that it saw a fully formed and effective radar-based air defence system in place in time for the Battle of Britain in 1940.[11]

In the Continental US in 1933, the US Army had undertaken a major reorganisation with four major field armies with specific geographical areas of responsibility. Within each of these four field armies there also existed an air district responsible for controlling the field army's limited air assets operated by its Air Corps (USAAC) personnel.[12] In 1935, the War Department issued its general directive on air defence to the four field army commanders designed to prepare an integrated air defence consisting of pursuit aviation (i.e. fighter aircraft), anti-aircraft artillery, and aircraft warning services for defending against coastal air attacks.[13] In Summer 1939, the Signal Corps was ordered to begin researching possible detector sites and information centre locations that would be required in the future.[14]

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[9] I have also seen the designation said to stand for "Set, Complete, Radio".

[10] *Technology Not Realized: Army Air Forces Radar Employment in the Early Pacific War* by William M. Cahill (*Air Power History*, Vol. 56, No. 2, Summer 2009) Air Force Historical Foundation https://www.jstor.org/

[11] *The Army Air Forces in World War II*, edited by Wesley Frank Craven and James Lea Cate (Office of Air Force History, Washington DC, 1983): https://media.defense.gov/2010/Nov/05/2001329891/-1/-1/0/AFD-101105-019.pdf

[12] USAAC = US Army Air Corps.

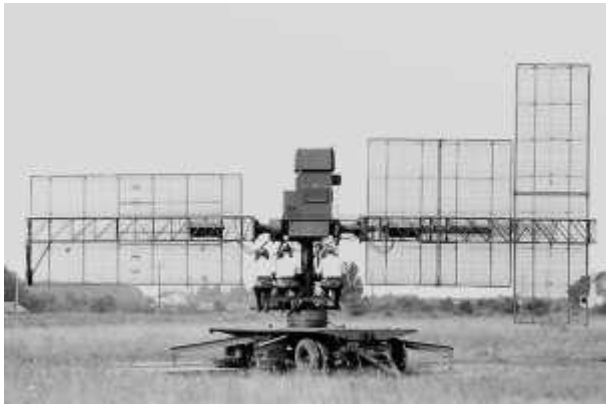
[13] By December 1940, rudimentary air defence information centres had been built in several major cities on both the US Atlantic and Pacific coasts.

[14] A study, completed in early 1940, recommended that 23 long-range detector sites be positioned around the US, providing information to nine centralised information centres.
The American Aircraft Warning Service Takes Shape by Randall DeGering (Air University Press, 2018): https://www.jstor.org/stable/pdf/resrep19549.10.pdf

Note that, in Panama and the Canal Zone, the abbreviation "AWS" identifies "aircraft warning sites", including radar locations. However, it can also be used to refer to the civilian ground observer organisation in the US, first organised in May 1941.[15]

THE US RADARS

The SCR-268 operated in the VHF band, at 205 MHz, and was the US Army's first radar that was designed to direct searchlights and, later, anti-aircraft guns.[16] The prototype was developed in 1938, and is saw operational use from 1940 until mid-1944. Serial production was by Western Electronics.[17] Due to ground reflections (aka ground clutter), it was unable to detect targets over land and below 1,000 feet (305 metres) altitude.



The complete set required four trucks and a trailer. The trucks carried equipment providing primary power, high voltage for the transmitter, as well as radar components. The radar aerial was mounted on the trailer, rotatable and with three antenna arrays, and behind each was a corresponding receiver. By the end of the war the system was considered out of date, having been replaced by the much smaller and more accurate SCR-584 microwave-based system.[18]

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[15] Becoming the Ground Observer Corps (GOC), it would have 1.5 million civilian observers at 14,000 coastal observation posts who used the naked eye and binoculars. The program ended in 1944, only to be re-established (as with the Observer Corps in the UK) for the Cold War, in early 1950, as an arm of the USAF Civil Defense service.

[16] The addition of lobe switching to later versions gave it the accuracy needed to directly guide the guns without the searchlight helping. Lobe switching was used on early radar sets to improve tracking accuracy. This was a technique that enhanced accuracy by alternating the antenna beam between two positions to better determine the direction of the target. The SCR-268 was one of the first radars to use lobe switching of its receiving antennas as a means to aim anti-aircraft searchlight beams at aircraft. https://www.eeeguide.com/antenna-tracking-system/

[17] One was present at Corregidor in the Philippines and fell into Japanese hands. It was shipped to Japan and gave the Japanese their first indications that they had fallen seriously behind in radar technology: http://pwencycl.kgbudge.com/S/c/SCR-268_fire_control_radar.htm

[18] http://pwencycl.kgbudge.com/S/c/SCR-268_fire_control_radar.htm

However, the first long-range early warning radar was the SCR-270 (and its fixed-site equivalent, the SCR-271). Operating at a nominal 106 MHz, it was the US Army's primary long-distance radar throughout World War 2, and it was a SCR-270 type set that detected the incoming raid on Pearl Harbor. By 1939, both mobile and fixed-site versions had been developed; with the former having been used in a successful demonstration in June 1939.[19] These two models used the same electronics, but the SCR-271 had an antenna of somewhat greater resolution.[20] An upgraded version, the SCR-289, was also produced, but would see little use.

An SCR-271 radar site in Panama (photograph from "US Army in World War II: The Technical Services: The Signal Corps: The Emergency" (Office of the Chief of Military History, 1956)

The SCR-270 mobile unit could have all necessary equipment carried on a total of four trucks – an operating truck where the radar operators worked, a power truck, a prime mover/trailer carrying the main antenna, and a "stake truck" carrying the rest of the antenna assembly. The SCR-271 included all the same equipment but was fixed in position, construction of which could be completed in about two weeks.[21] The fixed-site version had its antenna on a tower, and the transmitter and receiver in a building, but it was otherwise the same as the mobile version. Both had a crew of seven and, for 24-hour operations, a total of around 50 men would be required to operate the radar and communication radio and camp.[22]

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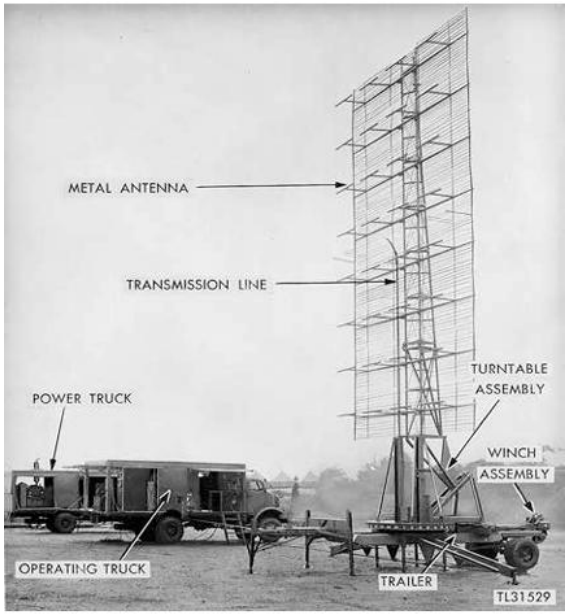
[19] *Technology Not Realized: Army Air Forces Radar Employment in the Early Pacific War* by William M. Cahill (*Air Power History*, Vol. 56, No. 2, Summer 2009) Air Force Historical Foundation

[20] https://radionerds.com/index.php/SCR-270

[21] https://pacificeagles.net/scr-270-scr-271-radar/

[22] *US Radar Operational Characteristics of Radar Classified by Tactical Application FTP 217* (US Navy, 1 August 1943): https://www.history.navy.mil/research/library/online-reading-room/title-list-alphabetically/u/operational-characteristics-of-radar-classified-by-tactical-application.html



SCR-270 mobile radar[23]

While the SCR-270 antenna could be rotated around to provide a two-dimensional picture of the situation in the air, and could provide bearing and range of the contacts, it offered no altitude information. In addition, its readings were not precise, the range readings could have an error of several kilometres, and the bearing could be off by more than a degree. Operators would have trouble discerning individual aircraft, and would see the enemy formations only as a large blip with a large radar echo. Operating at 106 MHz, this meant that it emitted on a wavelength slightly smaller than three meters, which led to it suffering from several drawbacks, including the relatively poor resolution.[24]

The SCR-270 variants would later be replaced by newer microwave radars, with their much shorter wavelengths, after the cavity magnetron was introduced.[25] This device would be used in the only microwave early warning system to see action during the war[26], the AN/CPS-1 Microwave Early Warning (MEW) radar, produced by General Electric, finally ready in Summer 1943, this would only be available in late 1944 – in time for D-Day. The AN/CPS-1 was first such array in the centimetre wavelength, in the 10 cm wavelength, with an effective range of up to 200 miles (321 km). More

[23] *The American Aircraft Warning Service Takes Shape* by Randall DeGering (Air University Press, 2018): https://www.jstor.org/stable/pdf/resrep19549.10.pdf

[24] https://www.radartutorial.eu/19.kartei/11.ancient2/karte005.en.html

[25] Developed by the British, with the first working example tested in February 1940, producing power nearly 100 times more power than anyone else had ever produced at such a short wavelength (about four inches or 9.8 cm). By May 1940, other researchers were using the device in a radar set that could detect a submarine periscope at a range of six miles (9.6 km). In September 1940, the British provided the cavity magnetron and persuaded the US to begin large-scale development of the device.

[26] Just six hand-built sets were made during the war, with the radar being used to counter V-1 flying bombs in Britain in 1944.

advanced sets like the AN/CPS-1[27] never replaced the SCR-270 family in active service during the war – and did not reach Panama,[28] and the older radars even served on into the postwar period (in fact, only six handcrafted AN/CPS-1 sets were made, with set number one operational in Britain in January 1944), half a dozen were used during the initial stages of the Korean War until more advanced radars could be deployed.[29]

The AN/CPS-1 operated at 3200 MHz (roughly 10 cm wavelength), or S Band. In contrast to the 3-metre waveband SCR-270, its narrow beam allowed for rather precise altitude and bearing calculations, giving a full three-dimensional picture. It could also scan for targets very close to the ground which would otherwise be lost in the ground clutter, so it substantially improved capability against low-flying targets. The beam was no longer steered by the physical rotation of the antenna (as with the SCR-270), but used a so-called phased array - an array of antennas which allows one to electronically steer the beam. The control electronics also included five 30-centimeter scope displays, allowing operators to track large numbers of targets.[30]

In 1940, John Randall and Harry Boot at University of Birmingham had developed the cavity magnetron, which allowed for radars with much shorter, centimetre wavelengths. The cavity magnetron reached the US a year before the Pearl Harbor attack, as part of the Tizard Mission, a British delegation aiming to share their secret R&D efforts with their US counterparts. Delivery of the cavity magnetron has been described in the US as "*the most valuable cargo ever brought to our shores*".[31]

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[27] The AN/CPS-1, aka Microwave Early Warning (MEW) radar, operated in the S-band. It resolved two serious problems with earlier radars – their poor angular resolution of targets and blindness to low-flying targets: https://www.radartutorial.eu/19.kartei/11.ancient2/karte005.en.html https://www.mobileradar.org/radar_descptn_1.html

[28] By the time the AN/CPS-1 was ready for operations, the threat alert levels in the Canal Zone were being lowered, with troop levels, large guns mothballed, and some of the outlying bases in other countries being run down or closed.

[29] https://pacificeagles.net/scr-270-scr-271-radar/

[30] https://www.radartutorial.eu/19.kartei/11.ancient2/karte005.en.html

[31] Ibid.

During Summer 1939, the Army announced that new secret electronic "detectors" would soon replace sound locater equipment for air defence.[32] Meanwhile, the Signal Corps was ordered to begin researching possible detector sites and information centre locations that would be required to defend the Continental US.[33]

ARMY RADAR UNITS DEPLOYED TO PANAMA

At the beginning of 1940, the Army Chief of Staff, General Marshall, had said –

> "*As long as the British Fleet remains undefeated and England holds out, the Western Hemisphere is in little danger of direct attack*".

However, he also added that "*the situation would become radically changed*" if the British Fleet were to be sunk or to surrender. For this reason, he said, plans had to be drawn up immediately to meet this possibility as well. The Fall of France by mid-1940 would reinforce this message.[34]

The 1st Signal Aircraft Warning Company was formed on 1 March 1940,[35] and the initial production SCR-270A sets were received by this unit for operational testing in May 1940. A production contract had been awarded to Westinghouse Electric and Manufacturing Company in August 1940.[36]

However, the security of the Canal was of such immediate concern to the War Department that, on 1 January 1940, the Signal Company, Aircraft Warning, Panama was established and ordered to prepare for deployment to the Canal Zone. Containing 93 men from numerous Signal Corps units and 43 new recruits, this company began emergency training at Fort Monmouth in the US. Using a fixed SCR-271 research radar

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[32] https://www.jstor.org/stable/pdf/resrep19549.10.pdf

[33] https://www.airuniversity.af.edu/Portals/10/AUPress/Books/B_0152_DeGering_Radar_Contact.pdf

[34] *The American Aircraft Warning Service Takes Shape* by Randall DeGering (Air University Press, 2018): https://www.jstor.org/stable/pdf/resrep19549.10.pdf

[35] This was described as "a new kind of military unit" in contemporary documents. It would be the first of over a hundred such units formed during the war. https://www.cecom.army.mil/PDF/Historian/Feature%203/Radar/Davis_SC_Development_of_Army_Radar_III_1945.pdf

[36] The Radio Corporation of American (RCA), which had been involved in development of certain elements, was a major subcontractor. Westinghouse had quickly ramped up production, and 112 SCR-270/271 series radars had been manufactured by December 1941.

set, they practised "*the strange and uncertain business of electronic detection*". It was uncertain that it would actually have its own radar set by the time the unit deployed to the Canal Zone later that year.[37] Having completed its brief training, it left for the Canal Zone in May 1940. Its mission had such high priority that they took the research SCR-271 set to use there,[38] and they were also accompanied by two engineers from the Signal Corps Laboratories to advise on the initial installation.[39]

The fixed-site SCR-271 placed the antenna on a tower, with the transmitter and receiver inside a building, but it was otherwise the same as the mobile version. Both the SCR-270 and SCR-271 series lacked an IFF system in 1941,[40] something which the Signal Corps was still developing.[41] As mentioned, neither type of radar was able to provide altitude data of targets being tracked.[42]

The first of two radar sites was established at Fort Sherman at the Atlantic end of the Canal, in October 1940. In December, the second set was installed on the island of Taboga, 12 miles (19.3 km) off Panama City, on the Pacific end of the Canal. It took about a month to complete both sites. By the time of the Pearl Harbor attack in December 1941, there remained only the two radar sets in use in the Canal Zone – one at each end of the Canal, with visual sighting and sound detection also still in use. In

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[37] https://www.airuniversity.af.edu/Portals/10/AUPress/Books/B_0152_DeGering_Radar_Contact.pdf

[38] https://www.airuniversity.af.edu/Portals/10/AUPress/Books/B_0152_DeGering_Radar_Contact.pdf
In March 1940, only one SCR-270 existed (still at Fort Hancock and completing final Army service testing), plus one fixed SCR-271 (in fact, the first research example, such was the urgency of the deployment) were available.

[39] https://www.cecom.army.mil/PDF/Historian/Feature%203/Radar/Davis_SC_Development_of_Army_Radar_III_1945.pdf

[40] Identification, friend or foe. This allows systems to identify aircraft, vehicles or forces as friendly, involving interaction with a transponder on the aircraft.

[41] Although the RAF had employed such a system during the Battle of Britain in 1940.

[42] There were attempts to cure the altitude tracking problem by also using the SCR-268 searchlight controlling radar as well at sites, but delivery of this type was already behind schedule due to priority having been given to the SCR-270/271 series. Modifications were attempted to the SCR-270/271, and to make the SCR-268 a standalone 3D system capable of ground-controlled interceptions.
Technology Not Realized: Army Air Forces Radar Employment in the Early Pacific War by William M. Cahill (*Air Power History*, Vol. 56, No. 2, Summer 2009) Air Force Historical Foundation
https://www.jstor.org/
https://www.radartutorial.eu/19.kartei/11.ancient/pubs/elec-09-1945-scr-270.pdf

initial tests the Fort Sherman set demonstrated the ability to detect aircraft at a range of 118 miles (189 km).[43]

In the still underdeveloped Panama, there were shortage of materials needed, not only for the radar installations, but generally for the great expansion of the defences of the Canal Zone then underway. For example, the steel framework required for the antenna tower at the Fort Sherman site had been delivered to New York, where it was loaded onto a ship, the *American Legion*, for shipment to the Canal Zone. However, that ship was then requisitioned by the US Government to evacuate US nationals from wartime Europe, and the steel had to be unloaded. It languished in New York for some time before being shipped, following a series of urgent telegrams from the Canal Zone enquiring about its whereabouts.[44]

Even when operating, to begin with there were no regular filter or control rooms to receive, assess and make use of the information they provided. There were only telephone links to the Army headquarters at Quarry Heights, so that the initial effectiveness of the sites was limited.[45]

Meanwhile, in the Continental US, the Air Defense Command had been formed on 26 February 1940. Later that year, its head was sent to Britain to obtain information about the successful defence mounted by the RAF during the Battle of Britain, where the use its radar network and control systems had enabled the British to make best use of available fighter resources. His report, and other data, informed a plan drawn up by the Plans Division of the Air Corps in October 1940, which called for a British-style air defence system, both for the Continental US and overseas possessions, including the Canal Zone.[46] The Army also opened the Air Defense School in New Jersey in March 1941.

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[43] https://media.defense.gov/2010/Nov/05/2001329891/-1/-1/0/AFD-101105-019.pdf

[44] https://www.cecom.army.mil/PDF/Historian/Feature%203/Radar/Davis_SC_Development_of_Army_Radar_III_1945.pdf

[45] https://www.cecom.army.mil/PDF/Historian/Feature%203/Radar/Davis_SC_Development_of_Army_Radar_III_1945.pdf

[46] *Technology Not Realized: Army Air Forces Radar Employment in the Early Pacific War* by William M. Cahill (*Air Power History*, Vol. 56, No. 2, Summer 2009) Air Force Historical Foundation

The SCR-270 system would soon be followed by the improved SCR-270A (which had minor changes to the antenna mount) and, by the time the US entered the war in December 1941, the SCR-270B version was in use.[47] This later version, still a mobile system, had the radar components moved from the antenna mount to an operations truck, and had a nominal range of 150 miles (241 km). It had four crew – two maintenance technicians, an operator and a communications specialist who relayed target information to the control centre.[48]

At the request of Secretary of War Stimson, in March 1942, the British radar expert and member the British Air Commission to the US, Robert Watson-Watt,[49] after inspecting the radar defences of the US West Coast, undertook to survey the situation in Panama. The report he submitted was as unfavourably critical as the one he had made a few weeks earlier on the West Coast situation.

The report referred to of disturbing weaknesses - including that the siting of radar units on high hills contributed to the ground clutter[50] which affected readings.[51] The British expert came to the opinion that concerns over the safety of the Canal from air attack was fully justified.[52]

Watson-Watt said that the detection system then in place recorded no more than 15% of all flights. He cited one occasion where there were 13 aircraft in the air, but the operation board in the information room showed only a single one. He also said that

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https://www.jstor.org/

[47] At least five SCR-270B sets were deployed in the failed defence of the Philippines in December 1941, one by the US Marines, while two fixed-site SCR-271 were in storage awaiting preparation of suitable sites.
December 8, 1941: MacArthur's Pearl Harbor by William H Bartsch (Texas A&M University Press, 2003).

[48] However, its operating manual gave a maximum of 80 to 120 miles (129 to 193 km) for bombers at 10,000 feet (3,048 meters) altitude; and 50 to 75 miles (80 to 120 km) for the smaller fighters.

[49] https://www.historic-uk.com/HistoryUK/HistoryofScotland/Robert-Watson-Watt/

[50] "Clutter" is the term used for unwanted echoes in radar. They can be caused by a number of things, but reflections from the ground (aka surface clutter) is perhaps the most obvious, and explains why low-level ("below the radar") air attacks became more common later in the war and postwar.

[51] *Security and Defense of the Panama Canal 1903-2000* by Charles Morris, Panama Canal Commission: https://original-ufdc.uflib.ufl.edu/AA00047733/00001/6j

[52] https://www.ibiblio.org/hyperwar/AAF/I/AAF-I-8.html

he had flown in a large twin-engine Douglas C-41 transport aircraft[53] at various altitudes of up to 10,000 feet (3,048 meters), only to discover on landing that the Aircraft Warning Service had failed to plot any part of his flight. He concluded that, despite the Canal Zone being the region where the Army had made its best efforts, "*no measures which are economically possible within the next two years*" could provide a warning service that would be as much as 80% reliable. He recommended that the SCR-270 and SCR-271 sets be replaced as soon as possible, and that the Canadian-built versions of the British low-angleCHL/GCI system be deployed instead[54] – although he conceded that the Army would have to persevere with the existing systems for the time being.[55]

In response, the Commanding General of the Sixth Air Force in Panama argued that report had been too critical. He said many of the undetected flights were training ones, with aircraft flying over mountainous terrain, where the efficiency of long-wave radars (such as the SCR-270/271 series) was very low. He claimed that comparing plots to known flights over the sea approaches (from where it was anticipated any air attack would likely come) showed 59% efficiency – compared to only 15% for approaches over land; though surely, even 59% efficiency would not provide satisfactory reassurance.[56]

Another factor was the small size of the Canal Zone, for effective use of the early radars, and to improve greatly the chance of then radars detecting an attacking force approaching from any direction, what was needed radar sites outside the Zone and in

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[53] A version of the DC.3 airliner.

[54] Chain Home Low was the name given to the British early warning radar capable of detecting targets below the minimum effective height range of the original Chain Home radars (with which they would normally be co-located). Operating in the VHF wave band, this radar could be used as both a medium-range search radar and as a shorter-range Ground Controlled Interception (GCI) radar with height-finding capability. The Canadian-built version was designated SCR-588 by the US Army: http://www.fortwiki.com/SCR-588
CHL with GCI only became operational in the UK in January 1941.

[55] The Canadian sets were designated SCR-588, initially being without height-finding. The CHL/GCI combination was the SCR-588B. However, production by Research Enterprises Ltd in Canada began slowly and operational versions would remain few in number until the end of the war.

[56] *United States Army in World War II.: The technical services* by George Raynor Thompson, Dixie R Harris, Pauline M Oates and Dulany Terrett (US Army, Office of Military History, Department of the Army, 1957).

the Republic. The negotiations over acquiring what would eventually total some 134 sites outside the Zone (consisting of a variety of types – airfields, gun sites etc, as well as radar and ground observer stations) would take a little time, with the final agreement only being signed in May 1942.[57]

In mid-March, immediately after Watson-Watt had made his report, Stimson himself went to Panama. He returned convinced that all forms of radar defences of the Canal, particularly ASV radar equipment for patrol aircraft, were of the highest priority.[58] Persuaded that without ASV air patrols would be of little value, and that with ASV the number of aircraft needed for patrol purposes could be substantially reduced, on his return he gave "*a considerable stimulus to the varied elements of the new defense system*".[59]

Later in March, Stimson submitted a report to President Roosevelt (using what then was the Navy's name for the detection system, radar). He said that he had been promised Canadian-built CHL systems, which would be effective against both low-flying and high-flying aircraft, with sites for them selected, and that equipment said was to be on its way to Panama – the Canadian Ministry of Defence had undertaken to give priority for four sets for use in defence of the Canal.[60] He noted that one of the original radar sites in use had been found to be in the wrong place to be effective. He concluded that action underway could be expected to very considerably improve the detection of low-flying aircraft, but that the interceptor fighter force still needed to be strengthened.[61]

By the end of March 1942, there were no less than eight early warning radar stations in operation in Panama, with six more under construction. However, there remained

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[57] For more on this story, and the ignominious and rapid withdrawal from the sites postwar, see https://raytodd.blog/2025/10/10/panama-operating-outside-the-zone-the-1942-agreement-and-the-1947-row/

[58] ASV = air-to-surface vessel radar, i.e. that carried by aircraft and capable of detecting surface vessels at sea.

[59] https://www.ibiblio.org/hyperwar/USA/USA-WH-Guard/USA-WH-Guard-16.html

[60] https://www.ibiblio.org/hyperwar/USA/USA-WH-Guard/USA-WH-Guard-16.html

[61] http://docs.fdrlibrary.marist.edu/PSF/BOX6/t71q06.html

concern that equipment in use at these stations was inadequate for early warning and "quite useless" for purposes of controlled interception.

Thanks to the insistence of the Secretary of War, the efforts of the Signal Corps and USAAF, and mounting production of radar equipment, by May 1942, ten long-range detectors (SCR-270 and SCR-271) were in operation in the vicinity of the Canal, two were being installed, and another would be available after reconditioning. Six SCR-268 sets had been modified for ground-controlled interception (GCI) application and were in operation.

Also in the course of being installed by May were two of the Canadian-built CHL sets, with another two either on hand or on their way to Panama. Two other British GCI sets were expected.[62]

While somewhat superior equipment was being received, this could not overcome shortcomings in personnel. The combination of inadequate equipment, poor site selection, and untrained operators was said to have produced such inefficiency that even the best station in Panama was "*far below any acceptable standard of operational utility*".[63] The shortages having effect were not so much of equipment as of trained operators and maintenance crews. Furthermore, despite more and better equipment and more expert, scientific placing of the radar sets there still remained a blind spot at low altitudes over the Bay of Panama, something not corrected until the end of 1942.[64] Also, the special equipment required for ground-controlled

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[62] In addition, there was an SCR-270 in operation at Salinas in Ecuador, and four SCR-271 were to be shipped to the Galápagos Islands base during the following six or eight weeks. Salinas and the Galapagos were two of the three points on the large patrol arc over the Pacific approaches to the Canal.

[63] https://www.ibiblio.org/hyperwar/AAF/I/AAF-I-8.html
From June 1941 to May 1943 the Japanese occupied two islands in the Aleutians, part of the Territory of Alaska, in the far north of the Pacific. They and Guam were the only US territory invaded during the war.

[64] Bear in mind, that the Bay is on the Pacific coast – the side thought more at risk from aerial attack (and, in fact, the Japanese were to develop plans for an attack, using aircraft carried on large submarines, from the Pacific – the submarines and aircraft being built, but with the war ending before an attack could be launched).

interception (GCI) had been slow to arrive, with the first two sets not installed until September 1942 and did not begin operating until the following month.[65]

Signal Corps Aircraft Warning Training

Technical training was a major mission of the Signal Corps during the war, and rapid mobilisation, and the urgent need for radar crews, required it to increase the number of training centres, but also demanded that it cut that technical training time drastically. Allied to this, a shortage of officers, so that National Guard and Reserve Signal Corps officer training was reduced from nine months to just three months *graduates were soon ridiculed as "ninety-day wonders").[66] Meanwhile, Regular Army officers saw their course was cut to just a single month overview of wire, radio, photography, and the newly emerging aircraft warning service. All enlisted technical training was shortened to just three months or less.

From late 1940, the Signal Corps over the next 18 months established three major electronic training centres related to radar or Air Warning Service AWS) operations.[67]

Prior to the arrival of the CHL sets, the early warning system that evolved for the Pacific approaches included –

- patrol aircraft, operating at about a 900-mile (1,448 km) radius, which were depended upon for the initial warning of the approach of a hostile vessel (such as an aircraft carrier) - obviously the advent of ASV radar improved the effectiveness of this;[68]
- long-range radar (the SCR-271 and its mobile version, the SCR-270), which was relied upon for the detection of enemy aircraft at distance (a notional 150 miles or 241 km, if at altitude); and

[65] https://www.ibiblio.org/hyperwar/USA/USA-WH-Guard/USA-WH-Guard-16.html#page431

[66] As an indication of numbers, the Signal Corps Officer Candidate School (OCS) at Fort Monmouth, New Jersey, graduated 21,033 new Signal Corps second lieutenants between 1941 and 1946.

[67] *The American Aircraft Warning Service Takes Shape* by Randall DeGering (Air University Press, 2018): https://www.jstor.org/stable/pdf/resrep19549.10.pdf

[68] In fact, when the Japanese did devise an attack, they planned to use aircraft-carrying submarines, which were far less likely to have been detected. See https://wordpress.com/post/raytodd.blog/43177

- still closer-in, the fixed anti-aircraft defences which relied upon the short-range, height-finding radar (SCR-268) for searchlight and fire control.[69]

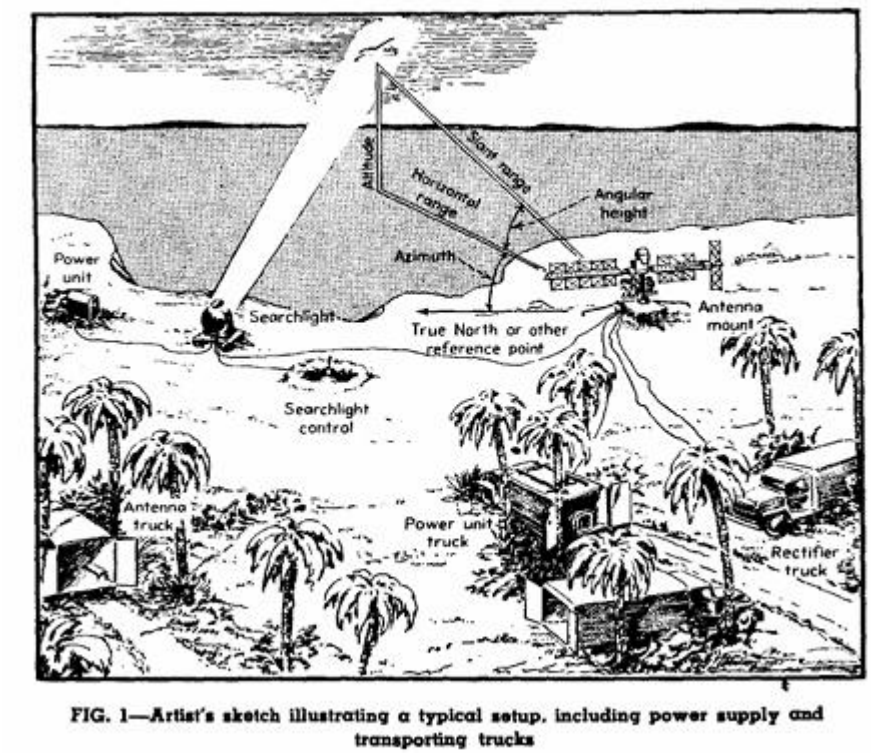

FIG. 1—Artist's sketch illustrating a typical setup, including power supply and transporting trucks

SCR-268 unit (Electronics Magazine, September 1945)[70]

In mid-1942, the Commanding General at the time, General Andrews, still concerned about the possibility of a carrier-based air attack, had asked that Panama be used as the test area for the newest and best radar. As a result, the scientists at the Radiation Laboratory at MIT,[71] who were developing the new radars, were asked to consider the problems of the defence of Panama – in particular, problems presented by the reflections from mountains affecting the efficiency of the systems. In fact, Panama proved to be the best place to trial microwave radar, which proved better able to detect aircraft over high land masses than the original, long wave radar. Hence, Panama did become the testing ground for new radars, especially microwave radars,

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[69] https://www.ibiblio.org/hyperwar/USA/USA-WH-Guard/USA-WH-Guard-16.html#page431
https://www.radartutorial.eu/19.kartei/11.ancient/pubs/elec-09-1945-scr-270.pdf

[70] https://www.radartutorial.eu/19.kartei/11.ancient/pubs/elec-09-1945-scr-270.pdf

[71] https://www.ll.mit.edu/about/history/mit-radiation-laboratory
Established at the Massachusetts Institute of Technology in Autumn 1940, to research into detection methods for aircraft and ships using microwave technology. During the war the Radiation Laboratory made a number of important contributions to the development of microwave radar technology, including in airborne bombing radars, shipboard search radars, harbour and coastal defence radars, gun-laying radars, ground-controlled approach radars for blind landing of aircraft, IFF beacon systems, and the long-range navigation (LORAN) system.

such as the SCR-615 10 cm waveband fixed-site, height-finding radar for ground-controlled interception.[72]

Two scientists from the Radiation Laboratory[73] also visited the Canal Zone soon after and worked out plans to send two SCR-582 and a SCR-615 microwave GCI radar for use there.[74] These would be the first Signal Corps microwave radars to be used on the ground, and could provide low-level coverage, which existing radars then in use in Panama could not.[75] They also urged the use of microwave ASV radar in place of long-wave sets then in use in patrol bombers.

In essence, centimetric radar employing a cavity magnetron and microwaves operated in the 3 to 30 GHz waveband, with wavelengths of 10 cm or less. The shorter the waveband, the smaller the object that can be detected, with greater accuracy, and the smaller the antenna required. For example, a radar with two metre waveband could only detect objects of two metres or more in size, and required and antenna of two metres, whereas a 10 cm one could detect of 10 cm in size, with a much smaller antenna.

The new SCR-615 radar was sent to Panama for test in late 1942, being sited on Taboga and replacing the inadequate SCR-271. It was, in fact, one of only two that had been hand-built by the Research Construction Company (the other having gone to an Army test centre in Florida). This was the first microwave GCI radar, having a range of

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[72] *The Signal Corps: The Test (December 1941 to July 1943)* By George Raynor Thompson, Dixie R Harris, Pauline M Oates & Dulany Terrett (Center of Military History, US Army, Washington DC), 2003. https://www.ibiblio.org/hyperwar/USN/ref/Radar/Radar-7.html

[73] Dr Bowles, from MIT, Secretary of the Microwave Committee of the National Defense Research Committee established by Roosevelt in June 1940, and the recently appointed expert consultant for radar to the Secretary of War, together with Ralph Bown of Bell Laboratories (and also a member of the Microwave Committee hosted at MIT).

[74] Based on a US Navy shipboard radar, the SCR-615 had been developed after it became apparent that the Canadian-built CHL/GCI radar (as SCR-588) would not be available for some months, and that the Signal Corps copy of the British GCI, being produced by General Electric, would also not be available for a time. Modified by the scientists at the Radiation Laboratory at MIT, while not actually ready before the SCR-588 was available in quantity, the SCR-615 actually proved a superior system https://www.ll.mit.edu/about/history/mit-radiation-laboratory

[75] SCR-270, SCR-271 and the British CHL (Chain Home Low) SCR-588.
The Signal Corps: The Test (December 1941 to July 1943) By George Raynor Thompson, Dixie R Harris, Pauline M Oates & Dulany Terrett (Center of Military History, US Army, Washington DC), 2003.

some 65-mile (104.6 km)[76] and providing good low-level coverage as well. The antenna was mounted on platform on top of a tower and enclosed in a turret. It was this set that tracked the Commanding General in Panama, General Brett, when he thought he had flown in unseen by the Canal Zone defences by adopting a very low-level approach.[77]

SCR-615

The history of the USAF Air Defense Command summarised the need for an effective integrated system –

> "*The Aircraft Warning Service does not merely "alert" defending pursuit aviation; it furnishes pursuit with the detailed, timely, and continuous intelligence necessary for pursuit interception. A proper conception of an Aircraft Warning Service is that of a complex and highly organized service carefully adjusting to the tactical requirements of the agencies it serves and efficiently integrating into the defense of a strategic area*".[78]

A BIT MORE ON ASV RADAR

Both Watson-Watt and the MIT experts had both recommended the use of the improved ASV radar, the former describing this as a matter of the "highest urgency". Such radars were considered not only necessary for hunting U-boats in the Caribbean, but would also to make patrols searching for Japanese aircraft carriers in the Pacific

[76] Seemingly refuting Watson-Watt's contention that only long-wave radar could provide long range coverage.
[77] *The Signal Corps: The Test (December 1941 to July 1943)* by George Raynor Thompson (Center of Military History, US Army, 2003).
[78] *The American Aircraft Warning Service Takes Shape* by Randall DeGering (Air University Press, 2018): https://www.jstor.org/stable/pdf/resrep19549.10.pdf

more effective.[79] 1942 saw the worst of the "Battle of the Caribbean", with U-boats targeting mostly the oil and bauxite traffic that crossed that sea, making their detection a priority, and centimetric radar would have a much better chance of detecting the relatively small target that a submarine conning tower or periscope might provide.[80]

B-18B Bolo fitted with SCR-517 radar in a modified nose (Pima Air & Space Museum photo)

The use of radar in the air-to-surface vessel role had been discovered by accident in 1937, when a British team testing experimental airborne interception radar noticed returns caused by harbour docks and cranes.[81]

The use of anti-submarine aircraft equipped with ASV radar had been proven by B-18 bombers fitted with the sets which had been modified airborne interception 193 MHz SCR-540 radars,[82] during early 1942. After the adoption of the cavity magnetron, came the SCR-520 (the first 10 cm microwave radar, designed for use on the P-70 night-fighter), which was converted to become SCR-517 for air-to-surface use,[83] both having been developed by the Radiation Laboratory and Bell Telephone Laboratories[84].[85] It was installed in the nose of the otherwise obsolescent B-18 bombers used on anti-

[79] *United States Army in World War II.: The technical services* by George Raynor Thompson, Dixie R Harris, Pauline M Oates and Dulany Terrett (US Army, Office of Military History, Department of the Army, 1957)

[80] For more on the U-boat threat, see https://raytodd.blog/2025/10/10/panama-and-the-u-boats/

[81] *Radar Days* by EG Bowen (CRC Press, 1998).

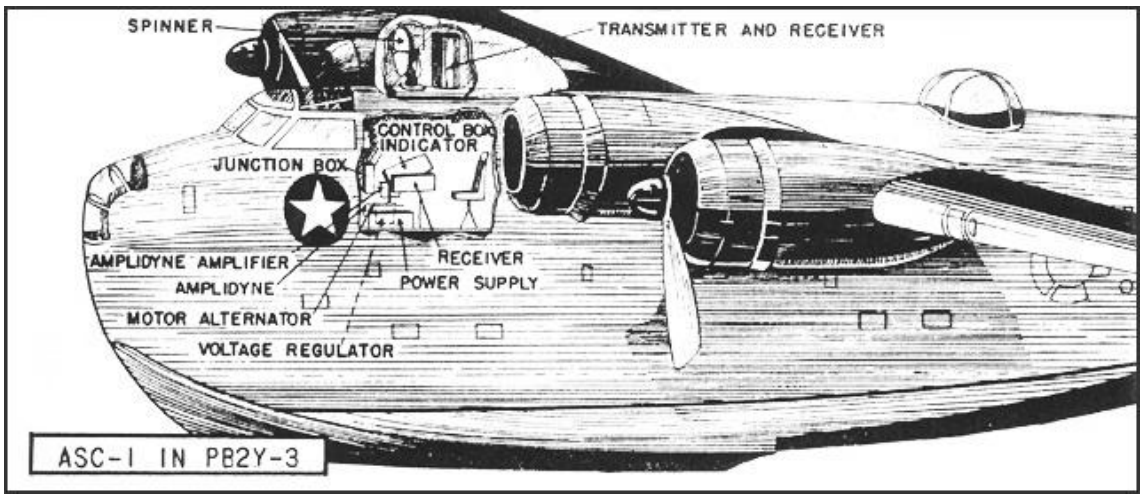
[82] As used on a handful of P-70 night fighters sent to Panama in 1942. The SCR-540 was a US copy by Western Electric of the British AI Mk IV, the world's first operational air-to-air radar system.

[83] https://www.radartutorial.eu/19.kartei/11.ancient9/karte004.en.html
It was also used on PT Boats: http://www.ptboatworld.com/PT_Boat_Info/571ARadar.htm

[84] https://www.ibiblio.org/hyperwar/USN/ref/Radar/Radar-10.html

[85] https://www.ibiblio.org/hyperwar/USN/ref/Radar/Radar-10.html

submarine duties in the Caribbean.[86] US Navy patrol aircraft operating from the Canal Zone, such as the PB2Y Coronado flying-boat, also carried a version of the radar.[87]



ASV radar would also be fitted to K-Class "blimps", airships used by the US Navy for anti-submarine patrols, including from Panama and bases in the caribbean area.

OTHER RADARS

As mentioned, Panama had been recommended as an ideal testing ground for new radars, and in mid-1942 the Army sent the SCR-582 Harbor Surveillance Radar to Panama. This fixed-site microwave ground radar could produce a map-like view of a harbour area, including all the vessels therein. It was designed and built by the Radiation Laboratory. The SCR-582 was tested, alongside another microwave radar, the SCR-615 (intended for shipboard use for aircraft warning and ground-controlled interception), by the 708th Aircraft Warning Company in Panama.

The SCR-582 evolved into the mobile SCR-682, a long-range early warning radar for Coast Artillery for use against aircraft and surface vessels.[88] Production of the SCR-582 ended after production of 55 sets, being replaced by the mobile version (mobile, but

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[86] In 1942, the Navy asked for the diversion of sets for use on submarine chaser vessels, which initially was its preferred option for the radar: *The Signal Corps: the Test (December 1941 to July 1943)* (Office of the Chief of Military History, US Army, 1957).
The maximum reliable range of the SCR-517 was said to be 18 miles (29 km) for a small target like a submarine (compared to less than 10 miles for earlier sets), or 40 miles (64 km) for a large ship

[87] https://www.ibiblio.org/hyperwar/USN/ref/Radar/Radar-10.html

[88] *The Signal Corps: The Test (December 1941 to July 1943)* By George Raynor Thompson, Dixie R Harris, Pauline M Oates & Dulany Terrett (Center of Military History, US Army, Washington DC), 2003.

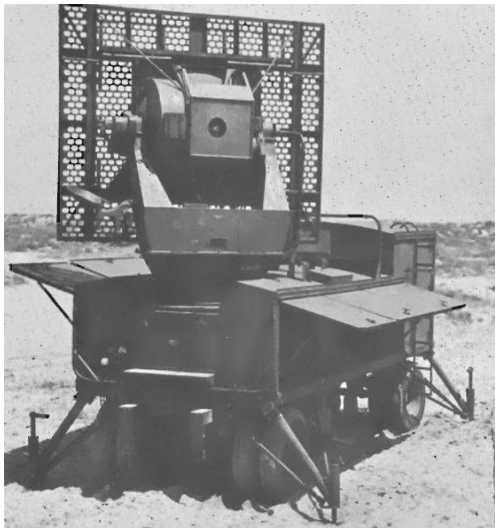
still requiring two or three 2½-ton trucks), and modified with a tilting antenna dish for aircraft detection, that was also deployed in fixed locations.[89]

SCR-582 Harbor Surveillance Radar at Fort Dawes in Boston (US Army photograph)

In May 1943, the SCR-547 Height Finder Radar, with its twin-dish antennae arrangement (resulting in its "Mickey Mouse" nickname), was received in Panama and installed at tactical positions, to supply slant range or altitude to anti-aircraft artillery fire control data. This came as a set consisting of an antenna trailer, tractor, and spare-parts truck – with early models also having a power van. However, this radar proved neither effective nor popular; and the program was cancelled and all were turned over to the Signal Corps in August 1944.[90]

SCR-547 Height Finder Radar (US Army Air Defense School)

[89] http://www.fortwiki.com/SCR-582
[90] https://radionerds.com/index.php/SCR-547



SCR-545 (US Army Air Defense School)

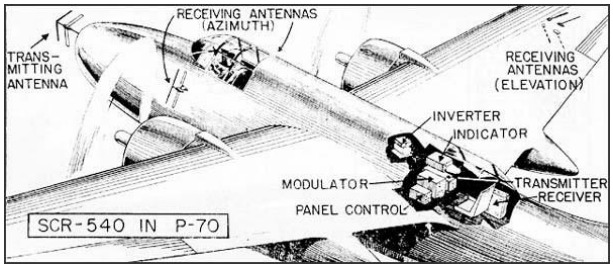
In April 1944, SCR-545 sets were received, replacing the SCR-268 and SCR-547. This new set still suffered from problems with ground clutter, but less so. The SCR-545 was a mobile aircraft search and anti-aircraft gun-laying radar, and was produced in limited numbers by Bell Laboratories. Like the SCR-547, it came as a set, a trailer and a prime-mover carrying a power plant. A spare parts truck was needed for each anti-aircraft gun battalion. It was said that five men could set up the equipment and associated director within 20 minutes. It was operated by three operators and a chief operator, although if a power van was used extra personnel were required.[91]

However, both the SCR-268 and SCR-545 were unable to detect targets over land and below 1,000 feet (305 metres) altitude. Due to the problems, the M-1 Height Finder device was used to determine the range of low-flying aircraft which could not be tracked by the SCR-545 radar. In addition, by 1944, daily tracking missions formed part of the training required to improve and maintain the efficiency of the crews of the radar sets.

[91] https://www.ibiblio.org/hyperwar/USN/ref/Radar/Radar-6.html

35th scale model of an M-1 Height Finder device (Commander Models Inc)

The M-1 was a mobile telescopic device, which came as a unit resting on a single-axle, two-wheeled bogie drawn by a trail. It was used to determine the slant range or altitude of an enemy aircraft and to transmit the resulting data to the mechanical director – the latter computed the firing data continuously. Power was supplied by a separate generating unit located nearby. Largely perfected by the Eastman Kodak Company, it was fundamentally a 13.5-feet (4.1 metres) stereoscopic range finder that converted slant range to altitude.[92]



While the primary concentration in Panama and the Canal Zone was on air defence and airborne air-to-surface vessel radars, as mentioned above, early SCR-540[93] AI (airborne interception) radars had been used on a small number of Douglas P-70 night-fighters[94] that were sent to Panama in late 1942 to try to make up for the shortfall in night defences there.[95] It was an US-produced version of the British AI Mk IV radar,[96] but was soon overtaken by newer microwave radars based on the cavity magnetron.

The P-70 was a modification of the A-20 light bomber produced to fulfil an urgent USAAC need for a long-range night fighter, and in September 1942 the first 59 were

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[92] http://tothosewhoserved.org/usa/ts/usatso01/chapter14.html

[93] The SCR-540 was soon replaced by the much larger, microwave AI radar, the SC-520. This meant that, by October 1943, the first US AI radar, SC-540, was already obsolescent.

[94] See https://wordpress.com/post/raytodd.blog/44146

[95] *The Signal Corps: The Test (December 1941 to July 1943)* By George Raynor Thompson, Dixie R Harris, Pauline M Oates & Dulany Terrett (Center of Military History, US Army, Washington DC), 2003.

[96] Used by the RAF on its Blenheim and Beaufighter night fighters.

ready for combat, with 59 of the new SCR-540, a version of the British-built AI Mk IV and produced by Western Electric, having been delivered to the Douglas Aircraft Company.[97] Of this initial batch, about half were sent to training units, with the rest deployed to Panama and Hawaii. At the time it was still considered a strong possibility that a night attack on the Panama Canal might he attempted. Subsequently, a further handful (fitted with the better SCR-540 radar) would be sent to Panama. However, use of the P-70 in Panama appears to have been short-lived, being withdrawn in 1943.[98]

A nice model of the P-70 Nighthawk, clearly showing the dipole aerials

Ray Todd

Panama City

Republic of Panama

22 January 2026

[97] https://www.militaryfactory.com/aircraft/detail.php?aircraft_id=1214

[98] *Conquering the Night Army Air Forces Night Fighters at War* by Stephen L McFarland (Air Force History and Museums Program), 1998: https://media.defense.gov/2010/May/26/2001330259/-1/-1/0/AFD-100526-018.pdf