CHAPTER SEVEN

World War II and Radar

I feel sure Mr Witt would have suggested that the facilities of the Research Laboratories be used to further the war effort. He was very proud of his establishment and was always in the forefront of any new development. Mr Witt and his two Assistant Supervising Engineers, Eric (E.P.) Wright and Ted (E.J.) Stewart, occupied adjacent offices at the front of 59 Little Collins Street, on the second floor.

Ted Stewart was in charge of all radio work and Eric was responsible for all other activities. Ted was small in stature, with very fair and rather sparse hair, thin-rimmed spectacles and a quizzical smile. He was a very logical thinker and could immediately appreciate the thrust of a technical argument. Quietly efficient, he was greatly respected by those who knew him and I was very impressed by his technical ability. Ted was the driving force behind the design work undertaken by the Laboratories for the armed services during the war.

In July 1940 Ted Stewart assigned me to experimental work on radar in association with the Radiophysics Laboratory of the Council for Scientific and Industrial Research (CSIR), which was located in Sydney, together with several other engineers in our Laboratories - Don McDonald, Alec McKenzie and Jock Campbell, a rather

Scotch mixture! Initially I was not told what "radar" was. It was TOP SECRET! I was given a small electronic chassis to test which contained several EF50 miniature vacuum tubes and was said to operate on a pulse frequency of the order of 200 Mc/s. I was given no clue to its function, but from the limited information available I was able to determine the basic principles of radar range-finding and was then admitted to the area of TOP SECRET information on the use of radar by the defence forces.

The newspapers and radios were full of shattering news about the Battle of Britain, which peaked in mid-August with the destruction of 260 German and 130 British aircraft in one week. It was understood that radar installations in Britain were playing a major part in the detection of enemy aircraft and ships within range of the weapons of defence. I had a great deal to learn.

I was familiar with the principles of the Western Electric Altimeter (from a technical paper published in January 1939) and of an Omni-Directional Radio Beacon described in a paper published in January 1940. By adapting these principles I conceived my own system of radio location, involving the use of frequency-modulated transmitters instead of pulse transmitters. My reason for developing this idea was to avoid the difficulties involved in constructing pulse transmitters with pulses of sufficiently short duration, and large and extremely

accurate potentiometers for range measurements. In my proposed system, range would have been measured by a calibrated beat-frequency oscillator, and bearing measurement required the provision of three transmitting aerial arrays placed in plan at the corners of a right-angled isosceles triangle having sides of the order of a hundred yards or so.

I made a rough laboratory set-up of the range measuring portion of my proposed system, using standard items of lab equipment, which demonstrated to my satisfaction the principle of that portion of the system for which I claimed originality. I then set this concept aside for future reference and concentrated on the immediate problems being tackled by the Radiophysics Laboratory.

As defence preparations gathered momentum in Australia, the Research Laboratories were asked to undertake other developmental jobs besides radar, and these activities were assigned to the groups under Eric Wright. Eric had worked with Mr Witt since the Laboratories were first established. He was tall, and very affable - kind hearted and considerate, with a boyish sense of humour. A dedicated protestant churchman and lay-preacher, Eric had very rigid ideas about proper human behaviour. He was a strict teetotaler, hating strong language and vulgarity, and would never think of entering a hotel bar or a picture theatre. It was said

he imposed the same restrictions on his family, and screened "suitable" films on a home projector, rather than allow them to attend a cinema. In other words, he was a wowser - but a likeable one.

One of the early jobs undertaken by the Labs was the incorporation of a microphone and headphones inside a gas mask, to facilitate intercommunication between service personnel under an enemy gas attack. Eric assigned this job to Perc Killey, who occupied the desk next to mine.

Perc produced a very efficient design and the prototypes were to be tested at the Army establishment at Puckapunyal. Eric was invited to attend with Perc, who gave me a detailed account of what happened on his return.

The troops taking part in the demonstration were lined up by a Sergeant, with gas masks at the ready. Eric noticed that the Sergeant had a regulation whistle on a halter round his neck. Eric gave him a boyish nudge and said jocularly -

> "I say, can you tell me how you blow that whistle when you have the gas mask on?"

The Sergeant looked at Eric, thought for a moment, and said -

> "You shove it up your arse and fart!"

Poor Eric blushed crimson, and withdrew hurriedly.

The Sergeant evidently realised he had made a faux pas, or whatever might have been his name for it, and waited for an opportunity to make amends. When the demonstration was completed satisfactorily he said to Eric -

> "You gentlemen might like to join us in the mess. We have some good whisky!"

Eric shied like a startled horse, and beat a hasty retreat to the Laboratories, leaving Perc to enjoy the hospitality of the Army personnel.

As the Battle of Britain continued from August to October 1940 it became obvious to the German forces that Britain was not to be conquered by air attack, despite the terrible destruction already wrought. There had been much speculation about the possibility of Japan entering the war on the side of Germany, because of her aspirations in the Pacific area. It was essential that Australia should direct all energies to assist the war effort. Everything else was irrelevant.

Since my arrival in Melbourne in June 1936 I had been very active in the Juniors and Students Section of the IEA and in the Rostrum movement - to both of which I had been introduced by Torchy Thomas. In Adelaide I had been Chairman of the J and S Section of the IEA, and was elected to the corresponding post in Melbourne in 1940. The November meeting took the form of a smoke social, at which I gave my first Melbourne conjuring performance.

In Rostrum I had been Secretary of No.4 Club in 1937 and President in 1938. These activities I thoroughly enjoyed, but the time had come for more serious things.

I withdrew from active participation in both the IEA and Rostrum in 1941. Those things could wait till the war was over.

Work at the Laboratories was classed as a "reserved occupation", but Bill Boswell left "for the duration" to join the Royal Australian Navy as an officer. Don McDonald moved to the Radiophysics Division of the CSIR in Sydney. The Research Laboratories Bulletin of December 24th, 1940, stated -

> "J.H.T Fisher is now full time on the special work for the Division of Radiophysics. He is remaining in Melbourne coordinating design and manufacturing facilities."

Jock Campbell was working with the Air Force on "Aircraft to Surface Vessel" equipment (ASV) and the Labs were also involved in "Gun Laying" (GL) radar systems. With Ted Stewart I had discussions with CSIR Radiophysics personnel - in particular Harold (HJ) Brown, who later headed the Long Range Weapons Establishment in Salisbury in South Australia, Joe (J.L.) Pawsey (who made his name in the field of Radio Astronomy) and Harry (H.C.) Minnett.

My first major radar project was the Shore Defence (ShD) System known as CANo.1. This was designed

for installation at high Coastal Artillery locations to give early warning detection of approaching enemy aircraft or ships. The circuit designs for this were developed by the CSIR Radiophysics Laboratories, who built a prototype. My responsibility was to translate this equipment into a form suitable for quantity manufacture, to have working drawings prepared and to arrange manufacture within the PMG's Department. I was assisted by two Lab engineers - Alec McKenzie and Ross Pitkethly and a team of draftsmen. Manufacture was undertaken by the Postal Workshops in South Melbourne under the control of Bert (A.F.) Spratt, who was later to become the first Managing Director of Australia Post. Inspection, installation and field trials were carried out by Army personnel. One of the critical development tasks I had to undertake was the production design of a range-measuring potentiometer. This was a 40 stud precision potentiometer having a pitch circle diameter of 9", with an auxiliary geared potentiometer to bridge the gap between studs. In conjunction with a cathode ray screen display, this potentiometer was designed to provide range measurement of radar targets up to 40,000 yards as indicated by associated dials. The potentiometer assembly was controlled by an operator from a handwheel, through a precision gearbox designed by the mechanical engineering section of the New South Wales Railways. Extremely fine tolerances were required in the manufacture of both the potentiometer and the gearbox.

Each ShD system comprised four cubicles of equipment, filled with several chassis which could be slid out for maintenance service. These were made by the Postal Workshops to our design, but the associated aerials were made by others. My work involved considerable liaison with the Radiophysics Laboratories, the Department of Army, the NSW Railways and various manufacturers of components. I had to make frequent trips to Sydney.

These systems were installed at strategic locations on the Australian coast in several States, but the only one I visited myself was at North Head, in Sydney. The equipment performed satisfactorily, and I was then given the responsibility of designing a modified version for use on corvette vessels of the Royal Australian Navy. This involved visits to the Garden Island Naval Establishment in Sydney Harbour, where I encountered Ian Nicholson, an old colleague of University days, in Naval uniform. In the Naval equipment, special steps had to be taken to secure the removable units against accidental damage when the ship encountered very rough seas. We had to solve a number of teething problems, such as become evident only when a new equipment goes into regular service.

Australian politics were suffering from the pressures of war. As a result of dissention within the United Australia Party, Bob Menzies resigned as Prime

Minister on August 29th, 1941, and was replaced by Arthur Fadden, who had been Federal Treasurer. However, when the Budget was presented in October his Government was defeated on a motion by John Curtin, then Leader of the Opposition. Curtin became Prime Minister on October 7th, 1941, and retained his position throughout the war, until his death in 1945.

Australia was abruptly brought face to face with the realities of war with the fall of Pearl Harbour and attacks on Singapore and Hong Kong. On the 7th of December, 1941, 94 ships of the U.S. Navy anchored at Pearl Harbour in Hawaii were attacked without warning by 360 Japanese aircraft, comprising bombers with fighter escort. Neither Japan nor the United States had until then been party to the war, and there had been no declaration of war by either country. In 90 minutes the U.S. Pacific fleet was devastated. Five battleships and two destroyers were sunk, and ten other ships either sunk or severely damaged. 140 American aircraft were destroyed and 80 damaged. Over 2000 Americans were killed and nearly as many injured.

On the same day, Japan bombed the British defence establishments at Singapore and Hong Kong. The Australian feeling of security engendered by the presence of U.S. naval forces in the Pacific, and by the British stronghold of Singapore, vanished overnight. We realised

Britain declared war on Japan next day, and Japan persuaded Germany to attack U.S. ships, wherever they were found. As Winston Churchill subsequently wrote in "The Grand Alliance", the third volume of his war history-

> "The mastery of the Pacific had passed into Japanese hands, and the strategic balance of the world was for the time being fundamentally changed."

Shock followed shock. On December 12th two of Britain's capital ships, HMS Prince of Wales and HMS Repulse, were sunk by Japanese aircraft off the east coast of Malaya and on February 15th, 1942, Singapore surrendered to Japanese forces pushing down from the mainland across the Straits of Johore. In January 1940 Australia had sent the first Division of the 2nd AIF to Palestine, to train before joining the British forces in France; following the Pearl Harbour attack in December 1941, some of these Australian forces were being brought home on the commandered Queen Mary and Queen Elizabeth ships to defend Australia - but they were off-loaded at Singapore to take part in its defence, and were then traped by the Japanese invasion, when 100,000 British and Imperial troops were taken prisoner, including more than 15,000 Australians.

In the midst of all this confusion and shock, we passed the most wonderful domestic milestone. On December 29th, 1941, Phyll gave birth to a beautiful baby girl, Christine Ann, at the Mercy Hospital in East

Melbourne. It was an uncomfortable confinement, but they were both well. We had almost given up hope of having a family - Phyll was now 30 - but this gave us a new outlook on life.

At the beginning of January, Ted Stewart informed me that I was being given the status of acting Divisional Engineer on the radar design work. This was a great encouragement, and meant a substantial increase in salary - very acceptable with our increased family responsibility.

Four days after the fall of Singapore, Darwin was raided twice by Japanese aircraft on February 19th - 72 bombers with fighter escort in the first raid lasting 30 minutes, and 21 in the second raid two hours later. Twenty of our aircraft were destroyed, 11 ships sunk, the Post Office was bombed and valuable supplies lost. All communications were put out of action and 243 people were killed. The Sydney Morning Herald said "It was a blitz of the most ferocious kind". News of the air raid was received at Alice Springs by morse code, transmitted by a makeshift connection to the line 8 miles south of Darwin on the day of attack. The telecommunications headquarters were re-established at Larrimah, 116 miles south of Darwin, as soon as possible.

Under the circumstances it is understandable that on February 20th John Curtin refused to agree to requests

from Winston Churchill and President Roosevelt, who asked that an Australian division (then en route home to Australia from the Middle East), should be diverted to Burma to assist in its defence against Japanese troops.

The situation is best illustrated by high level communications quoted in Winston Churchill's fourth volume of war history, "The Hinge of Fate" -

From Curtin to Churchill, 23 Jan 42:

> "Singapore is a central fortress in the system of the Empire and local defence - - - we understood that it was to be made impregnable, and in any event it was to be capable of holding out for a prolonged period until the arrival of the main fleet."

But Singapore had fallen to the Japanese, who had then paralysed Darwin.

Churchill wrote:

> "For the remainder of this brief campaign Darwin ceased to be of value as a base."

From Curtin to Churchill, 23 Feb 42:

> "We feel a primary obligation to save Australia not only for itself, but to preserve it as a base for the development of the war against Japan."

From Roosevelt to Curtin, 20 Feb 42:

> "I assume you know now of our determination to send, in addition to all troops and forces now en route, another force of over twenty-seven thousand men to Australia. This force will be fully equipped in every respect."

Burma was lost to the Japanese, which made Australia even more important as a base in the Pacific area.

In May 1942 a Japanese invasion force left Rabaul with the object of capturing Port Moresby. They were engaged by U.S. land and carrier based aircraft in the Coral Sea, and lost so many aircraft, in a struggle lasting four days, that they were forced to return to Rabaul because of insufficient air-cover.

On the night of May 31st four Japanese midget submarines entered Sydney Harbour. They were sunk before substantial damage was done, but this was further evidence of the growing threat to Australia from Japan.

The arrival of American troops in Australia met with mixed feelings. They were greeted with open arms by many girls. Their pay was high, compared with the salaries of our own men, and they were generous. Under the command of the somewhat flamboyant General Douglas MacArthur, who came to Australia from the Philippines in March 1942, they proceeded to take what they needed - with disregard for any red-tape encountered. An American officer setting up an office in Melbourne found he had a room with telephone wiring but no telephone. He sent one of his men down to the nearest public telephone cabinet to bring back the necessary instrument. It was quicker than waiting for the PMG's Department to supply one.

An American armoured vehicle, landed on the Port Melbourne wharf, drove through a locked security gate. It was quicker than waiting for the key.

The competition for female favours made the US troops unpopular with the local boys, and the slogan "GO HOME YANK" began to appear chalked on brick walls.

However, they were here for a purpose which was gratefully recognised and they were gradually accepted as comrades in arms, with a certain amount of give and take.

I had little occasion to deal with the Americans myself, and derived some amusement from their unfamiliarity with our customs and our unfamiliarity with theirs - including the question of accents. We knew the American accent from "talkies", as sound films were still called, but Australian speech was often like a foreign language to them.

With the threat of Japanese invasion in everyone's thoughts, the government began to enforce security measures at home. A "brown-out"was introduced, restricting external lighting to essential requirements for traffic only, and people were asked to paint the edges of steps white, to make them safer in the event of a complete black-out. Homes were required to cover their windows with black-out blinds at night-fall. We used sheets of "sisalcraft", attached to wooden dowel rods at top and bottom.

The public were encouraged to dig slit trenches in their back yards, to serve as air-raid shelters. I dug one behind our garage. It was about 2ft wide and 8ft long, and I struck some very heavy boulders which required the help of my next-door neighbour to remove. Our home was built on sandy soil, and although it was near the top of a hill there was a good deal of seepage through the subsoil. When I had dug down to about 3 ft I found that the bottom soon became water-logged after a shower of rain. Melbourne had very heavy rain when I was away in Sydney for one of my frequent trips on radar work. I returned home to find the trench full of water! I gave up. I decided that if we had a raid we would shelter under the kitchen table.

Rationing of many goods was introduced. At fixed intervals everyone was issued with a book of ration coupons. Butter, milk, sugar, tea and many grocery items could be purchased only on surrender of a specified number of coupons. Clothing was rationed similarly. Housewives had to make sure they had enough coupons to see them through to the next issue.

A Home Guard was established, and we had to attend lectures on air-raid precautions and rudimentary first-aid - given at church halls. Fortunately the situation at home never deteriorated to the stage where we had to put these measures into practice.

The Japanese fleet was based in the Carolines, and from August 1942 a fierce battle had been raging between American and Japanese forces for the possession of Guadalcanal in the Solomon Islands. The Japanese, foiled (in their attempt to reach Port Morseby) by the battle of the Coral Sea, had landed troops on the north coast of New Guinea. By September 17th they had advanced to within 32 miles of Port Moresby via the Kokoda trail across the 13,000ft Owen Stanley Ranges, against fierce resistance by an Australian Division in virgin jungle. In his fifth volume of war history, "Closing The Ring", Churchill wrote -

> "the stubborn resistance of the enemy, the physical difficulties of the country, the ravages of disease, and the absence of communications made the campaign as arduous as any in history."

The Kokoda trail campaign was to continue for two weary years.

Professor Marcus Oliphant who graduated in science at Adelaide University in 1923 had played a leading part in the development of radar systems in England from 1938 to 1942, when he offered his services to assist the defence of Australia. He arrived in Melbourne at the end of May and had discussions with the CSIR. He also visited New Zealand. I had the pleasure of meeting him at the University of Melbourne, which conferred on him the Degree of Doctor of Science on October 16th, 1942, shortly before he returned to England to take part in

atomic research. Professor Oliphant was very approachable. I discussed with him the work we had been doing on radar and told him of the idea of using frequency modulation for radar signals, which I had conceived in 1940. He said he would like to have details. Accordingly, I wrote a complete description of my proposed system, with diagrams and calculations. Mr Witt arranged for this to be forwarded to the Professor in London through the CSIR in November. However Professor Oliphant did not reach England until the end of February 1943, and soon became involved in nuclear research.

By mid October 1942, my work on ShD and the analogous Navy radar equipment was complete, and I was asked to attend a discussion at the offices of the Chief Military Adviser in Melbourne with Majors Huey and Blunden. They told me that the Army required the development of a new Searchlight Control Radar system (SLC) for use with a 150cm searchlight currently being designed in Sydney by Electric Control and Engineering Ltd. The radar equipment was to meet certain requirements peculiar to the Pacific area of operations, and the Army desired that its technical development, as well as its production design, should be carried out wholly by the PMG's Department in collaboration with the Army Design Directorate. They wished the project to be undertaken by the same group at the PMG Research Laboratories that had worked on the ShD equipment. It

was an exciting challenge, and I was glad to have the opportunity to participate.

The arrangement was formalised at a meeting on October 24th, with Major General Williams in the chair and representatives of the Army and the Ministry of Munitions. Mr Witt, Ted Stewart and I represented the Laboratories. It was agreed that the Laboratories should undertake the work and that the Lab group concerned should, in effect, function as an annexe of the Army Design Directorate. Three prototype equipments were to be produced by the Laboratories and quantity production of some 300 would then be arranged by the Department of Munitions to drawings produced by the Labs.

Before the advent of radar, searchlights used by the Artillery in the defence against night attacks by enemy aircraft had been controlled by visual means. "Spotters" on the ground, equipped with binoculars, would search the sky for hostile aircraft, whilst searchlight beams swept systematically across the heavens. The spotters had to work some distance from the searchlight, because atmospheric glare in its vicinity made it impossible to spot an aircraft in the beam. Twin sound locators, operating like a stereo sound system in reverse, were used to detect the approach of aircraft and localise the search. When an aircraft was "spotted", the spotter directed the training of the searchlight beam upon it by verbal telephone instructions to the searchlight crew,

who then attempted to follow it and keep it illuminated for fighter aircraft engagement or gunnery.

Such visual control had serious disadvantages. The aircraft had first to come within visual range, and the searchlight beam had to be switched on to enable spotting. Naturally, enemy aircraft would attempt to avoid such beams. Cloud or fog made detection difficult or impossible, and identification of a hostile aircraft was not always accurate.

The function of radar SLC systems was first to detect approaching aircraft in the dark, secondly to train the searchlight on the aircraft and follow it (with the beam still extinguished), thirdly to measure the range of the aircraft so that it could be illuminated as soon as it came within range of the light beam, and finally to identify friendly aircraft fitted with equipment capable of giving a characteristic response to interrogating radar signals. The most effective radar SLC system would be mounted on the searchlight itself, so that the light beam direction when "exposed" would automatically coincide with the direction of the detecting radar beam.

At October 1942 there were three types of radar SLC equipment in use by the Allied Forces -- one American, one English and one Australian. These were not considered

The American equipment was mounted separately from its associated searchlight and required two large trucks for transport, in addition to a power generator. It was not available to Australia, anyway.

The English equipment was mounted on its projector, but required two 3 ton trucks for transport plus trailer for the projector and power generator.

The Australian equipment was merely a duplication of experimental units produced at short notice by the CSIR Radiophysics Laboratory, and mounted on a 90cm projector. At a time when no English systems were available, 54 of these equipments were being produced - but their radar range was inadequate, their design unsuitable for quantity production, and they had to be operated on a raised platform to provide adequate ground clearance for the radar antennae.

The sizes 90cm and 150cm refer to the diameters of the reflectors behind the projector arc lamps.

None of these existing equipments had been designed for tropical conditions or for transport by aircraft. In Australia there was a pressing need for an SLC equipment that could be flownto the islands north of Australia, and operated under tropical conditions - with a performance

The high temperature and humidity experienced in the tropics, especially in jungle country, produced such rapid deterioration in normal electronic components, with fungal growth, that such equipment often had to be discarded as completely unworkable almost as soon as it was unpacked in jungle warfare operations. Australian troops were being trained for jungle warfare, and they needed equipment which they could rely on in tropical service. Manpower was at a premium, so it was desirable to reduce the necessary size of operating crews.

The general specification given to us by the Army required that the new equipment was to be demountable and transportable (together with the associated 150cm projector) on a single 3 ton motor truck or by cargo aircraft. And, compared with the current English and Australian SLC equipments, it was to have -

The same operating frequency (in the VHF band)
Common aerial working (in lieu of separate transmitting and receiving aerials)
Combined meter presentation (in lieu of separate bearing and elevation presentation)
Increased maximum range (preferably twice that of existing equipments)
Reduced minimum range (for tracking low-flying aircraft)
Improved angular discrimination (to match the narrow 150cm light beam)
Improved ease of maintenance
Complete tropic-proof design
Operation by a smaller crew.

The practicability of some of these requirements was to be determined by the developmental work to be carried out. The requirements meant that the units of equipment

would have to differ radically from those in the existing English and Australian systems - which could only be used as a source of reference. We were to be given free access to specimen English and Australian existing units and relevant data. We were required to produce all necessary specifications for the new units when designed, and to collaborate with the Army in test procedures and field trials.

I was given the status of acting Divisional Engineer in charge of the project, directly responsible to Ted Stewart. My staff was to comprise four engineers - Ross Baker and Charlie Rollan on circuit design and testing, Ross Pitkethly and Pere Killey on production design - with an average of ten draftsmen and two girl tracers under the general supervision of Sectional Draftsman Bob Cunningham. Ross and Charlie worked in a separate laboratory with their test equipment, but the rest of us all occupied a very large room on the first floor of the building overlooking Little Collins Street.

During the first few weeks of the project I attended some twenty conferences and meetings with Army and CSIR personnel, and with manufacturers of the existing Australian SLC equipment which was presenting problems in manufacture and in the field - especially in relation to some component parts. The Army provided a 90 cm projector fitted with a set of this equipment, which was installed in the St Kilda Cricket Ground under security

and used for initial testing of the new units produced by Ross Baker and Charlie Rollan. As this development work progressed, approved units were translated into detail-per-sheet manufacturing drawings by Ross Pitkethly, Perc Kelley and the drafting team. We all had to work under considerable pressure, with overtime extending to 10pm on two nights each week. My own work filled most week nights and many weekends.

Army liaison was provided chiefly by Major Dick (R.M.) Huey of the Chief Military Advisers Board, Major Coates of the Engineer in Chiefs Branch and Major Blunden of the Army Inspection Branch. We had discussions on manufacturing problems with Airzone, Radio Corporation and the Gramophone Company - whose Chief Engineer, John Briton, I was destined to deal with again some 15 years later. When the new equipment reached the testing stage I had a great deal of contact with Jock Macgrath of the Army Inspection Branch - a civilian like myself.

As they were progressively completed, the three new prototype systems were assembled in the Model Shop of the Labs under the supervision of Bill McKenzie as production engineer. There were 17 separate electronic and electrical units in each system and many special components had to be developed in collaboration with the manufacturers nominated by the Army for subsequent quantity production - especially in relation to tropic proofing requirements.

Marshall Fordham, one of our senior draftsmen, was sent to Sydney for eight weeks to work with Electric Control and Engineering Ltd on the design of fittings to mount the SLC units and aerials on the new 150cm searchlight projectors. The first of these projectors was delivered to the St Kilda Cricket Ground at the end of May 1943, and by the following October a full set of the new prototype SLC units had been completed and mounted on it - just 12 months after we commenced work on the project. The other two prototype sets were completed in November and December.

Compared with the earlier English and Australian SLC systems we had made some radical changes.

The first was in the aerial array. The earlier systems had one transmitting yagi aerial and four receiving aerials. We used the same four aerials for both transmitting and receiving. This had the effect of narrowing the transmitted radar beam and increasing the effective range, but it necessitated the introduction of a Transmit/Receive switching unit to prevent damage to the Receiver circuit by the powerful transmitter pulses, and to avoid loss of some of the weak pulses received back (after radar reflection) in the transmitter circuit.

The effective range was also improved by the

circuit, using a newly available "grounded-grid" triode tube.

Even with four aerials, the angle of dispersion of the radar beam is wide compared with the light beam of the searchlight. To offset this, SLC systems employ "beam swinging". Two of the aerials are mounted on either side of the projector barrel and the other two respectively vertically above and below. A beam-swinging unit changes the relative phase of the signals fed to (or coming from) these four aerials in rotation, so that the effective direction of the radar beam is swung successively to four different positions angled equally a few degrees from the direction of the searchlight beam. If the received radar signal is the same for each of these beam positions, then the light beam will be pointing directly to the target detected, if turned on. The earlier SLC systems employed beam-swinging for the receiving aerials only. We used it for transmitting as well as receiving. This improved the angular discrimination, but it meant that the beam-swinging unit had to be designed to handle the much greater power of the transmitted pulses.

We introduced a specially designed meter for indicating both bearing and elevation of a detected radar target. The earlier SLC systems had separate indicators (either cathode ray tubes or meters) for bearing and elevation, necessitating two separate operators who had

to sit on seats attached to the projector base and rotate with it as the beam followed a target. The bearing and elevations of the projector barrel was controlled by a third operator from a handwheel at the end of a long horizontal arm. He walked around the projector, holding this handwheel, to control bearing - and turned the handwheel to control elevation. As proposed by the army, we designed an illuminated crossed-needle meter unit, mounted directly above the handwheel. The vertical needle indicated bearing, and the horizontal needle indicated elevation. When the two needles crossed at the centre of the meter face, the radar beam was right on target - and so would the light beam be also, if exposed. This made redundant the separate bearing and elevation operators, saving two personnel and reducing the rotational inertia of the searchlight in bearing. It remained to be determined, by trials, whether this arrangement was operationally acceptable.

At the centre of this crossed-needle meter face, we provided a small circular hole inside which was located a red pea-lamp. Arrangements were made to cause this lamp to glow when a radar target had been selected for following - as a signal for the bearing and elevation operator to concentrate on his movements to centre the crossed needles. At the side of the projector base a seat was provided for a "Signal Selector" operator. He sat there, facing the cathode ray screen of the signal selector unit, with his face pressed against the light-

tight cowl surrounding the screen. On the screen he saw a green horizontal trace, with a hump at the left hand end, produced by the transmitter pulse. Radar targets appeared as "pips" along this line, further to the right with increasing range. His right hand rested on a range adjusting knob. This knob controlled the position of a bright spot on the horizontal trace on his screen, called the "strobe spot". He selected a target for following, by turning this knob to bring the strobe spot on to the pip produced by that target. This caused the red pea lamp to glow at the centre of the crossed needle meter watched by the bearing and elevation operator, who then began to follow by moving to bring the needle's intersection to the centre of his meter, in front of the red lamp.

An illuminated dial attached to the knob shaft was calibrated in thousands of yards to indicate the approximate range of the selected target. This could be read by the lamp attendant standing beside the projector barrel, who could expose the arc lamp when the target came within the effective range of the light beam. With a little bit of luck the target aircraft would then suddenly be illuminated, for the benefit of anti-aircraft artillery or fighter planes.

Ross Baker had succeeded in reducing the duration of the transmitter pulse and making other circuit changes which reduced the minimum effective range of the system

and improved the ability to separate closely adjacent radar signals.

The operating crew also included an engine driver who attended the power generators some distance away, and two spotters who provided auxiliary visual following of targets - with an NCO present as a free agent in charge of the crew. This brought the crew total to seven - two less than for the earlier SLC equipments.

Of course it was necessary first to search for targets by systematically scanning the heavens with the radar beam, turning the projector barrel in bearing and elevation with the light beam extinguished. All operators had telephone headset communication with each other. The signal selector operator watched for the appearance of echo "pips" on his screen and instructed the bearing and elevation operator to stop moving when he was about to select a target for following.

The four yagi aerials were mounted at the front of the projector barrel, lifted a satisfactory distance above ground for radar operation. The beam-swinging unit was behind the barrel and the bearing and elevation indicator unit was mounted above the handwheel at the end of the long horizontal arm. All other radar units were housed in enclosures on the rotatable projector base, which was mounted on "Slingsby" caterpillar type tracks for movement within the site. Screw-levelling jacks were

provided to fix it in the desired position. Radar power was provided by a small transportable petrol-electric set made by Kelly and Lewis in a weathered enclosure to our design.

All radar units were designed for easy maintenance access and economy in space was achieved by an "upright piano" form of chassis, with all connecting cables entering the "keyboard" section vertically.

At a conference in November 1943 the Army tentatively proposed February 14th, 1944, as the date for a decision to be made on quantity production. In the meantime field trials had to be carried out in Melbourne to evaluate the performance of the new equipment in relation to that of the earlier SLC systems. The question of adequate tropic proofing had to be examined also.

The Army chose the Williamstown Recreation Reserve as the site for comparison tests between the SLC systems. This site was open, roomy and very free of unwanted echoes, or "clutter", produced by surrounding buildings or topographical features. They set up an English 150cm projector with its radar system and an Australian 90cm projector with the earlier SLC system at this site and the first new prototype system with the associated Australian 150cm projector was moved there from St Kilda in November, 1943. The Army provided a searchlight

detachment of 14 men, already familiar with the operation of the earlier equipments. They trained for a month with the new equipment and were ready to make comparison tests at the end of December.

The RAAF personnel at Laverton agreed to make an aircraft available for the tests at night in suitable weather, when free of other commitments. The searchlight detachment used standby time to practice operation and study maintenance of the new equipment. When the weather looked promising for a test I drove a departmental car home after work, and if I received a call from the RAAF about dusk I drove forthwith the 14 miles to Williamstown to take part in the test and observations.

Ten night flight tests were made between the end of December and the end of February. The aircraft used were Beaufort bombers, Kittyhawk fighters and Anson trainers, flying at 200-250mph at altitudes of 10,000 to 20,000 ft over land and sea courses up to 18 miles from the test site. The three projectors were set up about 40 yards apart and each was tested in turn as the aircraft flew over the same course three times. The operating crew moved to the next projector at the end of each circuit of the course. Readings of bearing, elevation and range were taken at one minute intervals, and the light beams were exposed and doused at intervals.

Comparison tests were made of minimum effective range using a crossed dipole target suspended from a hydrogen-filled balloon, and angular discrimination comparisons were made using a fixed echo at the test site.

The tests all showed that our new SLC equipment was operationally superior in all respects to the two earlier systems. Its effective range was at least twice that of the other systems, and the range at which its projector could illuminate a target under radar control was also twice that of the other systems. Radar following was reliable to 30,000 yards range, even to 40,000 yards under favourable conditions, and following down to 1000 yards was possible. It was found that the bearing and elevation control of the projector by the one operator, using his crossed-needle indicator unit, was quite practicable.

The efficiency of target illumination when the light beam was exposed was about the same with the new equipment as with the English equipment, but to a much greater range and at much closer quarters. It was far more efficient than the earlier Australian equipment. In general, the new equipment was far more efficient in searching for undetected targets and the laying mobility of its projector was far greater than the others.

The second and third 150cm Australian projectors were delivered to the St Kilda Cricket Ground in July and August, 1943, and fitted with the new SLC equipment. The second projector with its full complement of radar equipment was subjected to high temperature and humidity tests in December in a large chamber at the Maribyrnong Munitions establishment. Tests of insulation resistence were made on all units after preliminary heating to 70oC for six hours, then repeated after two humidity cycles at 100% relative humidity. Jock Macgrath and I had to strip down to shorts and sandshoes and make our tests and examinations as quickly as possible before the chamber was sealed again for the next cycle. This was repeated three times over a fortnight. It was very enervating, and we were glad when it was over.

As a result of those tests, detailed modifications were made to a wide range of components in conjunction with manufacturers. I had to design special moisture-proof seals for fixed condensers and many types of glands and seals to protect equipment. Additional ventilation was provided in some enclosures. The third prototype equipment, so modified, and its projector was then subjected to high temperature and humidity tests at Maribyrnong in May 1944 with satisfactory results.

The first two prototypes were given temperature-rise clearance on continuous operation and then handed over to

the Army in May for "user trials" at Georges Heights, Sydney - 18 months after the project had begun.

Our tests had shown that all the initial requirements specified by the Army had been met, but there was not yet any decision about commencement of quantity production. About ten months after the commencement of the project, the Army had asked us to develop and design a number of additional features in the equipment. These included -

Provision for operating an English IFF unit with the system
Modification to improve performance in the presence of "Window"
Design of a test oscillator for alignment of the aerials
Design of a site-tester
Design of a trainer unit

The IFF ("Identification - Friend or Foe") equipment was designed to send an interrogating signal to the target aircraft. If the aircraft was fitted with an appropriate responder, it would send back a coded signal which would provide positive identification on the SLC radar screen.

"Window" was a device employed both by the allies and by the enemy at this stage in the war, to confuse radar systems. Dropped from aircraft, it consisted of large quantities of metal foil strips which fluttered slowly down through the air producing a multitude of false echoes on radar screens in the vicinity - masking the echo of the target aircraft. A partial counter to

this lay in the reduction of transmitted radar pulse width.

The test oscillator was to be mounted on a high pole, to facilitate alignment of the SLC aerials when trained on it.

The site-tester was to be a small portable outfit, incorporating some of the earlier SC radar units, which could be used for examining the suitability of prospective searchlight sites before actually taking the projector and new equipment there for defensive operations. Some sites which appeared satisfactory on first inspection might prove to be unsuitable because of "clutter" echoes.

The trainer unit was to be a small portable device, fitted with a hand-operated joystick, which could be connected by cable to the bearing and elevation indicator unit on the projector. Operation of this joystick would produce artificial "target" indications, so that it could be used to control the reactions of the bearing and elevation operator and train him, in following the crossed-needle indications.

An experimental English IFF unit was received in June 1943, and we developed the necessary circuit modifications and mounting facilities for its use with

transmit/receive yagi aerial, which we mounted on a folding tubular attachment above the projector barrel. This was added to the third prototype system in December 1943, and moved to Williamstown in February where it gave satisfactory results in tests with aircraft equipped with responders. A production IFF unit from England received later gave satisfactory flight test results in August.

After some modification to improve performance in the presence of "Window", the third prototype SLC system with its projector and IFF addition was handed over to the Army for packing and dispatch to the tropics for field trials. We had finished the development, production and testing of the three prototype systems and were very happy with the results.

June 1944 was an eventful month in the war. On the sixth day, British and American air and sea forces made a surprise assault on German occupied Normandy with a landing across the Channel on the Normandy coast which Churchill described as "the greatest amphibious operation in history". Thus began the Allied invasion of Europe - "D-day".

On June 22nd British troops in Burma linked up with Indian forces, and Admiral Mountbatten reported "The Japanese bid for India was virtually over, and ahead lay the prospect of the first major British victory in Burma".

American landings on the north coast of New Guinea in January and April had overcome Japanese bases and, as Churchill wrote in "Closing the Ring", - "the island was effectively in American possession before the end of June 1944. This marked the end of the two year struggle in New Guinea".

The situation had changed dramatically in three theatres of war.

On June 26th, 1944 - four months later than the date proposed at the previous November - the new SLC equipment was approved by the Army as "satisfactory for production". It had been given the official designation of "AA No.2 Mk.VI(Aust)" and advance prints of all our production drawings were supplied to the several contractors selected by the Ministry of Munitions for quantity manufacture, to enable tooling-up to commence.

However, there was a hiatus. The expected instruction for commencement of quantity production was not forthcoming. In September 1944 we were at last advised that the Army considerd the war in the Pacific had changed from a defensive stage to one of offence. Searchlights were essentially defensive devices. In view of this, and of the limited rate of quantity production possible in Australia, the Army had decided not to proceed with the full production programme.

Nevertheless, they desired to proceed with field trials of the prototypes as it was considered that the results obtained would be of value in the design of future Army equipment.

This was a sad blow to my design and development team who had worked so hard and with such dedication and success for nearly two years on this project. However - if the war was being won, that was all that really mattered. The project had been a wonderful experience for everyone concerned.

The Army required all drawings and specifications to be brought up to date with modifications introduced during the equipment tests. These were to be checked and handed over to the Chief Superintendent of Design, Department of Army, for sealing. This occupied most of the Lab team from July to October. We had prepared in the Laboratories -

Over 2000 sheets of drawing
17 detailed specifications
29 relevant Laboratory Reports
10 adjustment data and testing instruction bulletins
Draft operating instructions, searchlight crew drill and line-up procedure.

We still had to complete the design of a prototype site-tester. This was given field tests in December and handed over to the Army in January 1945 with relevant production drawings.

Throughout this radar project there had been a wonderful spirit of cooperation and good fellowship among all the staff concerned, and excellent liaison with the Army. We were like one big happy family. The draftsmen were the prime movers in many after-hours social activities. They arranged concerts, socials and art-shows in aid of the Red Cross - always well attended and thoroughly enjoyable. They played football matches against other departmental teams at the attractive Greensborough Recreation Ground, with apparently no limit to the number of players fielded. They started an in-house topical magazine called "WURLITZER (TO PROMOTE HARMONY)", edited by Marshall Fordham and Bill Waterworth - both blessed with an incurable sense of humour.

I was glad to contribute occasionally to their magazine. One of my contributions in praise of the drafting fraternity concluded -

> "Hail to you draftsmen, more power to your humerus
> Toiling past ten without thought of reward -
> Victory be yours, when your footballers numerous
> Carelessly frolic on Greensborough sward!"

Our daughter Chris was not forgotten. At the age of nearly three, we took her to a staff social at the Victoria Palace to celebrate Christmas, 1944. Toys made by the draftsmen were distributed to the offspring of all present. Chris received a delightful miniature kitchen dresser, made by Hugh McColl. Earlier she had received a teddy bear, unobtainable in war-time Melbourne, brought from Sydney by Major Dick Huey.

One of their concerts was held at the Postal Institute in Spencer Street, in aid of the Red Cross. They had their usual burlesque male ballets and some humorous sketches. I was billed as "Mandrake, and his blacker than black magic". This was the first time I had given a conjuring performance before a large public audience. I had constructed some new equipment, and one of the girl tracers acted as my assistant, providing an element of glamour. That was my last appearance as an amateur conjurer. Fortunately, all the tricks worked.

We started a music club, with weekly lunchtime recitals of recorded classical music, provided from the record collections of the several members, and I managed to attend the occasional symphony concert at the Melbourne Town Hall. All these activities served to preserve our sanity in a time of great pressure with no certain goal at the end of the tunnel.

Field trials of the third prototype SLC equipment had originally been proposed at Port Moresby, but in view of the changed war situation they were scheduled for February-March, 1945, at Darwin - during the "wet season", to test the tropic proofing measures we had taken.

I was required to participate as representative of the PMG's Department. The equipment and its projector was crated and sent to Darwin by sea

I flew to Adelaide with Phyll and Chris by commercial airline on January 29th. They were to stay with Phyll's parents at Glenunga. I spent the evening with my parents and Marjorie, and took off from Parafield airport next morning with Lieut. Keith Chick of the Army Inspection Directorate in a RAAF DC3 - an aircraft stripped for troop carrying with hard aluminium benches on each side of the fuselage which left black marks on the seat of your pants. I had been issued with the regulation khaki private's uniform, without rank, because I was entering a military area. Leaving at 4.30am we reached Darwin at 5.30pm, after touching down at Oodnadatta, Alice Springs and Gorrie. Flying over the "dead centre" we saw red yellow sand dunes dotted sparsely with saltbush, with shallow rivers curving repeatedly back on themselves as they struggled across the flat terrain to dried salt lakes. Light green patches became vivid green as we neared Darwin - the green of the Kunai grass that grows higher than a man in a few weeks of "the wet".

After tea at the officers mess of the 65th Australian Mobile Searchlight Battery, I slept under mosquito netting in a tent, and paid my respects to Major

Gus Larsson at HQ in the morning before a conference to discuss the programme of SLC trials.

Nothing much happened in the first week of February. Heavy rain flooded my tent one night and glow worms on the floor winked in the dark. I gave a talk on the equipment and met Lieut. Colin Lelean who arrived on the Montoro with the crates of equipment. He was to take charge of a searchlight detachment throughout the trials.

The 19 crates were unloaded on February 8th and opened next day on the Battery HQ parade ground. We had just removed the projector from the largest crate when torrential rain began. With Col. Lelean and Keith Chick I took shelter in the crate. I was intrigued to see a fellow walk stark naked through the rain carrying a coffee mug across the parade ground. It was probably preferable to having his uniform saturated. When it rains at Darwin it is like a tank being emptied, but it doesn't last long.

We assembled the SLC equipment on the projector that night. It worked well. Next day we carried out the necessary mechanical line-up, and on Sunday we went to "Music on the Lawn". There was no lawn, but the recorded music was good - the Tchaikovsky 6th Symphony which never fails to move me. The tropical darkness and remoteness of the place seemed to accentuate the heart-rending quality of that last movement.

On Wednesday 14th we loaded the projector and all equipment on a single 3 ton truck, drove to East Point and had everything ready for testing by 9.45am. We stayed there four days - jungle country at sea level. Tall trees with a thick undergrowth of creeper near a swampy coast fringed with mangrove trees. Then across the harbour by barge to two other sites - one in open scrub with 4ft Kunai grass and the other on a 50ft bluff projecting into the sea. After eight days at each we returned by barge to another site in open scrub. Some of the tracks between sites were exceedingly rough through the jungle.

The equipment operated well at each site. I took temperature and humidity readings at two-hourly intervals with a whirling psychrometer. Minimum shade temperatures were about 24o to 27oC near 2am, with relative humidities of 95 to 100%. Maximum temperatures were round 27o to 32oC near 2pm, with relative humidities of 80 to 90%. The lowest humidity encountered was 68% at 32oC. Darwin's latitude is 12.6o south, almost as tropical as Port Moresby.

Under these conditions there was a strong temptation to wear nothing but khaki shorts, and I suffered badly from sunburn blisters on my back, requiring medical attention. It was easy to understand how some fellows become "troppo", as they called it. I sometimes found

myself looking for my towel when I had it wrapped around my midriff, and looking for my pipe when it was already in my mouth!

I shared a tent with Col and Keith. Morning showers were from a 4 gallon petrol tin mounted on a wooden overhead support. You climbed a ladder to fill this with water from a bucket, then stood underneath and turned on a tap at the bottom. The water ran into a suspended jam tin with a perforated base, which gave a reasonable shower spray, but you had to soap yourself first - or the water would run out before you were fully rinsed.

Latrines comprised a steel pipe driven into the ground, surmounted by a large funnel. Wooden toilet seats were provided in pairs, and each was burned out on alternate days. You had to be careful to avoid the hot seat!

Meals were served in aluminium mess tins. You washed your own utensils and clothes. At one site on the coast the detachment had constructed a fish trap. A long fence of steel mesh extended out into the sea, terminated by a box-like mesh enclosure with J shaped guards on either side of the opening - in plan rather like the spade symbol in a pack of cards. Fish encountering the fence barrier swam out to sea and entered the box, from which they could not escape because the J guards

troops cleared the enclosure, which had a lidded top. It was always a mixed bag, but the fish was delicious and a welcome change from bully beef.

When near Darwin, we sometimes went to an open-air cinema show at night. Often it began to pour with rain, but sitting on a form in a ground-sheet you ignored this. Hollywood pictures made you forget your surroundings, but at the end of a reel you came down to earth with a thud and realised you had rain running down your back. But it was warm rain, and bearable.

Insects were a problem. Ants repeatedly made nests in my kitbag, and sandflies were voracious. One night I saw a pink egg-shaped object with legs, scuttling under my camp stretcher. It was a hermit crab, looking for a new haven to replace the one it had outgrown. At night there was always a pattern of blinking fireflies on your pillow.

The troops regarded me as an anomaly. Never before had they encountered anyone who could depart on an errand on top of a truck full of equipment and return in a staff car!

We had some minor troubles with the equipment and a good deal of moisture condensation, necessitating frequent replacement of silica gel capsules in

results in tracking aircraft. One day a Japanese reconnaissance plane was sighted over the area, but there was no sign of other enemy aircraft. The Army continued the trials after my departure in March.

With Keith Chick I left Darwin by a Guinea Airways DC3 on the morning of March 9th. Touching down at Borrie and Tennant's Creek, we stopped for lunch at Alice Springs. Steak was on the menu - the nearest I had come to a good grill for six weeks. I ordered one, but the last was given to a fellow sitting next to me. He had two mouthfuls and pushed it aside - suffering from heat exposure!

We landed again at Oodnadatta and reached Parafield at 9.15pm. I arrived unexpectedly at my family's home by tram, but not too late to go round to the Williams and see Phyll and our darling Chris. It was like returning from another world!

The "Report on Trials with Projector AA 150cm (Aust) Mk1 with Radar AA No.2 MkVI (Aust) Feb-May 1945", issued by HQ Darwin Fixed Defences stated -

> "While the Radar pick-up range has varied with height and type of the aircraft engaged, results have consistently been greatly superior to those of the English equipments."
>
> and
>
> "The crossed needle system of presentation simplifies control of the projector and ensures co-ordination of bearing and elevation. Trained

operators react very rapidly and appear to follow the needle instinctively."

and

"The stability of the radar components under adverse conditions was of a very high order."

and

"While performance of the equipment appeared to be unaffected by prolonged exposure to heavy tropical rains and humidity, some condensation of moisture occurred on the inside surface of the Bearing and Elevation Indicator Unit."

and

"Reasonable expectations may be held that successful engagements of aircraft can be achieved at long range with this equipment."

The equipment had fulfilled all requirements, which was a feather in the cap of the Research Laboratory team responsible for its design and development. The Army's confidence in the Laboratories had been justified. It was a pity that it was not practicable to apply the prototype equipment experience to quantity production for the advancement of the war effort.

The war began to move swiftly to its close - more swiftly than anyone expected.

On April 26th 1945, Mussolini, Hitler's ally in Italy, was shot by Partisans and German troops and Italy surrendered unconditionally three days later. Next day, with Russian forces surrounding Berlin, Hitler committed suicide. Germany capitulated on May 8th. The struggle in Burma ended with the recapture of Rangoon on May 2nd

26th the US forces at last captured Okinawa, south of the Japanese homeland.

The first atomic bomb was successfully detonated secretly in the Mexican desert on July 17th. Churchill wrote "Devastation inside a one-mile circle was absolute. Here then was a speedy end to the Second World War, and perhaps to much else besides."

On July 26th an ultimatum from the Government of USA, China and Great Britain was published, calling for the unconditional surrender of the armed forces of Japan. It was rejected by the military rulers of that country. Then, following warning leaflets dropped by US aircraft the day before, ten Japanese cities were bombed on July 27th and August 1st.

The last warning was given on August 5th.

Two atomic bombs were then dropped, at the direction of President Truman -

on Hiroshima on August 6th and
on Nagasaki on August 9th, 1945

The war was over. The formal surrender was signed on board the US Battleship Missouri in Tokyo Bay on September 2nd, 1945.

John Curtin, suffering the strain of wartime, died

Frank Ford acted as Australian Prime Minister until Ben Chifley (Federal Treasurer) was elected to the job on July 13th.

Churchill's National Coalition Government lost office at the British elections on July 26th - the day of the joint ultimatum to Japan. Clement Attlee became Prime Minister with a Socialist government.

The war had taken its toll in the ranks of the men who had shouldered the grim task of guiding our countries through these dreadful times.