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AN ACCOUNT

OF

THE DEVELOPMENT AND USE

OF

R A D A R

IN THE

ROYAL AUSTRALIAN AIR FORCE

BY

WING COMMANDER A.G. PITHER

RAAF HQ
MELBOURNE
DECEMBER 1946

RESTRICTED

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AN ACCOUNT OF THE DEVELOPMENT AND USE OF RADAR IN THE RAAF

INTRODUCTION

THE ORIGIN OF RADAR

Radar, which is the technique of locating distant objects by means of radio waves reflected from them, grew from phenomena known to science as early as 1920. About that time physicists had discovered that objects such as ships moving between a short wave transmitter and receiver could cause interruption of signals. This phenomenon was put to practical use about 1930 when high frequency radio waves projected vertically were used to measure the height of the various ionised layers of the atmosphere, the reflected energy being made to produce a record on a moving film. Work on ionospheric measurements was undertaken in all the main countries of the world including England, America, Japan and Australia, and it was during experiments in this technique that a British scientist, Mr Robert Watson-Watt, discovered that reflections could also be obtained from aeroplanes flying overhead. This discovery appears to have been made in other countries about the same time. As the prospect of war with Germany increased it became obvious that this technique could have great possibilities in the defence of England against air raids, in a situation where no known system offered adequate defence, and the British Department of Scientific and Industrial Research, by whom Watson-Watt was employed, established him at an experimental station at Bawdsey on the east coast of England for the special purpose of developing the new technique. For the sake of security it was labelled "RDF" and later became known to the public as "radio location".

By the beginning of 1939, the British had succeeded in constructing several high powered stations to form a chain on the east coast of England and they had also done experimental work on GL, AI, ASV and IFF. The other nations, having no similar defence problem, had made only elementary progress.

AUSTRALIAN INCEPTION

In February 1939, a cable was received by the Australian Government from the UK asking that a physicist be sent to England to be instructed in a new and important technique. Dr D.F. Martyn who had been working with CSIR on ionospheric measurements left for England in April and returned in August with details of RDF. At a meeting with Cabinet Ministers, the Prime Minister appointed Dr Martyn and Professor Madsen of Sydney University to undertake work on RDF in Australia and a grant of £67,000 was made to commence with. (An outline of the early history is given in files 201/14/45 Enclosure 24B, and 201/14/46 Enclosure 12B). The Standards Laboratory of the CSIR had just completed a building in Sydney University and Dr Martyn was set up in this building to establish the Radiophysics Laboratory.

RADIO PHYSICS ADVISORY BOARD

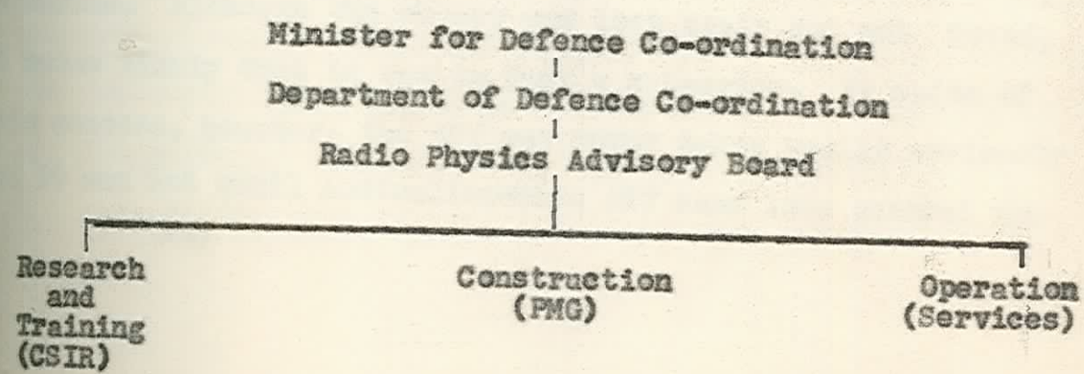
As the new work had vital defence implications it was essential that close co-ordination be maintained between the scientists and the services. After several initial meetings with the services a Radio Physics Advisory Board was approved by the Minister for Defence with the following membership:

Professor J.P.V. Madsen - Chairman
The Director General, PMG's Department
CNS (File 201/14/46 Enclosure
CGS 3A)
CAS
Sir David Rivett, Chief Executive Officer of CSIR

At its first meeting on the 1st September 1939, (File 201/14/46 Enclosure 4B), the Board was informed that Dr Martyn had on order from overseas certain British RDF equipment, and it was agreed that CSIR and PMG's Department would co-operate with the services in the selection and installation of new equipment. Thus on the eve of the outbreak of war, Australia had established the nucleus of an RDF organisation which was to grow to a size not then visualised by any of the men who started it.

With the outbreak of war, it was decided that closer contact should be made with the UK and Professor Madsen was sent to England to make more detailed arrangements. He returned in March 1940, and at the second meeting of the Radio Physics Advisory Board gave an account of his trip (File 201/14/46 Enclosure 11B). He stated that he had found an impression that Australia was interested merely in the production of equipment and not in research. As a result of discussions with Sir Phillip Joubert, Sir Henry Tizard and Mr Watson-Watt, a memorandum had been drawn up setting out the arrangements for RDF work including Research in Australia and New Zealand. It was agreed that the RP Lab. should act as a sub-centre to the main work in Great Britain and that the British would provide samples of equipment, stocks of components and detailed drawings of equipment. Arrangements were also made for liaison.

At its third meeting on the 16th May 1940, (Encl 12B) a formula was arrived at for the production and operation of RDF equipment as follows:-



Finance was to be arranged through the Department of Defence Co-ordination.

This arrangement was arrived at owing to difficulties over finance which arose because of the large number of Departments involved. The Prime Minister, who was also Minister for Defence Co-ordination, agreed to the arrangement but stated that he could not handle the matter personally and appointed Mr Shedden as his representative.

AUSTRALIAN REQUIREMENTS

The work undertaken by the new organisation was dictated by defence requirements. Japan had not then entered the war and the Government appreciation considered that Australia was not open to the threat of invasion and that we need only prepare for sporadic raids. Priorities were therefore allotted in the following order:-

Coast Defence
Sea Search
Anti-aircraft Gunnery (GL/SLC)

Air Force interests in RDF were therefore limited.

AUSTRALIA COMMENCES WORK

ASV

The RP Laboratory had already been equipped with whatever RDF equipment was available from overseas and work was put in hand to provide Australian equivalents in the priority set out above. High priority was given to coast defence equipment, later known as SHD (shore defence) and at the same time it was decided to produce an Australian ASV equipment which would be an improvement on the British Mark I ASV already held by RP Laboratory. In July 1940, the Army ordered 6 CD sets (SHD) and 28 AA sets. The decision as to numbers of ASV sets required for the Air Force was held in obeyance as the CAS was not satisfied with the performances quoted by RP Laboratory. Finally the CAS asked RP to fit the 4 English ASV sets to 4 Hudsons at Richmond. This was done in August and from then onwards the Hudsons with ASV were flown from Richmond.

The ASV was regarded as a curiosity, and no systematic use appears to have been made of it; nor was this possible with the scratch arrangements made to maintain it. In fact, at a later date it was discovered to have become completely unserviceable due to neglect on the part of the Air Force and Radiophysics. It is interesting, however, that on at least one occasion some real use was made of it as on the night of the 23rd December 1940, when a submarine scare arose in Sydney, the Hudson carrying a Radiophysics Laboratory observer located by ASV off Wollongong an object which was claimed to be a submarine. Although the object was lost again and not found, it seems likely that it was in fact a submarine. In spite of this success, however, the ASV was never taken really seriously and it was not until Australian-made ASV came into general use

18 months later that the RAAF could be said to be using ASV.

THE SEARCH FOR PERSONNEL

At an early stage it became obvious that if the programme were to be put into effect trained service personnel would be necessary. At its meeting on the 13th March 1940, the Radio Physics Board decided that service officers should be sent overseas for training, but very little appears to have been done about this until September, when a signal was received from the British Government asking that 2 signal officers from each Service be sent to England for training in RDF in order to obviate the necessity of the UK sending experienced RDF personnel overseas at a later date. The Army had an officer already in England (Major Gilchrist) who was detailed for this training and from the RAAF I was sent, leaving Australia in September. I was able to see all phases of RAF Army and Navy RDF activities in the UK and in addition attended a 2 months RDF course at the RDF School.

I returned to Australia via Canada and USA and was given the opportunity to study the RDF developments in both countries. It appeared that the Americans had discovered the application of the technique to warfare at about the same time as the British. However, as there was no direct threat to America, no special priority was given to development, with the result that when American and British information was pooled in 1940, it was discovered that the Americans had several rudimentary developments in RDF but had nothing to compare with that developed by the British. I returned to Australia in May 1941, and took over the Directorate of Signals, Section S7, then in the hands of Flight Lieutenant J.T. Phillips. From then on S7 looked after all RDF matters in the RAAF and was finally formed into a Directorate in April 1942.

SINGAPORE

In my discussions with the Air Ministry I had made several tenative arrangements concerning future developments in the Pacific. The Air Ministry intended to fit GR squadrons in Singapore with ASV and it was arranged that if possible Australian mechanics should go to Singapore and assist in the fitting and that I should supervise the work as this would provide excellent experience for Australian personnel and at the same time help the RAF. In June 1941 I visited Singapore with the object of assessing the problems of fitting ASV and examining the Air Warning Organisation. As no ASV had then arrived, attention was concentrated on the Air Warning Organisation which proved to be making a good start, although the filter and operations rooms were elementary in the extreme. As a result of this visit a close liaison was built up. It was later possible to lend much assistance as the situation grew worse, and a number of trained officers and mechanics were sent before the Japanese arrived. In the end, most of the effort put into radar in Singapore was written off as a loss.

RADAR SCHOOL

With the approaching advent of ASV equipment it was decided to form an RAAF RDF school, and in July 1941, two officers and four aircraftmen were sent to Radio Physics Laboratory for an initial course on RDF. These personnel, under Flight Lieutenant M.A. Brown, established the radar school at Richmond, the first course commencing on 4th August 1941. During my stay in England I had arranged with the RAF that the RAAF would undertake, if possible, the training of ground mechanics for them in compliance with the British request for Dominion personnel. I felt that this would ensure that a nucleus of ground personnel would be available in Australia if an emergency arose. The RAF agreed to send an officer, 4

mechanics and one CHL equipment to Australia to get this training under way. Squadron Leader A.E. Mitchell and 4 mechanics with their equipment arrived in Australia in September 1941 and joined the RDF School in October. The school thus got away to a flying start with training in ASV and ground RDF. This training in ground RDF which was originally planned for the RAF eventually became the saving of the RAAF when a ground radar programme was started.

UNIVERSITY TRAINING SCHEME

The problem of securing adequate numbers of suitably qualified personnel arose in the earliest days of RDF. In England a call was made on the country's already well established television system and this and the PMG's Department provided a vital nucleus which allowed RDF a good start. It soon became obvious, however, that vast numbers of personnel would be required and the problem was handed to a committee headed by Lord Hankey. This committee made special arrangements with all the British Universities and technical training centres which included the rapid termination of training courses already under way and the institution of special short syllabi designed to produce men suitably qualified to man the RDF organisation. Very soon these arrangements resulted in the depletion of suitable British manpower supplies, and early in 1941 the decision was made to call for assistance from the British Empire and in addition from the USA.

During my stay in England, I had several discussions on this problem and in a signal to Air Board in January 1941 (File 201/14/10 - Enclosure 10A) I advised of the British scheme to secure 8,000 personnel from the USA.

Australia was to be asked to help in this programme and it was finally agreed that 2,000 personnel could be enlisted

and trained for the RAF. About May 1941, Radio Physics Advisory Board discussed methods of organising a similar arrangement to the Hankey scheme in Australian Universities. These discussions culminated on 3/4 July in the calling of a conference in Melbourne of the Professors of Physics from all Australian Universities. At this conference the Chiefs of the Services outlined their requirements, after which Sir David Rivett outlined a short history of RDF and the aims of the conference. After two days discussion it was agreed that the universities would co-operate in any way possible and particularly that they would grant concessions to their first and second year engineering students who undertook RDF training. They were to be credited with completion of the year, after a period of successful service with radar. The onus was then thrown on the Services to make use of these arrangements. The Navy at this stage stated that it had no requirements for RDF personnel and the Army and Air Force agreed to use Adelaide and Sydney Universities respectively, giving undergraduates a special six months course. These arrangements were not finalised until August, and it was necessary to start the first training course on the 15th September which was the commencement of the next university term.

In the intervening period I visited Sydney, Melbourne and Brisbane Universities, addressed the students, and collected names of those wishing to participate in the scheme. Special arrangements were made for enlisting, a new mustering was established, and students were enlisted and commenced training on the 15th September. Although capacity for 100 men was originally planned, only 50 started the course owing to the difficulty in securing adequate numbers. No action whatever was taken by the Army and no use was ever made of Adelaide.

The course was under the direction of Professor V.A. Bailey of Sydney University. By the time it commenced War Cabinet had decided that only 200 personnel could be sent overseas and at this time it looked as if the special arrangements which had been made to train large numbers of men would be wasted. Much discussion took place around this War Cabinet decision which eventually proved to have been unnecessary as with the entry of Japan into the war, no RDF personnel were allowed to be sent overseas.

The first university course was completed in February 1942, and after some hesitation during which facilities of the university were offered to Radiophysics Laboratory for disposal, a second course was finally started in March 1942 followed by a third and fourth in August and September by which time the Army had decided that it needed many more personnel than it had originally foreseen, and was given the facilities for its own training.

THE ASV PROGRAMME CHANGES

On my return from overseas I found that the ASV set designed by Radiophysics Laboratory was based on the British ASV Mark I and was intended to be an improvement on it. In spite of this it used a 3" Cathode Ray Tube and had a very limited range. Radiophysics thought up to this time that British Mark II was purely a more finished version of Mark I, whereas in fact, it was a great improvement and Mark I was already going out of use. The Australian design was therefore obsolete before it started; further, the British had developed an ASV beacon which had enabled ASV fitted aircraft to home on it from ranges up to 100 miles. The Australian ASV would be unable to use this facility.

As the Australian set was stated to be nearing production it was decided to allow it to proceed and have Radiophysics design an improved model at a later stage. As time went on and the set did not appear, more difficulties arose; material was becoming scarce and one thing after another led to delays. All the time it was becoming more obvious that the Australian design was quite unsuitable and finally Professor White decided to change the indicator design to that used in the British Mark II (File 201/14/45 - Enclosure 25D). Service dissatisfaction with the Radiophysics Laboratory had been steadily increasing and shortly after this it was decided to remove the ASV project in its entirety from Radiophysics Laboratory and hand it over to PMG Department who would set about copying the British Mark II, a model of which was by this time available. The RAAF thus lost most of its interest in the RP Laboratory - at least for the time being, the only remaining project with RP being an ASV beacon.

GROUND RADAR

From the beginning the sole Australian interest in ground radar had belonged to the Army. Radiophysics Laboratory had imported individual British ground radar equipments, including one station type MB and 2 type CHL, and discussion had taken place from time to time as to the best use for these equipments. The CAS had asked that the MB be installed at Darwin but no action had been taken and in fact up to the end of 1941 the Army SHD programme was the sole Australian contribution to ground radar. The matter received some consideration at the 14th meeting of the Radiophysics Advisory Board on 29th August 1941 but as the Government appreciation still provided only for defence against sporadic raids, no definite action was possible

although some consideration was given to the production of a long range warning set by Radiophysics who were eventually asked to produce two of these sets.

It is of interest to notice that at this stage no policy existed as to whether Army or Air Force should man the organisation and as the Army operated the anti-aircraft defences, it looked as if the Army should operate the long range warning system. The only thing against this was the British precedent in which the RAF operated the warning system. It was not until October 1941 that the matter was given serious consideration and at this time War Cabinet in Agendum 421 decided that a long range warning system was necessary and a joint services committee was appointed to consider the matter and make recommendations. This committee, on which the DCAS was the Air Force representative, recommended the installation of warning stations at 32 places around the Australian and New Guinea coast (File 201/28/22, Enclosure 4A) and also recommended that the RAAF should man all warning stations.

These recommendations were accepted in Defence Committee minute 159/41 on 7 Nov 41 (Encl. 22B) and thus, on the eve of the outbreak of war with Japan, the RAAF was presented with a colossal RDF program. It was with this authority that the first trip for site selection was made by me in the Sydney area in November. The sites selected were Tomaree near Newcastle, Bombi near Gosford, and Kiama. The war with Japan broke out on 7th December and this may be said to mean the real commencement of radar activity in Australia.

The RAAF was faced with the necessity of providing 64 early warning stations (two to each site) and six GCI stations, together with the necessary personnel to man them (as yet not even enlisted) as well as the provision, fitment, and operation of some 325 ASV sets, the first of which had

just reached the prototype stage in the PMG laboratories. The organisation, which required above all, manpower to operate it, had a total of two staff officers and a school comprising two officers and eight NCO instructors with a total of approximately 20 mechanics in training and 50 potential officers in the university course at Sydney. In addition, arrangements were in hand to train mechanics at Melbourne Technical School at the rate of 25 per month. These mechanics and the Sydney University officers were to receive a further two months' training at Radar School before being employed on radar.

THE WAR WITH JAPAN

The Commencement of the Air Warning Project

On the outbreak of war with Japan the RAAF Radar programme changed from providing security patrols to an all-out effort in the defence of Australia. The ASV programme was already proceeding slowly but owing to shortages and manufacturing difficulties it could not be speeded up. For the air warning programme, staggering in its size, there was no equipment available nor any prospect of securing equipment from overseas within a reasonable time. Urgent action was taken by the Government and in January 1942 the Prime Minister, on advice from the Air Staff, cabled the UK Government asking for the immediate supply of radar equipment to meet the requirements of the Defence Committee Agendum. This equipment included 32 CHL 6 GCI and 54 AI.

It should be noted that this action was completely outside the normal RAAF supply arrangements and was the forerunner of much similar action which succeeded in most cases in securing quick results but which was the cause of administrative and accounting troubles for years afterwards. It was first examined and deferred in August 1942 (file 201/28/22 Enclosure 49B) when in Air Board Agendum 4117 approval was sought for the allotment of £1,367,000 to cover expenditure already committed (one million pounds had already been allotted and spent).

While this was going on, Radiophysics Laboratory, mindful of its duty to provide two early warning stations, got busy in an attempt to produce an improvised equipment. Working with the original Army SHD transmitter and receiver Dr Piddington was successful in a few days in producing a

radar set which was to become famous throughout the South West Pacific. In December 1941 Professor White wrote to CAS informing him that the Radiophysics Laboratory had been successful with a "lash up" radar which might be of use for early warning. Tests had been made at Bondi and it showed promise. It was agreed that three of these equipments should be made at high speed and after further tests it was decided that they should be installed at Kiama, Darwin and Rabaul in that order. The first equipment was actually installed at Kiama in January and while this was under way I visited Darwin to select a suitable site there, Dripstone eventually being chosen.

Arrangements had been made to fly the radar station to Darwin, the station to comprise an SHD serial system and the new AW radar. This move commenced on the 5th February, the personnel, P/O's Hannam Glassop and Hull being taken almost straight from radar school for the purpose. The move was completed in February but the station was still being erected when the first air raid was made on Darwin on 19th February.

The station for Rabaul had by this time become surplus owing to the Japanese capture of Rabaul, and it was decided that it should be erected at Moresby. It was flown to Moresby shortly afterwards and became operation in March. Shortly prior to this, early in January, the first CHL station had been erected from equipment held by Radiophysics Laboratory, at Shepherd's Hill, Newcastle by P/O's Choate, Hannam and Glassop. The station was operating on the 10th January and was thus the first air warning station to be operational in Australia.

In March the Air Force in Darwin decided that extra range was necessary on approaching Japanese aircraft, and it was decided that an SCR268 (GL) radar which had been converted for air warning use should be flown from Brisbane to Darwin for installation at Point Charles. This equipment was carried in two trailers, the total weight being about 20 tons. Nevertheless, it was dismantled on the 24th March and the essential portions all arrived at Batchelor by the 6th April. Assembly was completed next day, and it was moved over the 100 miles bush track to Point Charles on the 20th April, commencing operation on the 22nd. This move must have established a record for air transport at the time.

From this time onwards progress with the air warning organisation became very rapid indeed. An extensive programme of site selection was put in hand, during February sites being chosen at Brisbane, Caloundra, Coolangatta and Townsville, and also at Cape Jervis and Wedge Island in the Adelaide area. The supply of equipment had also been speeded up. A number of SHD aerial systems was available and as priority had been given to air warning, these were used for future air warning stations.

Arrangements had been made with the Gramaphone Company in Sydney to produce 6 prototype AW sets and this was soon increased to a total of 21. It is impossible to record on paper the frantic activity with which all this work was attended. Priorities had to be arranged, material had to be secured from contracts already existing, and last but by no means least, there was the problem of the construction of operating buildings for the stations.

THE ARRIVAL OF AMERICAN FORCES

In December, American Forces commenced to arrive in Australia. They had been diverted from the Philippines or from the Dutch East Indies and in February they brought with them two mobile air warning equipments type SCR-270 and six gunnery equipments type SCR-268. The air warning equipments had been landed at Perth and it was decided to make these provide cover for perth within the RAAF programme. They were set up at Gingin and Mundaring and after initial troubles provided good service for some considerable time afterwards.

The gunnery sets were handed to the Australian Army but as no American predictors were available for use with them they could not be used with Australian anti-aircraft guns. The Radiophysics Laboratory had been successful in modifying one from its usual working range of 20 miles to 100 miles. This was merely a matter of adjusting the time base. The sets thus became potential air warning sets and were handed to the RAAF for employment within the air warning programme. The first one was set up at Townsville under Pilot Officer Rann and later two more were sent to the Cloncurry area where they were established at Julia Creek (Dalgonally Homestead) and Quamby to cover Cloncurry.

Unfortunately, the absence of an adequate reporting centre rendered these stations useless. The most spectacular performance with 268 was the move of one of these by air to Darwin, as already described. The arrival of the Americans also caused complications in supply of equipment. Although they arrived with a certain amount of ground radar equipment it was soon discovered that this equipment was too heavy and bulky for the kind of operations likely to be carried out here and that the Australian AW equipment was to be preferred.

The Americans had no airborne radar and thus in both the airborne and air warning fields they became bidders for Australian equipment. An Allied Headquarters South West Pacific Area had been formed and the radar situation came to a climax when the Chief of Staff ordered that four LB 30 (Liberator) aircraft be fitted with Australian ASV (File 201/16/53 - Enclosure 1A). Fortunately this conflict did not persist and from then on the supply of equipment was well co-ordinated with the result that although many arguments arose the equipment was always distributed amicably.

FIGHTER SECTORS

The War Cabinet decision that the RAAF should man the air warning organisation meant far more to the RAAF than the mere provision of radar. It implied the existence of a chain of filter and operations rooms and a force of interceptor fighters. The fighters were supplied originally by the Americans who arrived with P.40 aircraft and later the RAAF made its own contribution with P.40's and Spitfires.

The filter and operations room organisation was placed in the hands of Air Commodore Vincent who had escaped from Singapore, where he had been associated with the operations room defending Singapore. He proceeded to set up a series of operations and filter rooms in all the capital cities, and at Darwin. Unfortunately, his experience in Singapore had not been based on the latest technique, and he relinquished control before he was able to get the system running efficiently. From then on the filter and operations room system became one of the greatest white elephants in Australian defence.

Very elaborate organisations were set up in Southern areas where no enemy was ever seen, while in the Northern areas which were frequently raided by the Japanese, only

scratch organisations were available. In spite of this the only operations rooms which really worked were those which were operating in the face of the enemy. The greatest trouble however was associated with the filter rooms. At that time the Radar and Filter organisations were quite separate. The responsibility of the radar organisation ceased when the teller in the radar station passed his information by telephone or radio to the filter room. It was extremely unfortunate that the people in the filter room usually had no conception of the problems or capabilities of the radar organisation, with the result that on many occasions radar warnings were wasted and many bitter misunderstanding occurred.

This unfortunate situation persisted until 1943 when, by determined effort, the Directorate of Radar gained control of the entire filter organisation and instituted a training programme which result in radar and filter personnel becoming more or less interchangeable, producing an understanding which was successful in removing most of the difficulties (File 201/28/64). This organisation was afterwards handed over to the Directorate of Operations as will be seen later.

Of all the fighter sectors in Australia Sydney provided the worst example. Inaugurated under the original scheme it was handed over to the Americans about March 1942 when they were made responsible for the fighter defence of the Sydney area. Unfortunately the American officers concerned had practically no knowledge or experience of fighter sectors and their first step was to move the sector underground into an old railway tunnel in the Domain. The resulting set up was cramped for space, the site was almost impossible for radio reception, and the manning and operation of the sector was so inexperienced that the sector became a farce.

With the move of the Americans towards the North, the sector was handed back to the RAAF who eventually moved it to a public hall in Bankstown. Here again it continued to be a farce because it was used as a transit point for personnel being posted North and never at any stage in its existence could it be said to be efficient for more than short periods when an exceptional CO was allowed to stay there for a reasonable. A typical report on its condition is given on file 201/14/670.

Darwin became the Australian example of the way in which a fighter sector should operate. After the first Japanese air raids on Darwin the AW radar station came into operation and began to pass warnings. At first no great use was made of these warnings and no fighters were available. Very soon however American fighters under Colonel Wurt-Smith arrived and gradually an organisation was built up which eventually put a stop to Japanese daylight raids on Darwin. As with most things new, real proof was needed before people would really believe the radar, and this occurred at Darwin when Katherine was bombed. Radar plotted an incoming raid which split, part raiding Darwin and part heading for Katherine. This second part was ignored by the defences, who realised their mistake when Katherine reported that they were being bombed.

From then onwards the control room believed the Radar.

The Darwin fighter sector, originally a tent with one radar station reporting to it, gradually grew until it had a network of radar stations reporting by radio links and was able to meet successfully every Japanese daylight raid and finally ended Japanese attacks. Its success depended on a sympathetic understanding by the CO of the fighter sector and

the staff of the filter room, of the radar organisation. This fighter sector set an example which was later copied successfully in mobile operations and which no doubt will always be used in future. Further notes on this problem are given later.

THE RAAF RADAR ORGANISATION DEVELOPS

ASV

In March 1942 the first Australian-made ASV equipments at last began to become available and these were fitted to Catalina, Hudson and Beaufort aircraft in that priority. The equipment had approximately the same performance as the British Mark II, but considerable difficulties were experienced with "teething troubles" and it was not until the end of 1942 that ASV could be considered to be a really serviceable equipment. At the same time an ASV beacon had been produced, the first tests taking place at Rathmines in December 1942, and it was put into operation, one of the first beacons being established at Castle Hill, Townsville.

One of the greatest difficulties with ASV was to persuade the aircraft crews to use it. The human tendency to resist change and distrust anything new was particularly marked among air crews, and this tendency was inclined to be justified by the unreliability of the new ASV equipment. During my experience in the UK with Coastal Command, I had noticed a similar situation but, unfortunately, it was not easy to profit by this experience in Australia. An attack was made on the problem by introducing ASV training at the GR OTU.

This OTU, however, was just commencing operation, equipment was scarce, and it was not until the end of 1942 that good results began to be achieved. In the meantime an Australia-wide fitting programme had been undertaken, the Directorate of RDF making the fatal mistake of sending personnel and equipment to fit ASV in the field instead of having it fitted in depots. This was more or less forced upon us by the acute shortage of aircraft, the pressure of

the enemy and the resulting urgency of the problem. In actual fact, however, better results would have been achieved had the commencement of fitting been delayed six months and then undertaken in depots.

Even when ASV was fitted in a squadron it was often not used properly by the crews, or not used at all. In an attempt to overcome this difficulty an ASV training party was formed, headed by F/O Barnes RCAF who had had extensive experience with Coastal Command, and armed with an ASV trainer it toured the operational squadrons giving instruction both on the ground and in the air. Unfortunately F/O Barnes, after several brushes with the enemy, was lost in the New Guinea area.

The ASV beacon played a major part in persuading air crews to use ASV. Even though a crew was sceptical about the possibilities of locating enemy ships by radar it took a liking to the equipment when it was discovered that range from the beacon could be measured up to 100 miles and that successful homing could be carried out under any conditions.

ASV and Torpedoes

One of the greatest disappointments of the radar organisation, not to mention any other persons concerned, was the attempt to develop a torpedo force. An OTU had been formed at Nowra and 100 Squadron was being trained in torpedo operations. A considerable amount of effort was put into this work by the Directorate of RDF, special beacons being produced, a special extra range being built into the ASV indicator, and all manner of co-operation being provided. In spite of this and the intense enthusiasm and training of the crews, no outstanding successes were ever achieved by the torpedo squadrons and the torpedo was finally abandoned by the RAAF as a weapon with corresponding waste of radar effort.

IFF (Identification Friend or Foe)

From the beginning differences of opinion arose between the Air Staff and the Naval Staff concerning IFF. Up to November 1941 the RAAF had no policy for IFF as with no air warning organisation IFF in aircraft was unnecessary. The CAS however was most anxious that all ships in Australian waters should be fitted with IFF in order that the problem of sea search might be simplified. With no IFF in the ship the searching aircraft had to deviate from its track and examine every ship picked up by radar. If the ship carried IFF it would be easily identified and all this flying time would be saved.

The proposal was strongly resisted by the Naval Staff on the grounds that it would mean loss of security in that the ship would be making wireless transmissions. It eventually became world-wide Naval policy to fit IFF to ships but it was not until late 1942 that a move was made in the Australian area.

When an air warning organisation was adopted in November 1941, Australia automatically accepted a requirement for IFF in all aircraft. A number of IFF sets were already available in the country and these were fitted to GR aircraft, particularly the torpedo aircraft in which a special 'Rooster' IFF was installed for homing one aircraft on another. In the meantime a lengthy discussion arose concerning the overall policy. IFF Mark II was going out of use in England and Mark III was about to be adopted. It was eventually agreed that IFF Mark III would be the standard Australian fitment and that it would be purchased from overseas.

The British Government decided that Australian allotments would come from American production and thus another item was added to the already long list of equipment on order from America. Supplies of Mark III eventually commenced to arrive in Australia in mid-1943 but it was not until 1944 that all Australian aircraft were fitted.

AI (Aircraft Interception)

Although it was the subject of frequent discussion AI was never fitter to RAAF aircraft. In the original order for radar equipment in January 1941, 54 sets of AI had been included as it was thought that it might be fitted to Beaufighter aircraft for night fighting purposes. This equipment was not available from overseas and it was at least a year before any arrived in Australia. Meanwhile the scale of Japanese night attacks had been very small and there was no real need for night fighter defence.

On several occasions moves were made to have a few Beaufighters fitted with AI and the problem of a night fighter squadron received much attention whenever development programmes were being produced. Fortunately the Director of Radar was able to point out very clearly the limitations of AI, the chief one being that unless a squadron using AI is kept in constant practice and not used for any other purpose it is practically useless. When this consideration was matched with the scale of Japanese attacks and the shortage of aircraft in Australia the decision was always reached that we could not afford a force of night fighters.

Toward the end of 1942 the Americans arrived in New Guinea with a number of AI Mark IV equipped night fighters, but owing to unserviceability, poor aircraft performance and lack of training, no spectacular results were achieved. On the other hand Australian and American day fighters were both successful on a number of occasions in shooting down enemy aircraft by night with the aid of search-lights or the moon. Even when AI Mark IV became obsolete and much better types of centimeter equipment became available, no move was made to use it in the Australian area and the RAAF finished the war without a night fighter force.

Rebecca-Eureka

In 1942 information was received of a small radar being developed in England which would allow supply dropping or paratroop carrying aircraft to locate a radar beacon and drop supplies accurately near it. The airborne equipment was called Rebecca and the beacon Eureka. This equipment appeared attractive to the RAAF and it was decided that it should be ordered from overseas. As time went on and no equipment became available, the RAAF's need for the equipment increased owing to the change of role from defence to offence.

In November 1943 a climax was reached. An attempt had been made by the British to use the equipment in the invasion of Sicily but owing to its having been introduced at the last moment without adequate training and preparation, very poor results were achieved. The RAAF decided however that there was still a use for it in this area. Developments had been going on at Radiophysics and promising results had been achieved, so it was decided to cancel the overseas order and concentrate on local production.

RAAF Command specified an operational requirement for all transport aircraft and certain others to be fitted with Rebecca-Eureka and big developments appeared likely. Delays occurred however in production and even when the equipment had been produced no success was achieved in having it used operationally. This was due to no fault of the equipment but to the fact that the Army, who were to carry the beacons, could not be persuaded that they were worthwhile carrying, and the war ended without any real use having been made of Rebecca-Eureka.

Ground Radar

From the beginning of 1942 till the end of 1943 most RAAF effort was concentrated on the ground air warning programme. This was due to the fact that in the early part of this period air warning was vital in defence and towards the end of the period it began to play a part in the offensive operations which began the drive to Tokyo. The first CHL station and the first three AW stations which have already been mentioned were soon augmented by additional stations as the equipment and personnel became available. The programme was divided into two parts -

(a) The establishment of fixed radar stations to fulfil the requirements of the War Cabinet Agendum, and

(b) The provision of transportable or mobile stations to meet the needs of the moment in forward areas.

In order to get the fixed station programme under way a site selection party was formed under Flight Lieutenant Wadsley and toured most of the coast of Australia selecting sites for the various types of stations planned. Perhaps the greatest problem of all, however, was the works problem of erecting operating buildings, towers and living quarters, often in the most inaccessible regions such as Gabo Island, Wedge Island in Spencer Gulf, Dunk Island and Cape Weymouth, etc. A special section of DWB was formed to deal exclusively with radar and a standard set of buildings were designed. Thereafter DWB engineers and architects visited each site, prepared their plans and specifications for buildings and services, and contracts for erection were let by the State Works branches.

Although all this seemed to be a lengthy process, at the time the results were surprising. Buildings, masts, power supplies, etc, were completed in Southern areas for no less than 50 such stations in the matter of about 12 months. By the end of June 1942 records show that a total of 23 air warning stations were in operation with 12 more due to begin operation in a month's time. Of these 23, 5 were American 270 type manned by Americans, and 7 American 268 type manned by the RAAF - and all this from a zero start in January.

THE DEVELOPMENT OF AN AIR PORTABLE WARNING STATION

LW/AW

As early as December 1941, I had proposed that the RAAF radar organisation be developed around a readily transportable equipment (File 201/28/22, Enclosure 32A and at 87A). This suggestion was deferred as not being appropriate at the time but when the problem of installing radars in inaccessible areas began to materialise in early 1942, it became obvious that some more readily transportable equipment was essential. After much lobbying I persuaded Allied Air Forces to ask for ten transportable sets with fifty more later (File 201/28/22, Enclosure 96A and File 201/16/218).

We had already moved towards this in the construction by Mr Worledge of the NSW Government Railways Annexe of an SHD aerial system and operating hut combined, which was build of steel girders, was self-supporting and did not need concrete foundations. It could be transported by Douglas aircraft if necessary although it weighed about 12 tons. About 20 of these equipments were manufactured and gave useful service in such places as Port Keats and Melville Island in the Darwin area.

It was clear, however, that this structure was not the solution to the problem and in June I had written to Mr Worledge (file 201/36/4, Enclosure 1A) asking him to investigate the possibility of producing an aerial having the same performance as the CHL array but weighing about 2,000 to 3,000 lbs. Mr Worledge's answer to this was surprising. By July he had produced a tentative design and after further correspondence and personal consultation the first of these equipments was actually manufactured in September. It was called the LW and later, owing to its

outstanding success and as a tribute to its designer, it was christened the "Worledge" array. It should be mentioned at this stage that an equipment of this type was only made possible by the availability of the AW radar set turned out by Radiophysics in January 1942. This set was so much lighter than anything available from overseas that it could be classed as an air transportable equipment.

When the new station looked like being a success, the problem of providing numbers of the equipment arose, and the main obstacle was power supplies. The only one available was made from a Howard cultivator engine and the Army had the output on order. It took much persuasion and conferring to persuade the Army to hand over some of these sets, but it was finally arranged (file 201/16/218, Enclosure 18A, 23A). The first Worledge array was sent to the Radar School at Richmond and shortly afterwards two stations were formed complete with operating personnel and equipment and flown to New Guinea. Here, after a short pause at Moresby, one, under the command of F/O Griffiths, was flown over the Hump to Buna, erected overnight and next day succeeded in providing warning of the approach of some 60 Japanese aircraft which were intercepted, 20 of them being shot down by Allied fighters. This was a performance which had never been achieved before.

It had been with some misgivings that this move had been made. The array had been constructed without any advice or consultation with Radiophysics who, when they heard of it, condemned it as impracticable, and in fact adequate operational trials had not been made prior to sending the equipment into operation, so great was the urgency. From this time onwards, however, the LW/AW quickly became the outstanding radar set in the South-West

Pacific area. No more programmes for fixed stations in operational areas were produced; RAAF Command merely asked for a number of radar stations. These were formed in Sydney, flown to the area named and thereafter moved as required. In one case a station which was operating in the Buna area was moved to the aerodrome, flown 200 miles, carried to site and re-erected with a lapse of only 36 hours non-operational.

OVERSEAS INTEREST IN LW/AW

Early in 1943 we received a report from ORS India complaining of the troubles experienced in the transportation of radar equipment and the problems of permanent echoes due to hilly country. I signalled India giving a brief account of our work in New Guinea and S/L Findlay was sent to this area to examine the radar situation in Australia and New Guinea. On his return to India he recommended that the LW/AW could be used successfully in the Burma theatre and a total of six sets were eventually despatched from Australia for this purpose.

FURTHER DEVELOPMENT OF AW

When the LW/AW programme began to get under way, efforts were directed towards the improvement of its performance. It had originally been intended that Radiophysics Laboratory should produce a more permanent air warning equipment with better range but it was soon decided that the AW as it then stood was satisfactory although it could be improved by an increase in power and the provision of height finding facilities. A new valve, known as NT99, was becoming available and had been used by Radiophysics Laboratory in the development of a high powered Naval equipment.

It was decided that the Radiophysics Laboratory should proceed with the production of an AW Mark III embodying this valve. In the meantime a few AW Mark II had been made from a set made for the Navy but for which valves could not be obtained. After many difficulties the Mark III transmitter was eventually made to work satisfactorily but by that time (late 1944) plans were in hand for a better equipment on a different frequency and the Mark III never got into production. Early in 1943 an attempt was made to produce a GCI station using the Worledge aerial system modified to give heights and the American SCR602T6 as the radar equipment. The 602T6 was originated from ASV Mark II but a PPI had been added to it, giving it great possibilities for GCI purposes. Originally, 50 equipments of this type, known as LW (First reference, file 201/28/22) had been ordered from UK but supply had been held up and the order was finally transferred to America and the T6 substituted.

With Radiophysics advice, Mr Worledge had constructed a suitable aerial system and operating hut, and a T6 was borrowed from the Americans for the tests which took place at Bankstown in October and November 1943. It was found that the equipment worked satisfactorily on aircraft up to 20,000 feet but over this height poor results were achieved and eventually a decision was made to re-design the aerial system. The scheme finished up as the GCI Mark II, a number of which were used in RAAF operations at Tarakan, Balikpapan and Labuan.

THE DEVELOPMENT OF MICROWAVE RADAR

On his return from overseas towards the end of 1941 Sir John Madsen produced considerable information on the development of microwave radar in UK. At the time, much work had been done in UK on a wave length of 10 centimeters and outstanding success had been achieved in all cases where precision reading was needed or where extra range on sea targets was required. A report on the subject was submitted to the Radiophysics Advisory Board in November 1941 (File 201/14/125 - Enclosure 2B), and it was decided that experiments should proceed in Australia on the new technique. At that time the technique was applicable mainly for Army and Navy purposes.

Work was proceeding in England on a centimeter AI equipment for the RAF but for some considerable time no special RAAF applications appeared. In February 1942, with the adoption of an air warning programme by the RAAF the Navy decided that it required special ship watching facilities at the following points around the Australian coast:-

Neptune Island

Wilson's Promontory

Gabo Island

Sandy Cape

Cape Grafton

Centimeter equipment was specified owing to its extra range over the sea. As the RAAF was to have air warning stations at these points it was agreed that it should also accept responsibility for the special ship watching sets and thus the RAAF acquired its first interest in centimeter radar.

The event of this new equipment created a new problem in research and development. As this problem is likely to

occur again it is worth studying. The paramount need of the country and particularly of the RAAF was air warning. As centimeter radar was at this time not suitable for air warning, the RAAF had no special interest in it and concentrated all its energies on the long wave length air warning equipment then being developed. It was backed up in this point of view by the other Services.

The scientists on the other hand, in very essence always searching for something new, were anxious to push on with centimeter development, and thus arose a difference of opinion which lasted in one form or another for some considerable time. The scientist was undoubtedly right in his desire to develop new equipment. The RAAF was equally right in its urge to acquire equipment to suit the needs of the moment. Situations such as this will inevitably arise wherever the research organisation is mixed with the development or production side and only careful adjustment will produce a reasonable solution. The matter received some attention at the meeting of the technical committee on the 15th March 1942, and from then on frequent discussions on priorities occurred.

The development of centimeter radar centred around the special valves which it used, namely, magnetrons and klystrons. A very considerable effort was put into this problem by the Director of Radio and Signals Supplies and the Radiophysics Laboratory, resulting eventually in the construction of suitable valves in Australia. Progress of centimeter radar was given a tremendous boost by the visit of Professor M.L. Oliphant to this country in June 1942. Fresh from the latest information in England he was able to point the way developments were likely to go, and Australia owes much to the far-sighted picture which he painted.

In August the Radiophysics Laboratory succeeded in interesting the RAAF in a centimeter aircraft set. They proposed to design a 3 centimeter set which would be a combination ASV and AI and small enough to fit into such aircraft as Hudsons and Beauforts. Much controversy surrounded this set which never got past the design stage and at its best had few advantages over the centimeter equipments which were shortly afterwards to be turned out in mass production in America.

The first centimeter sets to appear in actual use in this country arrived from America in Ventura aircraft (PV1) in May 1943. These were type ASD and were the cause of considerable trouble. ASD was the first American production versions of this type of equipment (3 centimeter) and was full of "bugs". It was so bad in fact that maintenance crews had the greatest difficulty in keeping it operating and it was not until it was replaced with ASD 1 that real success was achieved. It served to initiate the RAAF into the mysteries of centimeter technique and the work which had been done by Radiophysics Laboratory proved invaluable in supplying training and experience for the RAAF maintenance personnel who were specially trained before the PV1's arrived.

About this time too an ASG equipment was secured from America and was given to Radiophysics Laboratory for examination. It was too bulky to be fitted to any operational RAAF aircraft although it was eventually fitted to a Beaufort for experimental purposes.

In June 1943 plans were well in hand for the production of a torpedo Beaufighter. This aircraft was designed to carry ASD for torpedo purposes, all aircraft to be wired, but only 25% to be fitted. When the RAAF

eventually gave up its torpedo programme this ASD equipment, which had not yet arrived, was cancelled. Our final sally into the field of centimeter airborne radar was with SCR 717 in Liberators. This item is a story in itself, and will be dealt with separately.

RAAF ORGANISATION FOR RADAR

RAAF HQ

In the beginning, radar matters were the problems of the Director of Signals. Section S.7 of the directorate had been formed early in 1941 to concentrate on radar only, and this section continued until April 1942 when expansion became so rapid that a change in organisation became necessary. Group Captain Wiggins, Director of Signals, was appointed Director of Communications, Allied Air Headquarters, and radar was separated from signals, becoming the Directorate of RDF. I was appointed as Director.

As the radar organisation had started from scratch with only three Service officers as a nucleus, it was necessary to train all personnel and allow them to gain experience before they became useful as staff officers. The organisation therefore went through an exceedingly difficult period, much work falling on the original staff during the period that new officers were becoming qualified to take staff jobs. I adopted the policy that no officer would serve at HQ until he had had experience in the field. As the training organisation was gradually stepping up it began to look in 1943 as if adequate personnel for all purposes would soon be available, but with the change of the strategical situation and the retreat of the Japanese, the demand for radar increased and at no stage during the war could it be said that sufficient manpower was available to meet all requirements.

RIMU

About May 1941 the first shipments of the mass of radar equipments which had been ordered from Great Britain began to arrive and it became obvious that a major problem

was developing around the need for storage, checking and despatch of this equipment. It was therefore decided to form a special unit known as the Radar Installation and Maintenance Unit (RIMU) for the special purpose of receiving, storing, checking and despatching of this overseas equipment as well as equipment from local production. The Presbyterian Ladies College at Croydon, Sydney, was available, and this became the home of the new unit with S/L A.E. Mitchell, RAF (the officer sent from UK to start CHL training in Australia) as its first Commanding Officer. The difficulties through which this unit passed in the next two years were probably no more than those of many other units, but they were very great.

The unit rapidly became the centre for all radar equipment in Australia and embraced such functions as mobile installation parties, calibration flight, modification centre, etc etc. Very soon storage space became so limited that an extra site was taken over at Figtree where an old film studio was available, providing excellent accommodation for technical storage. By this centering of technical detail at RIMU it became possible to separate most technical matters from Air Force Headquarters, allowing the Headquarters staff to concentrate on policy.

Radar Liaison Officer, Sydney

With the production by Radiophysics Laboratory of the first AW equipment, a new problem arose - that of maintaining close contact with the Laboratory and at the same time keeping a check on progress of manufacture and deliveries etc. Early in January 1942 Pilot Officer B.F. Israel arrived in Melbourne after escaping from Singapore where he had been sent as part of the first RAAF contribution to RAF radar. As he was a Sydney man and had been closely associated with the radio trade pre-war, I

sent him to Sydney as RDF Liaison Officer, set him up in the office of the Area Technical Officer and gave him an open hand to assist in any way he thought necessary, the progress of radar.

This proved to be a very fortunate move. He was extremely energetic and enthusiastic and his intimate knowledge of Sydney manufacturers proved invaluable in assisting the manufacture and delivery of AW equipments. He maintained close contact with Radiophysics Laboratory, RIMU, and the many suppliers of equipment and raw material and established an organisation which was to be of major assitance to the RAAF for the rest of the war.

Radar Organisation in the Field

In the field radar grew up as a private empire. This was unfortunate but in the circumstances there was probably no alternative. Although AOC's were kept informed of developments they and their staff were often too busily occupied in other matters to give much attention to this new and unknown organisation. Radar personnel appearing in the area got amounts of assistance from the different staff officers varying from obstruction to co-operation.

The first example occurred at Darwin where, although I had visited the area, selected a site and made verbal arrangements with the area staff, the assistance provided for the radar personnel under P/O Hannam when they arrived was meagre. This was partly due, no doubt, to the fact that the officers concerned were new in the Service and did not know their way around, but they maintained that although Area co-operated it was not until the first enemy raid on Darwin on 19 Feb 1942, with the resulting chaos which ensued, that they were able to secure adequate assistance from the local RAAF Station, and then only because they were able to

step in and help themselves. It is to their everlasting credit that they continued with the job and did not join the rush South.

Radar started at Townsville and Port Moresby by similar arrangements. As several stations appeared in the area the most experienced officer was detailed by RAAF Headquarters as Area RDF Officer and from this the organisation gradually built up until by the end of 1942 it had reached considerable proportions. As the organisation grew its defects became more apparent. The arrangements in the field were far from satisfactory as the radar stations were more or less motherless and I made several attempts to have a system of radar wings organised but without success.

At this time Squadron Leader Gibbs of the Royal New Zealand Air Force arrived to examine our radar organisation and I took advantage of his presence to force the issue. After inspecting the organisation he wrote a report (File 201/28/64, Enclosure 1B) which caused RAAF Command to ask RAAF Headquarters to set up an organisation almost identical to that which I had proposed. Radar wings were established in the areas Darwin, Townsville and Moresby and more important still, the Directorate of Radar was finally given responsibility for the filter organisation with the object of combining the filter rooms and the radar stations as an entity.

The result was a pleasant change for radar personnel. It must be emphasised here that the lot of personnel on radar stations was often an unenviable one. Stations were usually situated in outlying areas, often in places where no land communication was possible and they therefore had to be fed and maintained by air or sea. From the early stages strenuous endeavours had been made to secure luggers or small

schooners for this purpose but all small craft had been taken over by the Army and for one reason or another it was impossible to arrange a reliable service by the Army. In one case a man who broke a leg had to be kept at the station for 10 days before he could be moved to hospital. There grew up, therefore, an opposition Air Force small boats organisation and this, backed up by communication aircraft, succeeded in keeping the radar stations reasonably well supplied.

Before the advent of the wings, this problem had been on the shoulders of the area radar officer and results had not always been good. When the wings became effective, however, all the problems of the radar stations were handed over to them with a resulting very great improvement in general maintenance and welfare of radar personnel. This wing organisation continued throughout 1943, but when forward moves began in the New Guinea area it tended to become stretched out and a new organisation was introduced. The filter organisation is dealt with separately.

The Air Organisation

The organisation for airborne radar did not change. The original conception provided for a squadron radar officer who operated in parallel with the squadron signals officer and this organisation continued throughout the war.

Area Headquarters

When Radar wings were formed it became necessary to provide for radar advice to the AOC. An Area radar officer was therefore appointed, originally in parallel with the Area Signals Officer, but later as a member of the Signals Officers' Staff. His duties covered both ground and air-borne radar from the staff point of view. Originally he was also responsible for filter rooms but when this organisation was

handed over to the operations staff a separate staff officer was appointed for this purpose.

RAAF Command

American Headquarters and GHQ which were originally established in Melbourne in 1942 found it necessary later in the year to move closer to the war and in mid-1942 the whole organisation was moved to Brisbane. It became necessary for the RAAF to maintain close contact with the Americans and RAAF Command was formed to establish this contact and was given responsibility for the operational employment of the RAAF. Group Captain Wiggins was appointed Chief Signals Officer and originally he dealt with all signals and radar matters. In October however, he found it necessary to increase his staff and was appointed as his radar officer.

From then onwards RAAF Headquarters gradually lost interest in the tactical employment of radar stations and became more concerned with the supply of equipment and personnel, the disposition of which was RAAF Command responsibility. From many points of view the whole arrangement was not a happy one and it will not be enlarged upon here. At the same time a system of specification of operational requirements was established. Prior to this we had lived from hand to mouth, securing equipment wherever possible and using it in any way that appeared useful.

In 1943 the situation stabilised somewhat and it became possible to plan ahead and aim at the production of equipment to meet special requirements. This resulted in RAAF Command setting down in the broadest terms their intended use for the equipment. It was then the responsibility of RAAF Headquarters to select an equipment which would meet this requirement as far as possible and notify RAAF Command of any likely shortcomings. This arrangement also covered research and development and it was to meet RAAF Command's

operational requirements that the new radars which were in the course of development by Radiophysics when the war ended, were put in hand.

The WAAAF Problem

As early as 1940 approval had been given for the formation of a Women's Auxiliary but it was not until 1942 that a use for it in Radar arose. The manpower situation was acute and it was obvious from British experience that many women could replace men as Radar operators. File 201/20/72 tells the long and complicated story. The subject was first raised in April 1942 when D/WAAAF agreed that women could be used on Radar Stations, and it was immediately approved by AMOE. While the Directors of Recruiting and Training capitalised on the rush of women into the Service to enlist and train very large numbers of radar operators, a long and bitter tussle commenced between the RAAF and the Minister for Air as to the places in which they might be employed.

The Minister for Air contended that the employment of WAAAF personnel on radar stations in isolated areas would be immoral and it was some considerable time before a selection was made of those stations at which WAAAF personnel were allowed to serve. After this DWB was faced with a further problem in the construction of special WAAAF living quarters etc, to accommodate them. In many cases this meant the letting of new contracts at very considerable expense owing to the fact that during the arguments the contractors on the original jobs had finished and left the site.

In August, approval was obtained for WAAAF to be employed on a total of 17 stations. By this time, however, the training organisation had excelled itself in the production of WAAAF radar operators with the result that there were already several hundred for whom no jobs could be found. For as long as 12 months afterwards WAAAF radar

operators were still being employed in kitchens, stores, depots, etc, and some of them never saw a radar station.

In order to cope with the special problems of WAAAF personnel at stations a WAAAF Administrative Officer was posted to each station. This was a very fortunate arrangement as this officer was able to take over all station administrative problems leaving the RAAF Commanding Officer to concentrate on radar matters. When the Directorate of Radar succeeded in acquiring control of the filter rooms in 1943 some of the excess WAAAF personnel were put to good use when a policy was adopted whereby the filter room personnel would be interchangeable as far as possible with those on radar stations. It had been found at an early stage that the organisation worked very much better if the filter room people had had experience of radar stations, and arrangements were made to exchange filter room and radar station personnel at regular intervals. In this way an excellent understanding was built up and greatly improved results were achieved. Even at this stage WAAAF personnel were a mixed blessing. Very soon the expansion of the radar programme was halted by the shortage of manpower. This meant that all radar personnel were employed full time on radar stations, no reserve was available and men in northern areas could not be granted leave or be exchanged to southern areas on completion of their tropical tour. The logical arrangements would have been to exchange them with personnel on southern stations. These stations however were already manned entirely by WAAAF and medically unfit RAAF with the result that no exchange was possible.

I do not intend to suggest here that WAAAF did not prove useful or were not more valuable than the trouble they caused. In fact they were the saving of the situation. In

the frantic days of 1943 when radar stations were being formed at the rate of 6 to 8 per month it was replacement of men by WAAAF on Southern stations which allowed us to fulfil our obligations. Further, there is no doubt that a woman is much better suited for the duties of radar operator than is a man. Her temperament is suited to the more or less routine work involved and her ability to fill in dull moments with such things as knitting ensures that she does not suffer from boredom.

The War of Paper

From the earliest days one of the greatest difficulties was the securing of current information from overseas and its distribution to those who could best make use of it. Originally all information on radar came through CSIR who had a liaison officer in Australia House, London, and received information from him through Radiophysics Laboratory Sydney. Very soon the Services entered the field and the RAAF secured information from its Radio Liaison Officers both in London and Washington. The original trickle of information soon became a flood, and the arrangements of the RP Laboratory became inadequate. Up to the end of 1942 there were piles of documents in the laboratory about whose existence no one appeared to have any information. Data was received by sea mail and airmail both in its original form and on microfilm, and it was not until a very determined attack was made on the problem that some semblance of order was restored.

Radiophysics Laboratory eventually produced a series of accession lists detailing all documents as they arrived and these lists were distributed amongst those likely to be interested. From the RAAF point of view at least, this was merely the beginning of the problem. The RAAF by this time was also receiving piles of documents from both London and

Washington and there were two serious problems; firstly the proper receipt and custody of the documents and secondly the scanning of the vast amount of information available by those interested.

Radar Library

The Directorate of Radar had tackled this problem from the beginning when it became necessary, with the advent of Australian ASV, to produce a manual of the equipment. There was on the course at Richmond at this time one, pilot officer J.M. Moyle, who by profession was a technical journalist and he was given the responsibility of compiling and reproducing the manual of ASV. This was done so successfully that Moyle was established at RAAF Headquarters with the Directorate of Radar with responsibilities for all matters concerning documents. His section rapidly grew into a small empire which received documents from overseas, catalogued and filed them and prepared lists for distribution throughout the Directorate. At the same time a serious problem arose in the reproduction of other radar manuals as more equipment became available, and Moyle's section took this responsibility as well with notable success. By the end of the war a very comprehensive library had been established, backed up by an exhaustive filing and cross-reference system and a very considerable number of manuals had been printed and distributed.

SUPER-REFRACTION

As soon as radar equipment began to be used on the Australian coast it was discovered that maximum ranges varied from day to day. While the normal range for a 10,000 ton ship was about 30 miles, on some days this range would be extended to well over 100 miles. The new phenomenon caused considerable speculation and provided scope for scientific investigations for several years. It became particularly noticeable when the RAAF warning station at Kiama was installed, and a case is on record where the warning station at Gabo Island reported a ship at well over 100 miles range.

An investigating aircraft was not plotted until it arrived at the ship and was not plotted on its return, the reason apparently being that the aircraft flew out at about 5,000 feet and descended to a low altitude on reaching the ship. It thus appeared that while low level performance was increased, high level performance was decreased, but no real proof of this latter assumption was established. It soon became apparent from observations made off the coast at Sydney that this phenomenon occurred when a temperature inversion was present at about 5,000 feet and it became known as the "Temperature Inversion" effect, "Anomalous Propagation" or later, "Super-refraction".

Considerable work was done on the problem by Radiophysics Laboratory but unfortunately this work was not continuous owing to the many calls for full-time effort on other problems. At one stage an Anson was flown off the coast at Sydney every day for two weeks and took readings at progressive heights up to 10,000 feet. These readings merely showed that the lobes of a radar station were bent down slightly on days of temperature inversion but produced no proof

of decreased coverage at high altitudes.

As more stations were built the phenomenon was found to extend into tropical areas and an attempt was made in New Guinea by Flt Lt Syer, a scientific observer, to forecast radar performance from daily meteorological conditions. He found that meteorological information was inadequate and finished by forecasting meteorological conditions from radar performance. This established a pointer towards future possibilities but no systematic forecasting was done in SWPA during the war. At the same time work had been going on in both England and America on the problem and in 1944 Dr Booker, an English authority on the subject, visited Australia to investigate conditions. He found that work here was in some respects in advance of that being undertaken anywhere overseas, and his visit provided a considerable boost to Australian activities.

By this time the work was being carried out almost entirely by Radiophysics although the RAAF co-operated as much as possible. This co-operation extended to the establishment in 1944 and the operation for 12 months of special observation stations in the Darwin area and the collection over an extended period of radar observations from a considerable number of stations round the Australian coast. When last heard of the mass of data produced was being attacked by an analysis section at Sydney University with the help of a number of WAAAF personnel. Sufficient data exists to keep the section busy for some years to come. This phenomenon of anomalous propagation is likely to increase in importance with the advent of high powered and longer range radar and may well become as important a factor as meteorology in future operations.

Operational Research

Following the example which I had seen in England, I had early advocated the establishment of an operational

research group for the RAAF. Unfortunately this suggestion did not get very far until the matter was raised by Sir John Madsen after one of his trips to England. At the first meeting of the Radiophysics Technical Committee (File 201/23/64 - Enclosure 2B) January 1942, he proposed that Australia should collect a small team of suitable personnel under Dr Martyn at the Radiophysics Laboratory. This suggestion was referred to the Radiophysics Advisory Board on 16th January 1942 (File 201/14/125 - Enclosure 7B). The suggestion was approved and several university graduates were enlisted by CSIR for the work. Later they were joined by several oil geologists who had escaped from Sumatra and the group was handed over to the Army for operational control although they were maintained by CSIR.

From the start this arrangement was unfortunate. ORG as it was known almost played the role of beggars. Individuals were posted in the Sydney, Brisbane and Townsville areas and by industrious prying produced reports on sundry widely diverse subjects, most of which received little attention. In fact it can almost be said that no practical use was made of ORG at this stage. These remarks apply particularly to the RAAF point of view as although the radar organisation felt the need for the advice of ORG the arrangement existing did not make this advice easy to get and it was not until 1943, after visits to Australia by Professor Oliphant in 1942 and Sir Henry Tizard in 1943, that the Air Force became sufficiently interested to set up its own operational research group under Dr Bower. From that time onwards operational research became a part of the branch of the CAS and its activities extended to a much wider field than purely radar.

Scientific Observers

From the beginning of radar, arrangements had been made to enlist the aid of trained observers who would study the operation of the filter rooms and by careful analysis of data provide suggestions which would improve the efficiency of the organisation. Three such people were listed early in 1942 and were posted to Sydney, Townsville and Darwin fighter sectors. They were Flt Lt Syer, Flt Lt T. Sutherland and . Here they did excellent work, but owing to a series of misconceptions as to their role they never received the recognition which was their due and it was not until the inception of the MFCU and ADHQ organisations in 1944 that their role was properly recognised.

THE SITUATION IN SEPTEMBER 1943

In September 1943 a number of important changes took place in the radar organisation, the chief of which was the change in Directors. It is therefore appropriate to summarise the situation at this time.

THE DIRECTOR OF RADAR. The end of 1943 had marked the completion of an era of development in radar. The advent of the LW/AW and the successful progress of the ASV programme brought to a conclusion a period of frantic development, the outcome of which was a system of radar which was adequate to cope with the threat of the Japanese at the time. In point of fact, this system was really adequate for the rest of the war. With the defeat of the Japanese in the Solomons and at Milne Bay, the war looked like taking a turn for the better, and it began to appear that we were entering a new stage.

I felt that this new stage warranted a fresh outlook, and as it was then two years since the radar organisation had had direct contact with overseas in my visits to England and America, I felt that there was a real need for reviving this contact. Early in 1943 I therefore proposed that the RAF be asked to send an inspecting officer to Australia to examine the radar organisation. The RAF replied that no suitable officer was available. Shortly after this I proposed that an exchange be arranged with a suitable officer from the RAF. The RAF, at first unwilling, finally agreed and Group Captain G.P. Chamberlain was sent to Australia in August to take up the duties of Director of Radar.

ASV. Fitting of ASV Mark II was continuing steadily and it had been reduced to a depot job together with the fitting of all new Beauforts as they came from DAP. A total of 420 aircraft had already been fitted but there still remained some 200 for fitment in 1944. Most of the training problems had been overcome and a comprehensive ASV training syllabus, together with a very good training organisation, was in

operation at the GR OTU.

Enthusiasm for ASV had been steadily increasing and some very interesting operational results had been achieved including the sinking by a Catalina at night of an enemy ship in the Coral Sea and the location and destruction of enemy aircraft in the Arafura Sea. The beacon programme had been extended and had been responsible in a large measure for the enthusiasm with which ASV was used. New beacons were installed at each forward base as it became operative and a total of some 40 beacons were in operation.

ASD. The ASD fitted Venturas (PV 1) were being made ready for sea search activities north of Darwin but the greatest difficulties had attended the procurement of spares and test equipment

IFF. IFF Mark IIN had been fitted as an interim measure to a number of aircraft prior to the advent of Mark III. Mark III was becoming available in large numbers in July and GHQ had set as its objective a change-over to Mark III by the end of October. This objective was not in fact reached but it is interesting that by July a total of 450 aircraft had been fitted with IFF of one type or the other.

GROUND EQUIPMENT

ACO

A total of 9 ACO stations had been established and were operating, this completing the programme of fixed stations which originally numbered 32. The equipment was found to be too heavy and bulky to warrant further use in operational areas and as the war moved further North the stations already operating in Southern areas became surplus and were eventually closed down without having made any major contribution to the war effort.

CHL

The CHL programme was stopped in September 1943 as it was found that LW/AW was capable of providing comparable cover and could be moved much more easily. CHL stations were by this time operating in over 40 sites chiefly on the mainland and in southern areas.

GCI

The fixed GCI programme had been completed and work was progressing on the production of 4 additional mobile stations. By this time a total of 9 GCI stations were in operation including 2 RWG from Canada and 7 British type GCI.

LW/AW

The main effort of the radar organisation was by this time being put into production and formation of LW/AW stations. The programme provided for the formation of three stations per month and this rate was maintained for some considerable time. By July, 30 stations were actually operational and as each new stations became available it was immediately sent into operation, so that no pool could be built up as a reserve. The shortage of manpower had become less acute and it had become possible to devote more time

and care to the formation and training of LW/AW stations.

These stations represented a problem of their own. Almost invariably a new station was sent to some outlying area where it was confronted with very great difficulties. It was either so close to the enemy that very special precautions were necessary or else in an area where nature was the main enemy in that living conditions were extremely difficult. In some cases both problems occurred at once and this matter will receive more detailed consideration later.

AW Mark III

An experimental model of this equipment had been completed but the standard LW feeder system would not carry the increased voltage and a new feeder system remained to be designed.

LW/GCI

The first Worledge LW/GCI had been completed by New South Wales Railways Workshops and tests were about to commence at Bankstown.

Interrogators

The decision to change to IFF Mark III meant that most of the existing radar equipment could not identify aircraft carrying the new IFF owing to its operating on a different frequency. It had therefore become necessary to instal a separate transmitter and receiver at each radar station for the special purpose of interrogating the new IFF. This new equipment was known as an interrogator and supplies had early been ordered from America. The first interrogators arrived in August and a frantic programme of fitment to radars in forward areas was put in hand. The programme was well under way in September.

Summary of Programme up to July 1943

The following equipment was in operation by July 1943:-

ASV aircraft fitted - 420

IFF " " - 450

Ground Stations operating or formed:-

Col & AW	GCI	ACO	LW/AW	Total
42	9	6	30	87

Calibration

Calibration flight had been formed as part of RIMU and aircraft were kept extremely busy calibrating new stations as they were formed and re-calibrating others. It is not surprising that many stations still remained to be calibrated, as new ones became operational at the rate of 6 or 8 per month.

Radar Officers' Conference

During the week beginning 23rd August a radar officers' conference was held at RAAF Headquarters. All area radar officers and CO's of Wings attended, together with representatives from the radar school, RIMU training organisations and the RNZAF. The conference lasted for a week and a very extensive programme was covered. It was the first time that it had been possible to gather officers together to discuss common problems and much benefit resulted. It occurred at a time when the drive towards Tokyo was about to commence and the opportunity was taken to warn all officers to make preparations for the change in outlook from defensive to offensive tactics. Group Captain Chamberlain RAF had just arrived from the UK to take over the duties of Director of Radar and it was a unique opportunity for him to meet some of the officers concerned and learn many of their problems first hand.

Adoption of the Term 'Radar'

Up to this time the British had used the term RDF while the Americans used 'Radar'. It had been becoming very plain that considerable advantage would accrue from the

adoption of the American word and this was finally done by all British forces in September 1943. The Directorate at RAAF HQ thus progressed through the stages of S7, D Radio Services, DRDF, D Radar.

THE STRATEGICAL SITUATION CHANGES

Offensive Strategy

The end of 1943 and the beginning of 1944 saw a marked change in many aspects of radar. The limit of Australian manpower resources had been reached, the pendulum of the Japanese advance was commencing its back swing, new types of radar equipment were quoted as operational requirements, and the RAAF Headquarters Signals Organisation was to be re-organised.

With the establishment of RAAF Command adjacent to GHQ in Brisbane, RAAF Headquarters became a supply organisation and RAAF Command a user. As far as ground radar equipment was concerned the tune called by RAAF Command had been a fast one but when the RAAF Command programme for 1944 was received in Melbourne in August 1943 a decrease in tempo became necessary. The programme called for the provision of a total of over 2,000 additional personnel during 1944 and when this total was added to the requirements in other musterings the RAAF allotment of manpower could not satisfy the demand. It was necessary therefore to inform RAAF Command that only 1,000 radar personnel could be produced for the next year and it was their responsibility to use them as they thought best.

Progress during 1943 can be judged from the following figures:-

Aircraft fitted with ASV Mark II increased from 100 at the beginning of the year to a total of 600 in December, while ground stations increased from 35 to 90 during the same period.

These extra 55 ground stations implied a total of approximately 2,000 personnel of whom over 600 were trained radar men. Early in 1944 a stop was put to most airborne radar development, mainly by the abandonment of the BD43A (Beaufighter) torpedo project. This aircraft was to be fitted with ASD 1 while Radiophysics were also developing a three centimeter equipment known as J33 for the same purpose. Both these equipments were cancelled and no great changes occurred in the airborne programme until the arrival of Liberators towards the end of the year.

The ground programme however was to expand considerably. The way appeared clear at last for securing long-needed height finding in conjunction with RAAF radar. At the same time a similarly long felt need of warning against low flying aircraft seemed possible of fulfilment. Ever since the early days of the AW the limitations of height finding and low flying cover had been the cause of some concern. In spite of the fact that no heights were given by the AW, great success had been achieved by the fighter organisation largely due to the unimaginative tactics of the Japanese.

At this stage it is interesting to study the Japanese radar developments. Although a Japanese radar had been captured by the Americans at Guadalcanal the tactics of Japanese bombers and escorting fighters seemed to indicate that the Japanese commanders had no knowledge of the capabilities and limitations of their own or our radar. Postwar investigation has shown that this was due to the veil of secrecy surrounding radar and the inability of the scientists to co-operate with the Services. The result was most fortunate for the Allied forces as the enemy bombers usually came in at the same height on every occasion and ononly one occasion in attacks on Darwin did the enemy use low flying tactics. Even in this case it is not clear that the operation was intended to

defeat the radar.

To meet the threat caused by these two shortcomings RAAF Command early in 1944 produced operational requirements for a GCI station which would be air transportable height findings on air warning sets, and a low flying cover equipment capable of giving warning of the approach of enemy aircraft at very low heights. At the same time the radar conscience had suffered considerable pricking owing to the common frequency in use by practically all RAAF and American radar. This, combined with the simplicity of the radar sets themselves would have made jamming by the enemy a very simple matter. Some attention was therefore given to a variation in frequency, the most notable move in this direction being the AWH.

This equipment grew from developments in the valve laboratory of the Melbourne University under Professor Martin. Professor Martin had been successful in making magnetrons equal to those produced overseas and Radiophysics decided that here was an excellent opportunity to branch into a purely Australian radar development. They chose a wave length of approximately 30 centimeters as being one which had not been used extensively overseas and which would give many of the advantages of centimeter techniques combined with a number of the advantages of 1.5 meter radar. Radiophysics therefore set about the production of the AWH which was to be a 30 centimeter radar of considerable power and giving heights to an accuracy of 2,000 feet at long range. Other radars planned were the CMH which was to use an SCR 717, 10 centimeter airborne equipment to give height and range only, the LW/GCI Mark II and the LFC.

All these equipments were in development in 1944 and early 1945 and several LFC and GCI Mk II stations had been produced by the time the war ended. None of the other however got past the development stage.

While these developments were proceeding no special attention was being given to the problems of enemy jamming, as the new equipments were to cope with this. The landing of the Americans on Leyte in the latter part of 1944 produced a series of reports and rumours of jamming by the Japanese of American 200 megacycle radar. This resulted in a period of frantic activity at Radiophysics during which plans were made to modify existing AW receivers with interim anti-jamming devices and at the same time a completely new AW equipment based on the original, but incorporating all possible anti-jamming measures, was designed. This was to be known as the AW Mark V. Here again the timely collapse of the Japanese saved us much development and manufacturing trouble. No AW Mark V had been produced by VJ day though a number of AW's had been modified with the interim anti-jamming system.

Change to Wheeled Transport

With the move of the war from New Guinea towards the Philippines a radical change took place in the methods of transportation of equipment. While the main base was Moresby and while radars were being established in isolated areas in Northern Australia and Northern New Guinea, air transport was the only suitable means of carrying radars into the area. To meet this need the LW/AW had been produced. After the capture of Buna and Lae, operations changed to the more conventional amphibious warfare in which landings were carried out from the sea and all equipment was carried in landing barges. Under these conditions air transportable radar was at a disadvantage as it had to be carried loose in vehicles and assembled ashore.

It was towards this type of operation that RAAF efforts were directed in 1944. No attempt was made however to re-design the radar for vehicle mounting, RAAF Command being satisfied to carry the equipment loose in vehicles for erection ashore. This sudden change in tactics is a very useful pointer

for the future. Air transportable characteristics will always be necessary for operations such as were carried out in North Australia and New Guinea, owing to the need for operating from bases only accessible by air or sea, and the shortage of sea transport. At the same time it will always be necessary to provide vehicle mounted equipment for landing operations. The ideal would be a radar which is airtransportable as well as being capable of mounting in and operating from a vehicle.

Beach Warning

A further lesson can be drawn from the landing operations North of New Guinea where it was found that long range warning was not really necessary in the first phases as this could be provided by escorting Naval vessels, but that short range warning of,say 25 miles, was adequate. This was sufficient to alert the anti-aircraft guns and have them pointing in the right direction by the time the enemy aircraft arrived. Such facilities could have been provided by man pack type radar although in the future anti-aircraft guns will no doubt include their own warning system of this type.

Radio Countermeasures

Early in 1942 there occurred an event which shook the allied Radar organisation to its foundations. The German battle ships Scharnhorst and Gneisenau which had been sheltering at Brest for some considerable time broke out under cover of bad weather and sailed through the English Channel under the noses of the British defences. Just when the RAF radar system was about to be used for attacks on these vessels it was suddenly put almost out of action by a barrage of enemy jammers on the French coast. The possibilities of jamming had been foreseen by the designers of radar but this was the first occasion on which it had been used and it was significant that only an experimental 10 centimeter radar which was in use at Dover was not affected. The fact that this radar could not

pass its information owing to poor communications was incidental.

This event marked the inauguration of an entirely new activity in radar which came to be known as Radio Countermeasures or RCM. In Australia the Navy was the first to be interested in RCM, their main interest at the time being the provision of a receiver to be carried in ships to pick up enemy radar transmissions, thus giving warning that the ship was under radar observation by the enemy. The matter did not receive very great attention however until 1943 when GHW took an interest in it, forming "Section 22" which was charged with all matters concerning RCM. This section which had available to it all the facilities of the American forces in the area, collected reports from agents, from receivers carried in submarines and from landing forces as at Guadalcanal and was able to build up a fair picture of the Japanese radar organisation.

RAAF interest in RCM commenced when Section 22 borrowed RAAF personnel to fit special receivers to American aircraft and fly with them on missions over enemy territory. Later similar receivers were fitted to RAAF aircraft in the North Australian areas but it was soon discovered that the use of operational aircraft for this purpose had considerable disadvantages. These aircraft were concerned solely with dropping bombs or fulfilling their reconnaissance mission and returning to base, and only exceptional crews would devote time to searching in enemy areas for possible radar transmissions. Usually problems of serviceability and operational losses also arose and toward the end of 1944 it was decided to follow British and American practice and establish RAAF aircraft specially for RCM duties.

These aircraft were to be known as Ferret aircraft and would be fitted with an array of receivers, recorders and

analysers. In the meantime RAAF Headquarters decided to become better informed on RCM matters and early in 1944 two radar officers, Flt Lt's Nash and Thomas were sent to England to make a thorough examination of the RCM organisation. On their return they took up the cause of RCM and concentrated their interests on the Ferret project. Early in 1945 No 201 Flight was established comprising two Liberator aircraft under the command of Wing Commander C.S. Davis, and these aircraft were allotted to APU for special fitment as Ferrets.

An extensive programme of RCM was commenced. All RAAF Radar and Signals equipment was examined for possible anti-jamming modifications, special operators were trained in Kana for Ferret purposes, a number of training teams were formed to introduce RCM techniques in operational areas, and an RCM training manual was produced. As time went on it became increasingly obvious that the RCM programme would be too late. The war was moving rapidly towards Japan, the Philippines had been captured, the remaining Japanese forces in the islands were more or less disorganised and certainly represented no menace from the RCM point of view. It was unlikely that the Liberators would have a job to do. In actual fact the war ended before they were put to operational use. The experience gained was valuable but it has probably been lost by the departure of the officers concerned from the Service.

OPERATIONAL PROBLEMS

Transportable Radar Stations

The problems presented in the operation and control of transportable radars deserve special attention. The extensive use of the LW/AW and later of transportable GCI's taught us many lessons. The first transportable radars used by the RAAF were constructed in Melbourne from two ASV sets with portable aerial systems and were sent at short notice to New Guinea with a crew of a Sergeant and three men each. They were eventually established at the Eastern entrances to Milne Bay where they were to give warning of the approach of aircraft and shipping.

From the beginning the enterprise was unfortunate. They were sent out into the blue and were immediately forgotten, with the result that they became unserviceable, the personnel were neglected, and serious loss of life could have occurred under less favourable conditions. The lessons of these two stations should have been learned when LW/AW's were formed but unfortunately events were occurring so quickly in those days that adequate preparations were not practicable. The first LW/AW's were formed in Sydney, also at short notice, and were transported to New Guinea by air or surface transport. The results depended mainly on the skill and experience of the station CO.

Most of the CO's in those days were men straight from the accelerated University course, usually under the age of 21. While technically qualified, they were not used to handling men, least of all under tropical jungle conditions. No others were available, however, and they had to be sent. In some cases results were excellent and in others administration and discipline suffered considerably. The problem was eventually

met, firstly by not commissioning men who were under the age of 22, and secondly by posting an additional officer with administrative experience to stations situated in out of the way areas.

Another problem of the early stations was the difficulty of securing NCO's. All the radar people were boys together. They had come straight from radar school and stations usually formed with no NCO's whatever. It fell on the shoulders of the area receiving the station to appoint acting NCO's from those who appeared to warrant the responsibility but here again the interest taken by the area varied and it was not until Radar Wings were formed that the stations received the attention which they required.

Guards

One of the problems was the provision of guards. The need for guards varied from anti-pilfering duties in Southern areas to protection against the enemy in Northern areas. A policy was eventually adopted of posting four guards to Southern stations while the guards for Northern stations varied at the discretion of the local commander. Radar stations were often the closest Allied troops to the enemy and some stations in New Guinea area were allotted as much as a platoon of infantry. This was often justified as wandering bands of Japanese were encountered on several occasions. A further problem arose in Southern Dutch New Guinea where stations were located in head-hunter country. Here again special guard arrangements were necessary.

Special Training for Radar Personnel

From the beginning it was obvious that those men being posted to radar stations required special training. The policy was adopted of putting all such men through special commando courses and following this with a period of special training at a radar tation. However, so great was the demand for stations that it was not until late 1944 that this policy

could be implemented. A special organisation was eventually set up at Radar School, Richmond., for the jungle training of radar stations. New stations were formed at the radar school and were then sent into the mountainous country near Richmond where they carried out several weeks training in camp life operations and tactics. This produced, long after it was due, a party of men who had some chance of looking after themselves when they arrived in tropical areas.

The Problems of Air Transport

The first LW/AW left Mascot by air and nearly all subsequent ones also travelled by air. One of the difficulties was the provision of suitable handling facilities at the end of the air journey. Eventually it became possible to provide a jeep and trailer for each station so that equipment could be moved from the aerodrome to the final site. Other problems were those of schedules of equipment, proper packing, priorities of movement, etc, all of which were eventually reduced to a formula.

The Problems of Isolated Sites

Once a station was established in the jungle it was usually many miles from its supply base and perhaps hundreds of miles from its filter room. Supplies were arranged by various means, often by special small boats run by radar wings, and at times by air. Communication was usually by radio, two complete radio sets being supplied to each station, or when landline communication was possible, one radio set as a reserve to the landline.

Security of Communications

From the earliest days much thought was given to the problem of security in passing plots by radio. A false grid system had been used in England but the first step here was to introduce a special code which was applied to all radar plots.

This code was soon abandoned owing to the delays which it caused and most telling was eventually done in clear. As time went on the need for security decreased with the dwindling of enemy forces but the problem still remains and no adequate solution has yet been produced.

Power Supplies

Possibly the greatest problem with which the radar organisation along with many others had to contend was the provision of a light and reliable power supply. The first radar stations went to New Guinea equipped with a twin cylinder air-cooled motor, originally designed to drive a Howard agricultural cultivator, driving a 2½ KVA alternator. This motor required very careful maintenance and gave considerable trouble when it was not forthcoming. Fortunately the problem was tackled early by the Signals and Technical staffs and a set was eventually produced comprising a Ford 10 horsepower engine driving a 5 KVA alternator. It proved to be a very excellent solution to the problem as it was extremely reliable. However it suffered from the serious disadvantage of weighing 15 cwt and as two of these were always sent with a radar station they represented more than half the weight of the technical equipment.

Unfortunately, right up to the last days of the war, no better solution was found than these sets and we finished the war still short of a really suitable power supply. Much time was spent in designing radar equipment which could be broken down into man pack sizes of about 150 pounds each but this work was more or less wasted as it became necessary when a station was to be operated continuously for any length of time to send a Ford 5 KVA generating set weighing 15 cwt as its power supply. Towards the end of the war lighter weight units were becoming available in America but their saving in weight

over the Fordset was not outstanding, and no information is available on their comparative reliability. A real solution to the problem still remains to be found.

THE PROBLEMS OF OPERATIONS ROOMS AND FILTER ROOMS

The Air Defence Organisation in Australia got away to a bad start but it is most surprising that no real attempt was made to rationalise it for three years. Mention has been made of the difficulties experienced with filter rooms and the problem will be enlarged on here. In January 1942 with the fall of Singapore a frantic programme was commenced in Australia for the provision of filter and control rooms at focal points. At the same time a training organisation was established at New Lambton, Newcastle, this school being intended to become operational in the event of an attack occurring. No good purpose will be served in outlining the incredible series of mistakes and disorganisation which followed but the trouble can probably be traced to the failure of the air staff to realise the requirements of air defence.

The Air Staff at that stage was a mixture of American, Australian and RAF, the RAF personnel being aware of the requirements and trying to establish an organisation following British precedent, while the remainder worked on new ideas of their own. The first result was a control organisation which had no connection with or understanding of the reporting organisation - either radar or air observer corps. These misunderstandings were exaggerated by the personnel who were chosen as controllers; in most cases they were failed aircrew or other officers who had no conception of the problems of air defence. The situation became worse until in 1943 I was able to gain control of filter rooms and combine them with Radar into one organisation, thus remedying part of the difficulties.

Another factor militating against success was the influence of ex 3 Squadron personnel at RAAF Headquarters. These officers had come from fighter squadrons operating in the desert and had established an excellent name for themselves. Unfortunately, however, they had had no experience whatever of static air defence and had never been controlled by radar to an interception. They tended therefore to think of fighters in terms of desert warfare, tactics which were extremely successful in close support at Milne Bay but were quite unsuitable for the radar controlled defence of Darwin. Further difficulties arose in the case of GCI controllers. This was partly due to the fact that the number of Japanese night raids was very small and there was no real need for GCI CONTROL. Nevertheless and rightly, the Air Staff required GCI facilities at all fighter sectors.

It was not until 1944 that this GCI problem was straightened out with the importation from England of two trained officers, one experienced in GCI and the other in filter rooms and fighter interception. Meanwhile the lessons had been learned in operational areas, particularly at Darwin, by bitter experience, and Darwin had become a very efficient air defence organisation. Moresby on the other hand was under the control of the Americans who had not by this time developed a really successful system of control of their own.

It was unfortunate that while the RAF control system had been adopted in toto by the American training organisations in America and in fact officers trained in this system were being sent to New Guinea from America, the Americans in New Guinea refused to abandon their local system and the controllers from America had to forget the British-American system and learn the local New Guinea system. And so it went on until by the time the Philippines were reached and the RAAF was operating from Morotai, experience, combined with a certain

amount of advice from overseas had produced an effective control system. In the case of the RAAF this resulted in the establishment of MFCU's and ADHQ's, where the fighter defence organisation was an entity, Radar, observers, filter, control and fighters all being under the officer responsible for air defence.

PLOTS ON SHIPPING

Throughout most of the war, the greatest difficulty was experienced in dealing with shipping plots. In the days of the Joint Services Committee on air warning, the Navy had expressed their need for special coast watching equipment at six points around the Australian coast and as the RAAF was due to instal air warning stations at these points, it was agreed that they would also assume responsibility for special ship watching radar. Even before this special radar was installed, the standard air warning stations produced many shipping plots, in the case of Kiama up to ranges of 60 and 70 miles, and these were passed in the same way as air plots by telephoning to the filter room. It had been agreed that the Navy would be responsible for dealing with information from this point onwards.

The first difficulty was encountered when plots began to arrive in the filter room and no naval representative was available, nor was the NOi/c interested. From then on a long and complicated series of discussions took place between RAAF Headquarters and Naval Headquarters which resulted eventually in the establishment at least in Melbourne Fighter Sector of a Naval Section manned by navy personnel for the special purpose of dealing with shipping information. Similar arrangements were eventually made at other Fighter Sectors but in every case the greatest difficulties were experienced in interesting the Navy in shipping plots.

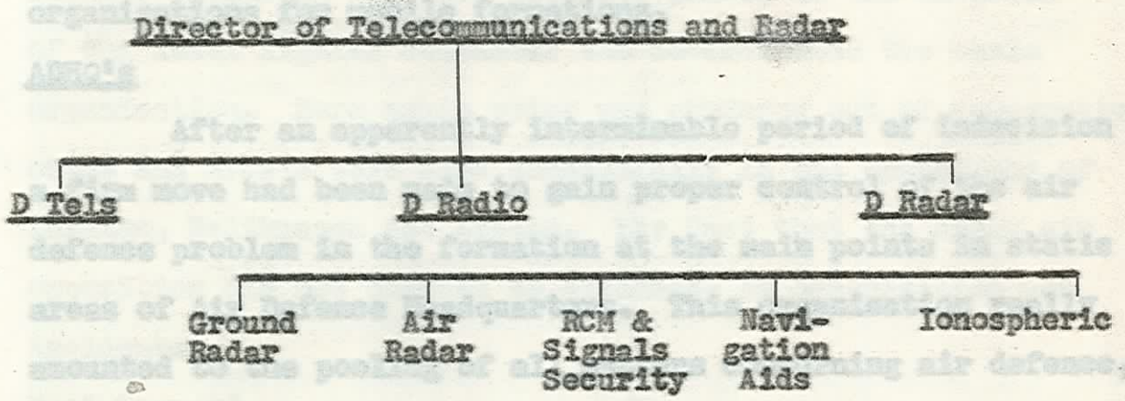
It eventually became obvious that owing to the restrictions on radio signalling imposed upon ships at sea, the Naval authorities had no information as to what ships were likely to arrive off the Australian coast and therefore no real identification was possible of these shipping plots. This more or less unsatisfactory state of affairs persisted right up until the end of the war, when with the advent of the ADHQ organisation, slightly better co-ordination was possible. The problem will continue in the future and warrants special attention.

THE SITUATION AT THE BEGINNING OF 1945

I returned from overseas service in December 1944 and in March 1945 was again appointed Director of Radar. Considerable changes had taken place in the meantime, chief amongst which were the following -

Organisation at RAAF Headquarters

About April 1944 the CAS, who had for some time considered that closer co-ordination was necessary between Signals and Radar, decided to amalgamate the two directorates under a common head and the Directorate of Radio Services was formed with Group Captain Chamberlain as Director. He controlled two deputy directorates, D/D Radar headed by Wing Commander J.T. Phillips and D/D Signals headed by Wing Commander V.E. Marshall. This arrangement continued until the end of 1944 when Group Captain Wiggins left his post at RAAF Command and became Director of Radio, RAAF Headquarters. He then appointed Group Captain Marshall to draw up an entirely new organisation for the Signals and Radar services. This organisation was introduced early in 1945 and from the Radar point of view is outlined below:-



D/Radio was responsible for planning, personnel, publications, etc, D/Tels for Signals organisation, D/Radar for the operational aspects of the sections shown above, while D/Tels was the common provider of all equipment. Very soon after this organisation was introduced the European war ended and reductions began to take place at RAAF Headquarters with result that the organisation did not get a fair trial. It tended however to be top heavy in that it required a considerable increase in personnel at RAAF Headquarters to do the work which had previously been done by smaller numbers. In essence it really meant the scrapping of the unwieldy signals organisation and the re-modelling of the whole of the Radar setup.

No 1 RIMU

No 1 RIMU had been re-named Radio Development and Installation Unit and took over responsibility for signals matters as well as radar.

Radar Wings

These had been abolished and in their place a number of RIMU's had been established which were responsible for the storage, installation and repair of all communications and radar equipment in the area. They also served as base organisations for mobile formations.

ADHQ's

After an apparently interminable period of indecision a firm move had been made to gain proper control of the air defence problem in the formation at the main points in static areas of Air Defence Headquarters. This organisation really amounted to the pooling of all matters concerning air defence, including radar filter rooms, operations rooms, air observer corps and fighter squadrons under an officer sufficiently senior and experienced to accept responsibility for the air defence of the area. It was the first time the air defence

problem had been appreciated properly and it looked like producing order out of the existing chaos.

Prior to this an attempt had been made to establish a system of zone filter rooms which regarded the radar, observer corps and filter room organisation as a permanent facility which could be used by a mobile operations room and fighter organisation to "tap in" wherever a threat appeared. The arrangement was very logical but was never brought to completion owing to the shortage of manpower and the diminishing need for it as the war moved north. The new ADHQ organisation was at last a workable solution but again it was to be paralysed by the shortage of manpower and the need to send all able-bodied personnel to Northern areas. However, it sets an excellent precedent for the future.

MFCU's

In the process of re-organising air defence, steps had been taken to provide a more logical organisation for mobile operations in the establishment of a number of fighter control units. These units were designed to follow the war in operational areas and were equipped as self-contained units with LW/AW and GCI radars, communication systems, filter and operation rooms and ample staff. They did not control the fighter squadrons but were actually placed at the disposal of the local fighter commander who co-ordinated the whole organisation. Here again order was produced out of comparative chaos and MFCU's were used successfully in the operations of Tarakan, Balikpapan and Labuan. The fact that the enemy air opposition did not warrant so elaborate an organisation was incidental.

RAAF Command

Early in 1945 RAAF Command moved to Morotai where it was established in the same area as Headquarters 1st TAF. By this time it had accumulated a complete radar staff of

its own, the Staff Officer radar functioning under the Chief Signals Officer. The staff officer radar, however, had surrendered his original responsibility for operational control and confined himself to more technical matters. A staff officer filter rooms had been appointed under the Director of Operations, and being a radar officer he was in a position to deal with operational matters concerning radar.

At the same time the problems of higher policy were dealt with by the Director of Operations in consultation with the Staff Officer Radar. This organisation again had placed operational responsibility where it belonged. I found that some dissatisfaction had arisen concerning RAAF Command's employment of the radar organisation, this situation culminating in a minor revolt at the Signals Officers' conference towards the end of 1944. This was an echo of previous differences which had arisen in 1943 over the employment of 4 radar stations in the Gulf of Carpentaria and one in the wilds of New Guinea. All these stations had been sited in completely isolated areas where not more than one aeroplane per day was ever plotted and nothing is more calculated to undermine the morale of a radar station than inactivity. When this was backed up by an extremely inefficient communication system the plight of the stations was unenviable. In spite of this they were kept in these positions by RAAF Command for many months after the threat which caused them to be placed there had disappeared.

A similar situation had developed in New Guinea where our radar organisation was under the control of 5th Air Force but had to serve a dual master in RAAF Command. The Americans tended to send RAAF radars into very sticky positions, the worst example being the establishment of a

radar on Batt Island near Manus some time before the landing took place. This station was withdrawn some weeks later with two men dead and all the crew seriously ill. 5th Air Force preferred to send RAAF radars to these jobs, if not because the jobs were unsavoury at least because the RAAF personnel and equipment were the only ones in the area which could be relied upon, and the situation became so bad that a serious shortage of manpower developed; after the Manus operation RAAF Command was forced to curtail considerably the number of radars at the disposal of the Americans.

Technical Details

GroundRadar

A number of new radars were under development as listed elsewhere, including the LW/AWH, GCI Mark II, GCI Mark III, LFC, AW Mark V, etc. Of these only the GCI Mark II ever got into operations, the remainder being in the hands of Radiophysics when the war ended. During a visit to Morotai early in 1945, I was successful in obtaining RAAF Command's agreement to the cancellation of the AW Mark V project. It was intended that this should be an AW equipment completely re-designed to embody all possible anti-jamming measures. At the same time the AWH was being designed to perform the same function better, and RAAF Command agreed that enemy opposition was so slight that the extra facilities provided by the AW Mark 5 would not be needed before the AWH was available.

Airborne Radar

ASV Mark II was in extensive use, with various modifications including a Polyplexer, and an extensive organisation of ASV beacons had been established throughout operational areas. A number of ASD equipments were being operated in Venturas but these never reached large numbers,

while ASB was in use in some of the Catalinas but was being replaced. A new project, SCR 717 in Liberators was just coming into being and will be dealt with separately.

Radio Countermeasures

Plans were in hand for a special Ferret flight of two Liberators carrying all manner of detection and recording equipment and elaborate plans had been laid for training personnel in RCM matters. At the same time a complete survey had been made of all RAAF radar and radio equipment with a view to the introduction of anti-jamming measures.

Ionospheric

A thriving organisation had been built up and a new contract was under way for the production of a re-designed recorder which was to be established at such places as Manus, and one of which was likely to be sent to Chungking. At the same time considerable thought had been given to the problem of tropospheric investigations based on anomalous propagation records by RAAF Radar Stations, and a special investigation by CSIR was under way at Darwin.

Navigation Aids

These were now the responsibility of the Director of Radar and were in a turmoil. The standardRAAF navigation aid had been high frequency D/F but this now looked like being abandoned. Much discussion arose as to suitable replacements and the policy to be adopted to meet RAAF Command's operational requirements for navigation aids in all Service aircraft. The matter was so bound up with future Civil Aviation policy, RAF policy and the advent of new equipment that no easy solution was possible.

Of all the navigation aids Loran deserves special mention. The Americans had established a Loran chain in the Darwin area and this had been used by American aircraft

operating over the NEI. As the equipment became available it began to arrive in Australia in transport aircraft, bombers, and in fact all large aircraft supplied from USA, and it found the RAAF unprepared to use it. A training school had been established by the Americans at Nadzab and a number of RAAF personnel had been sent to this school, after which an attempt was made to introduce Loran training at OTU's.

The story is really a repetition of the old ASV story in which much technical equipment was flown in RAAF aircraft but not used because the crews were insufficiently trained. This persisted, making little improvement up to the time the war ended, and was due partly to the fact that so many other navigation aids were available that the crews did not bother to learn to use a new one.

Operations in 1944

By the beginning of 1944 radar in the RAAF had had its day, mainly because opposition by the enemy had practically disappeared. Airborne radar was used only as a navigation aid if at all, except in the case of Catalinas in the laying of mines in enemy waters. Ground radar, which was finally available in good numbers, had no enemy aircraft to plot. In Southern areas an attempt by RAAF Command to maintain the already unemployed chain of fixed stations had to be abandoned owing to the shortage of manpower, and stations were gradually closed down until by the end of the war comparatively few were operating.

In a flush of enthusiasm a very elaborate MFCU organisation had been established to cover the projected attacks in Borneo. This again, as it happened, proved to be unnecessary in that the total number of enemy aircraft seen during all the Borneo operations could almost be

counted on the fingers of both hands. The RAAF had finally built up a really adequate radar organisation only to find that there was no real use for it. This story is a little skin to the one of radar and filter rooms in 1942 where the over-elaborate ones in Southern areas saw no enemy and never became efficient, while the scratch ones in Northern areas which had a real enemy to deal with became very expert. So with radar in operational areas. In the bad days of 1943 during the New Guinea operations, radar turned up trumps under appalling conditions. By the time it became properly organised in 1945 there was no use for it.

Liberators and SCR-717

The introduction of Liberators towards the end of 1944 warrants special attention. Specifications for the Liberator had been considered as early as 1943 and originally RAAF Command stated that no radar would be necessary, or alternatively that ASV Mark II would be adequate. Early in 1944 it was announced from America that the Liberators available would have SCR-717 and AN/APQ5B already installed, so RAAF Command agreed to accept them with this fitment. SCR-717 is a sea search 10 centimeter radar specially designed for anti-submarine work and AN/APQ5B is a highly specialised radar used in conjunction with SCR-717 as a low altitude bomb sight - that is, below 2,000 feet.

The first 78 Liberators arrived without radar and RAAF Command immediately asked for retrospective fitment to standardise them with the remainder. RAAF Headquarters agreed to fit SCR-729 but as the remaining radar required 3,000 man hours per aircraft and manpower was exceedingly short, no action was ever taken to instal it and the project finally lapsed, RAAF Command still requiring it and RAAF

Headquarters unable to comply.

In August 1944 RAAF Command asked that all Liberator crews should be trained in the use of LAB and as a result Flt Lt's McQueen and Tyler with two aircrew officers were sent to USA for training in its use. At this stage it is necessary to point out that APQ5B had been built specially for very low altitude attack on ships under conditions of zero visibility and two special American squadrons had operated in this area in 1943 with excellent results. The equipment, however, was so highly specialised that only continuous practice and the devotion of the aircraft to this special role full-time was likely to achieve reasonable results. It is not clear, therefore, why RAAF Command specified that all Liberator crews should be trained in its use.

On return of the party from America training of mechanics and WAGS was commenced at Radar School, Maryborough, using SCR717 equipment which had been used to train American personnel. From there partly trained WAGS went to Ballarat where they joined aircrew members and received further training on ground handling and some flying. They were finally crewed up at Tocumwal in the heavy bomber OTU and an attempt was made to produce efficient low altitude blind attack crews.

From the start the project was unfortunate. As with many previous RAAF aircraft an attempt was being made to produce a general purpose crew and therefore a correspondingly short period of time was available for radar training, the period being in fact about one-quarter of that declared by the Americans to be necessary. It was argued that this extra time would be made up when crews arrived in operational squadrons but here again arrangements seemed to

go wrong as the aircraft were used mainly for high altitude day work and later in close support and there is no record of the special radar equipment ever being used against the enemy. As the strategic situation was changing fairly rapidly about this time the reason for this may have lain in the move of the Japanese northwards but the net result was that practically all the time and effort spent on radar training, particularly in the use of APQ5B, was wasted. A similar story with minor variations can be told of Loran in those days.

THE PROBLEMS OF EQUIPMENT

Organisation for Production

Of all the problems which confronted radar the production of equipment was by far the greatest. Enlistment of personnel, training, and establishment of suitable organisations were all easy in comparison, as they followed accepted Service practice. Never before, however, had the Services been faced with the problem of translating a scientist's dream into an operational requirement and then securing equipment to put it into practice. The original conception has been mentioned in the discussion on Radiophysics Laboratory. In this case RP Laboratory was to produce prototypes and PMG Laboratory was to arrange manufacture.

The first problem which arose was the need for operational tests on the prototype. This meant that the RP Laboratory had to produce equipment which could be used operationally by the Services. A strong Service flavour was therefore necessary in the RP Laboratory. Unfortunately, this had not been arranged, partly because the problem does not seem to have been properly appreciated, partly because of the shortage of suitably qualified personnel, and partly because the Laboratory intended originally to do only "Research". The Laboratory in those days tended to be a law unto itself and the result can be seen in the ASV equipment which, when finally produced as a prototype complete with manufacturing drawings, could not be manufactured without re-design.

When the British ASV equipment was handed to the PMG Laboratories, success was finally achieved as the same organisation designed the equipment and arranged production,

and this gives the key to the problem. By the end of 1941, and with the entry of Japan into the war, production problems reached new heights. The Americans entered the field and it looked as if chaos would develop. Fortunately the problem was properly appreciated and it was decided that a central organisation should co-ordinate all radar production. In January 1942, therefore, the matter was handed to the Department of Munitions, a Directorate of Radio and SignalsSupplies being formed to deal with it.

This directorate was headed by Lt Col S.O. Jones, an Army signals officer, who had seen service in the Middle East and had been a PMG engineer. From then on things took a turn for the better although the most difficult stage was just beginning. The Directorate of Radio and Signals Supplies, although formed from scratch and comprising an untrained staff, gradually gained control of supply arrangements and finally was able to look after production as well. The story of radar at this stage (1942-1943) is one of continual shortages of vital items of equipment. Very great difficulty was experienced in securing supplies of "micropup" transmitting valves which were the essential valves in ASV as well as SHD and AW. These were secured in very small numbers from overseas until finally the Directorate was able to set up manufacturing facilities in Australia.

Similar difficulties were experienced with many other types of equipment including concentric cable, 1852 valves, etc etc, but the co-ordination of all requirements under one Directorate enabled supplies to be distributed in order of priority and saved untold duplication and confusion. In the services a working committee had been set up to advise day to day distribution of items in short supply as they

became available, while with the move of GHQ to Brisbane an Allied Services Signals Standardisation Committee was organised on which all Services, together with Munitions and CSIR were represented. This committee helped to eliminate duplicate production and ordering of equipment and at the same time had some success in persuading several services to accept the one type of equipment instead of having a special design for each.

Supply from Overseas

The institution of lease-lend arrangements by America in 1941 opened the way in theory to the unlimited supply of American equipment and an organisation was set up in Washington to procure and despatch equipment as it became available. The difficulties which this organisation experienced and the complications of procedure are almost unbelievable. The RAAF sent Squadron Leader J.T. Phillips to Washington towards the end of 1942 for the official purpose of securing information on the situation and returning to Australia. Actually he stayed in Washington for nearly two years and was able to shepherd Australian radio and radar orders through the many supply channels.

Ordering in Washington was done by Australian War Supplies Procurement and in Australia a section of the Customs Department, known as Division of Import Procurement, was the ordering authority. The complications which arose between Division of Import Procurement, Munitions and the Air Force in Australia and AWSP and the Air Force in Washington were considerable. As an example of what happened, Australia was asked, early in 1943, for its forecast of airborne radar requirements for the next 12 months. Although this request had been with Div. Impro. in Australia for some considerable time, the Air Force was given only a few days to produce the answer. After this

forecast had been telegraphed to Washington by Directorate of Radio and Signals Supplies, Washington asked for firm orders, giving only one day for a decision to be made. Munitions passed the forecasts as firm orders, the figure totalling about £2,000,000.

Most of this had later to be cancelled owing to changing Air Staff requirements, causing ill feeling on all sides. This one incident is quoted as an example of many similar occurrences which indicated the confusion existing at the time. Towards the end of 1943 the position began to stabilise and the Directorate of Radio and Signals Supplies gained a firm grip on the situation. From then on ordering became easier and things were sorted out much better.

Research and Design for Production

It has already been shown that from an early stage complications arose between the research and the production organisations and a study of past history may help to point the way for the future. In the original conception Radiophysics Laboratory was to undertake research and development and the PMG Laboratory production. Very quickly difficulties arose owing to overlapping or gaps between the two organisations and no real satisfaction was ever reached until the one organisation handled all aspects of the problem. The Radiophysics Laboratory soon realised its shortcomings and endeavoured to overcome them by setting up a model shop in which workable equipments could be produced in sufficient numbers, to provide up to half a dozen for operational use.

Very soon too the PMG's Department practically withdrew and the problems of production were taken up by the Munitions Department. The situation had thus changed to Radiophysics producing workable models and Munitions organising production with the manufacturer. Here again things went wrong. Most RAAF production was done in Sydney

where the representative of Munitions was the Board of Area Management. Unfortunately Munitions Headquarters in Melbourne appeared to have very little control over the Board of Area Management which caused considerable trouble by acting regardless of Melbourne wishes, and it was only the presence and tact of the RAAF Radar Liaison Officer in Sydney which allowed arrangements to run smoothly.

Taking a cue from overseas methods Radiophysics and munitions finally adopted the practice of inviting engineers from the radio firm selected to make the final equipment to work in the laboratory until finality had been reached and then take the prototype to their own factory and organise production. In this way a reasonably smooth process was finally arranged. Experience gained by the Australian organisation, combined with policy developed overseas, points more and more to the importance of not separating research development, and to a certain extent, design for production. On the other hand it is the declared policy of CSIR that Radiophysics Laboratory must confine itself to pure research and that other organisations can be given the job of development and design. This policy, though declared during the war, was never carried out. In the first place, Radio Physics Laboratory did practically no pure research, and secondly the logical development of the system forced on them the necessity for following the job through to the manufacturing stage.

If the policy is to be followed, the laboratory does not need its large model shop which should be given to the appropriate organisation. Above all though, it is essential that the organisation for applied research, development and design for production be co-ordinated.

The New South Wales Government Railways Annexe

As soon as Radiophysics commenced the production of prototypes and the SHD programme was accepted, need arose for the manufacture under conditions of reasonable security, and particularly where suitable priorities could be obtained, of the new equipment. Early in 1941 the Radiophysics Board decided that this work would be done in the New South Wales Government workshops. As the work grew in scope however, it soon became necessary to set aside a special establishment for the purpose and at the end of 1941 a special Railways annexe was established from money provided by the Radiophysics Board.

This annexe was under the direction of the Chief Electrical Engineers Department and Mr J.G. Worledge was directly responsible. Its first efforts went into the production of SHD aerial systems for the Army but interest very soon shifted to RAAF AW aerial systems which were based on the Army SHD. From then onwards RAAF work grew considerably and included such items as the construction of a combined operating hut and aerial system for AW and the installation of English CHL arrays on these huts when necessary. In August 1942 the first LW array was produced and from then on the annexe devoted most of its effort to LW, a total of well over 100 arrays eventually being produced.

From the beginning of 1944 the annexe acquired a very wide field of interest, producing LW centimeter sets for the Army, prototype centimeter sets for the Americans and prototypes of a number of equipments for the RAAF. The remarkable thing about the annexe was the versatility of Mr Worledge. His ingenuity and readiness to meet suggestions for improvement often meant that modifications to equipment were produced almost as quickly as their need

became apparent.

So co-operative and understanding was he that it was decided that the RAAF programme would benefit considerably if he visited the operational areas, and early in 1943 he did a tour of the New Guinea areas, gaining first-hand information of the problems being met by the LW/AW radar and on his return was able to contribute materially to improvements in design. It can reasonably be said that without the services of the Sydney Radar Liaison Officer on the one hand and Mr Worledge and the New South Wales Government annexe on the other, development of RAAF ground radar would have been from 6 to 12 months slower.

Movement and Storage of Equipment

With the movement of the war northwards a Transport and Movements Organisation was established to take care of the extended lines of communication. This organisation had sections at all focal points and was responsible for receipt, storage and forwarding of equipment from Southern areas. Its operations involved for one reason or another the loss or ruin of many thousands of pounds worth of equipment.

In the first instance equipment was despatched from Southern areas inadequately packed, with the result that serious breakages and pilfering occurred. On arrival at Northern areas such as Townsville, inadequate storage was available for equipment awaiting forwarding, with the result that the already broken packages lay for considerable periods in the rain. Further damage during shipment followed by more extensive periods in the open resulted in much of the equipment which reached such places as New Guinea being practically useless.

Fortunately, the radar organisation suffered less than most from this system, mainly because equipment was fragile and secret and consequently received better packing and was usually escorted. However, considerable damage was suffered and a move was made in 1943 to produce adequate sets of transit cases which would ensure proper protection of the equipment in transit and storage.

A further problem appeared, when on a number of occasions during landing operations radar equipment was thoroughly swamped by salt water with tragic results. In 1944 therefore a determined effort was made to produce a set of transit cases which would be sufficiently strong for transport purposes and which would be watertight when closed, so that if necessary they could be thrown overboard and floated ashore. By the end of 1944 these cases were approaching production and several of the radar stations which took part in the Borneo operations were fitted with them.

To summarise, it may be said that, from the many bitter experiences of losses during transit and storage it became obvious that the greatest possible precautions had to be taken in the construction of transit cases, otherwise the strenuous efforts of the production organisation were largely wasted.

Tropicalisation

Before the war commenced the RAAF had seen very little service in tropical areas and although it was realised in a general sort of way that special precautions were necessary in the manufacture of radio equipment to withstand tropical conditions, no experience of these precautions had been obtained. From the radar point of view the tropical problem was first seen at Milne Bay towards

the end of 1942. A CHL equipment was established there but it was soon found that the receiver broke down frequently due to arcing over of high tension components. It was also found that this trouble occurred only after the equipment had been non-operative for some time, and herein lay the secret which was to save us for almost two years before proper precautions were taken.

It was realised that the breakdowns were due to the condensation of moisture on and in various components such as transformers owing to the cooling down of the equipment and the sucking in of humid air which then condensed. Very soon after this AW radars without special tropic proofing were sent to the New Guinea area and it was found that the provision of a heating element at the base of each cubicle would save most of the trouble. The element was switched on whenever it became necessary to close down the equipment, thus ensuring that the air inside the cabinet was well above ambient temperature at all times. These precautions combined with the sealing of high tension transformers in airtight cans made the AW radar a reliable equipment under almost any conditions.

It should be noted at this stage that this is only half of the trouble of tropicalisation; the other half lies in the problems of transit and storage. It is probably safe to say that almost any piece of radio equipment which has been constructed to sound manufacturing principles will operate indefinitely if treated as outlined above. However, special precautions are necessary for equipment which is to be left in store for some time or transported by road or sea. In this case high humidity often results in the growth of fungus on various components and deterioration of metal finishes, etc.

It was this fungus growth combined with results of bad maintenance and atrocious transport and storage which finally prompted a move by CSIR early in 1943 to attack the tropical problem. A number of scientists were appointed and Flt Lt Kerr-Grant, a RAAF radar officer, was attached to the party which then proceeded to New Guinea to examine tropical conditions. The party investigated all manner of tropical conditions, particularly the performance of clothing, etc, but it cannot be said that much advantage accrued to the RAAF radar organisation from their investigations, which tended to be long term rather than immediate. In short, the progressive modifications which had been introduced by the Service with the progress of time had already succeeded in making the radar equipment reasonably tropic-proof, so the discoveries of the tropical investigation section were more applicable to industry in the post war period.

Early in 1943 the RAAF began to take a keen interest in tropical problems. This was due to the impending South East Asia operations and it is quite surprising that the RAF who had been supplying equipment to the India, Burma, Singapore area for many years previously, had not already evolved its own tropicalisation processes. However, they had had word of the developments in Australia and in response to a request two officers, Sqn Ldr Hannan and Flt Lt Parr, were sent to England to assist the Ministry of Aircraft Production in any way possible. It is not intended to outline their activities here but the RAF embarked on a major plan of tropicalisation which was cut short by the early end of hostilities. This is an interesting example of Australian aid to the UK instead of the reverse.

THE PERSONNEL WHO MADE IT POSSIBLE

During Hostilities

No record of the radar organisation would be complete without special reference being made to the personnel who made it possible. There is a strong tendency to think of radar in terms of technical equipment capable of a certain performance and to ignore the human beings whose skill and ingenuity produced it and whose tenacity and enthusiasm made it produce the best results. Throughout this record, mention has been made in various places of individuals by name. They are not the only ones deserving comment, they merely happen to be those concerned with very interesting stages of development.

While great credit was due to those who built up the organisation and assisted in the design and production of the equipment, the greatest credit is due to those who worked on radar stations and in aircraft in the face of the enemy. We have the first classic example at Darwin where the personnel of the unfinished radar station took no part in the general evacuation which followed the first Japanese attacks, but worked with renewed vigour on their station. Throughout the whole war, the ground radar story repeatedly shows examples of this type of tenacity. Stations erected and operated on bnely islands or at inaccessible places in the jungle with very poor communications with base areas had to rely on their own resources to compete with the menace of nature in climate and disease or of the enemy in bombing or marauding forces. Aircraft using ASV put up very creditable performances, particularly in the case of night operations by Catalinas during which at least one enemy vessel was sunk. It was only the incredible courage and

ingenuity of all these people that made the organisation useful. Presented with comparatively untried and definitely unreliable equipment to be used in inaccessible areas where no facilities were available, they made it work and kept it operating, knowing that many others depended on them.

At the Conclusion of Hostilities

When thewar ended, the radar organisation included over 130 ground stations and 500 aircraft fitted. This required approximately 300 officers, 1500 mechanics and 1400 operators with a total of at least 4000 personnel of various ranks and musterings on ground radar stations alone. As soon as the demobilisation started, radar personnel appear to have headed the exodus with the result that shortly afterwards practically no radar personnel of any kind were left in the Service. The reasons for this are various, but there are probably two main ones.

Firstly, there were no permanent radar personnel, all having been secured for the duration of hostilities and they were naturally keen to get back to civilian life, many of them going to their original or new jobs and many others to finish University courses. Secondly, the lot of radar personnel, at least on ground stations, was not an enviable one. While they were happy to serve in lonely and isolated spots in the bush during war, they were not keen to continue this existence in peacetime. Combined with this was a certain resentment of their treatment.

When in 1944 signals and radar were combined, the radar people were placed under the control of the local signals organisation and,invariably, the signals personnel being senior, radar took a second place. They felt, rightly or wrongly, that in addition to this they were given a raw

deal by their signals masters and some resentment existed in many places.

All this points a lesson for the future. With the co-ordination of signals and radar, there must eventually be a common radioman rather than signals or radar, and the sonner this co-ordination is achieved the better. In the meantime, the radar people are not a dead loss; many of them are completing University courses and in a year or so time will be much more useful than they were when they left the Service. They are thus a potential reserve against the day when better terms and conditions can be offered them and really qualified men are again required.

CONCLUSION

Radar, which started from zero in 1939, became the greatest scientific development of the war. In conjunction with the fighters, it won the Battle of Britain, and in Coastal Command it put an end to submarine warfare. In conjunction with fighters, it stopped the Japanese raids on Darwin, and the tremendous Japanese losses at bases without Radar cover in the islands are an indication of what would have happened to Allied bases in Northern Australia and New Guinea in the absence of radar warning.

As far as Australia was concerned, it reached its peak in 1943. In the LW/AW and ASV Mark 2, Australia had two weapons which proved to be adequate for the rest of the war. For the war against the Japanese in particular, the LW/AW equipment was ideally suited to the conditions in this theatre and no other equipment in existence could have done the same thing so well. By 1945, however, a complete reversal had taken place. The war requirements had changed from air transport to sea transport, and European type radar was suitable for these tactics; in fact, with the possible introduction of RCM and the masses of aircraft likely to be encountered, European type radars were desirable.

Australian radar therefore suffered a complete eclipse; from being the only radar suitable to the area, it became outdated in the matter of a year and we finished the war with completely antiquated radar by European standards. This, combined with the almost complete loss of radar personnel, takes us back to scratch, but with one advantage; we are not hampered by masses of radar which might have been of use for some time during peace. Our

radar is so out of date that completely new and up to date radar - radar which has not even been designed yet - must be secured. It will be the outcome of research carried out on the new Rocket Range in South Australia, and our war-trained radar men will be the reserve of experience which will be necessary for this work in the future.

APPENDICES

RADIOPHYSICS ADVISORY BOARD

The history of the Radiophysics Advisory Board is really that of radar, at least up to 1943. The Board was appointed on the 26th October 1939 and held its first meeting on the 29th November 1939. Its constitution and responsibilities are set out in file 201/14/46 at enclosures 3A and 11B. The original membership of the Board was as follows:-

Professor J.P.V. Madson - Chairman
Director-General, PMG's Department
CNS
CGS
CAS
Chief Executive Officer, CSIR
Sir David Rivett

The Board was originally designed to control all Radiophysics activities in Australia and as time went on this control was extended from decisions as to what work was to be undertaken at the Radiophysics Laboratory to co-ordination of Service orders for radar equipment, co-ordination of manpower requirements, training, etc. The Board was originally under the Minister for CSIR but in May 1940 it was found necessary to change this control to the Minister for Defence Co-ordination who at that time was the Prime Minister. He appointed Mr Sheddon as his representative to deal with all matters raised by the Board.

This changeover became necessary owing to financial difficulties which arose because of the great number of Government Departments with which the Board had to deal. The original chairman was Professor (later Sir John) Madsen of Sydney University but when he left to visit UK in March

1941 the services of Professor White were obtained from New Zealand and Professor White occupied the chair until November 1941. From its inception the proceedings of the Board appear to have been dogged by misunderstandings. The Chairman of the Board was also the Chief of the Radiophysics Laboratory and a member of CSIR and as Sir David Rivett was also a member, CSIR had the biggest individual representation.

This was no doubt correct, as CSIR was fostering Radiophysics work, but it had unfortunate results which were largely due to the very high level at which the Board operated and the fact that while CSIR had technical representation, the Services were represented by their chiefs whose knowledge of technical detail was not extensive. The net result was that the Service Chiefs were "blinded by science" and the progress of radar was marked by a long string of promises which often proved impossible of fulfilment.

The trouble lay mainly in the fact that the scientists of CSIR, in the usual enthusiasm of scientists, did not foresee the difficulties involved and the considerable time necessary to design equipment and produce prototypes. Further, even when prototypes were produced they had to be handed to PMG's Laboratory for manufacture and it was then found that they had been produced by people without knowledge of commercial technique and, as a result, had to be re-designed before they could be manufactured. From the Services point of view the fault lay in the fact that there were no scientific advisers available to the Chiefs of Staff, with the result that the Chiefs had to meet the scientists in conditions where

they were out of their depth and had to waste much personal time listening to technical details which they could only refer second-hand to their technical staffs.

As time went on it became more and more apparent that the influence of CSIR on the radar programme was too strong. The problem had moved from pure research (if it had ever dwelt there for long) to development and production of prototypes. Further, the Chiefs of Staff began to realise that they could not cope with the technical detail involved and therefore in December 1941 a number of changes were made. The control of the PMG's Department had been switched to the Department of War Organisation of Industry and it was considered that Mr McKay, Chief Electrical Engineer, should be appointed to the Radiophysics Advisory Board. As Munitions was coming into the picture in the procurement of equipment, Mr Brodribb was also appointed to the Board. Mr Witt, Chief of the PMG's Laboratories, attended the meetings as representative of the prototype and production organisation and thus the Board acquired a production bias which was very necessary at this stage.

At the same time a Radiophysics Technical Committee was appointed to discuss technical detail. Members of this Committee were:-

Professor White - Chairman Sir John Madson	Radiophysics Laboratory.
Commander H.J. Buchanan -	Navy
Lt Col F.H. Nurse Captain N.R. Buring	Army
Gp Capt C.S. Wiggins Wg Cdr A.G. Pither	RAAF

Mr S.H. Witt - PMG

Lt Cdr Whittaker - RN

From this time onwards all technical matters were referred to this Committee whose proceedings were referred to the Radiophysics Advisory Board for decision as necessary. In July 1942 a further change took place when the Chiefs of Staff handed over their seats on the Board to their representative technical officers. As I was then Director of RDF, I was appointed to represent the CAS. All this time increasing dissatisfaction had been felt by the Services with the progress of radar, and at the meeting of the RP Board on 14th July 1942, a revolution took place.

The cause of this dissatisfaction was the conduct of the Radiophysics Laboratory and will be dealt with separately. File 201/14/173 sets it out in detail and it hinged around the fact that the design and production of radar equipment had lagged so much that the services had lost faith in the CSIR management. The Services arrived at the Radiophysics Board meeting on 14th July 1942, determined to overthrow CSIR control. CSIR was equally aware of the general feeling and Sir John Madsen opened the meeting by tendering his resignation (File 201/14/125 - Enclosure 28B). He pointed out that the role of CSIR was to engage in research and that the problems of production were rightly the problems of the Services or other organisations. Mr McVey was nominated as chairman and things looked like taking a new turn.

However, at the 22nd meeting of the Board on 24th September, it was announced that the Prime Minister had

decided to transfer the Board back to the Minister in charge of CSIR. Sir David Rivett stated that he had not been responsible for this move nor was he in sympathy with it, but there appeared to be no alternative. At this meeting considerable discussion took place concerning the proper roles of each of the authorities concerned with radar, ie RP Laboratory, Munitions, PMG's Department, RP Board, Services. This matter will be dealt with under 'production'. From this time onwards the Radiophysics Advisory Board suffered a decline. More and more work was done at the level of the technical committee and from the middle of 1943 onwards the Board became more or less a figurehead, meeting at less frequent intervals.

RADIOPHYSICS LABORATORY

This laboratory was formed late in 1939 for the purpose of carrying on radiophysics work in Australia. Initially (pre-war) it had the following role:-

(a) Instruction and training of staff in the use of equipment;

(b) Adaptations of equipment to suit the particular needs of Australia and New Zealand;

(c) Research on special parts of radiophysics, decided in consultation with Great Britain;

(d) Training of personnel for operating equipment;

(e) Assistance to neighbours, particularly New Zealand;

(f) Planning for possible production in emergency;

(g) Application of radiophysics technique to the needs of civil aviation and industry.

With the outbreak of war and the visit by Professor Madsen to England, arrangements were made with the British authorities that the Australian Laboratory should become a sub-centre to the main activity in Great Britain. The British Government was to provide samples of equipment, stocks of components and drawings of equipment. The Services immediately started asking for equipment and it was arranged that the laboratory would design and produce equipment up to the prototype stage and then hand over working drawings to the PMG Laboratories in Melbourne who

would arrange production. The RP Laboratory was accorded absolute priority in the acquisition of scientific apparatus, equipment and personnel, and grew very rapidly into a large and influential organisation.

Owing to an unfortunate combination of circumstances its operations were soon covered by a shadow from which they did not emerge for some years. From the RAAF point of view the ASV project was the main case in point. The original Australian ASV equipment was based on the British Mark I although a Mark II had already been designed in England, and because of repeated delays it had not reached prototype stage when a British Mark II equipment became available in Australia 18 months after work had commenced on the Australian version. Shortly after this the Australian version was ready for handing over to the PMG Laboratories and it was then found that although it had been brought to the prototype stage with complete working drawings, manufacture would be impossible without re-design by people familiar with manufacturing techniques.

This, combined with the fact that it was based on an antiquated design, led to the decision in August 1941 to hand the whole project to the PMG Laboratories who would proceed to copy a British Mark II equipment, starting again from scratch. Thus, from the RAAF point of view the RP Laboratory had spent 18 months on a project which was very largely wasted. From this time onwards the RAAF had practically no interest in the laboratory until the war with Japan and the advent of the AW equipment which, it may be said, was the only worthwhile produce of the laboratory in the first three years of its existence. In March 1942 dissatisfaction by the Services resulted in a proposal for its re-organisation. Details of this move are set out in file 201/14/173.

The following record of SHD equipment as provided by the Army on this file is an indication of the situation:-

July 1940 - Orders placed for six sets, this number later being increased to 30.

September 1940 - RP Laboratory informed the Board - "15 sets would be completed almost at once".

May 1941 - Professor White informed the Board that it appeared that in August next SHD sets would be in production at the rate of one per week.

September 1941 - A schedule showing delivery forecasts was distributed by Professor White covering 18 sets, the first to be delivered in September and the last in January 1942.

March 1942 - One set just installed and two others nearing completion.

A similar story is recorded of GL equipment. In November 1940 the Chairman of the RP Board reported that "work on an improvised GL set would be completed in 6 to 8 weeks". At the RP Board meeting on 24th September 1942 (file 201/14/125) it was decided to cancel all work on Australian GL equipment as adequate supplies were arriving from overseas. At this stage Australian GL had not commenced production .

The chief cause for complaint by the Services was the inability of the Laboratory to live up to its promises, due, the Services felt, to poor organisation within the laboratory. Various proposals for re-organisation were made but they never reached CSIR officially and the

Services responded by taking as many projects as possible away from the laboratory and dealing with them direct through manufacturers. In the case of the Navy this resulted in a contract for centimeter radar with AWA in which Radiophysics played no part.

The Air Force had no important items with RP until the beginning of 1943 when RP was invited to assist in the design of a transportable GCI. In July 1943 negotiations were again opened up for the design of an air warning equipment giving heights, and based on a 30 centimeter magnetron which had been produced by Professor Martin in Melbourne University.

This equipment is mentioned elsewhere but a study of its progress is outlined on file 201/59/4 - Enclosure 74A will serve to indicate the general situation:-

8/7/43 - Original specification raised (see file 201/28/258 - Enclosure 20) given priority 1 by Radiophysics Laboratory and an experimental set to be completed by December 1943.

19/4/44 - CSIR reported that the experimental set had reached the stage where co-operation with the manufacturer was desirable.

3/6/44 - Air Board Agendum 5881 provides £20,000 for the development of two prototypes LW/AWH Mark 2 to be delivered by December 31st 1944.

2/9/44 - File 201/63/1, Enclosure 7A, severely criticises Radiophysics for failure to carry out certain requirements for LW/AW Mark II and suggests that the project be taken from the laboratory and given to a suitable manufacturer.

22/11/44 - Experimental model to be tested at Bondi during December. AWA unable start their prototype until later.

After this continued delays and changed occurred until finally with the conclusion of the Japanese war the project was cancelled and diverted to a new system abandoning height-finding.

The problem of Laboratory, Scientist and Service has been dealt with elsewhere. That they can be made to work together is demonstrated in the success achieved by TRE and the RAF in England and MIT and the Services in America. Each had its troubles, no less than did the Australian counterpart. From the RAAF point of view, the RP Laboratory was extremely valuable at many stages in the war, the real possibility for improvement being the achievement of quicker and more definite results.

The one lesson which must be learnt for the future is the need for close and properly organised co-ordination, and above all, really experienced business management of the laboratory. This of course crosses the principles of the scientist who claims that he must be "free and unfettered". Unfortunately, however, the free and unfettered scientist is usually no business man, and the answer lies in some kind of compromise.

APPENDIX 'C'

VISITS BY OVERSEAS SCIENTISTS

The development of radar in Australia depended for its progress on contact with overseas. This was due mainly to the astonishing amount of effort which was put into radar both in England and America and the consequent difficulty of thinking of something which had not already been thought of before. This, combined with the need to concentrate on immediate requirements, resulted in the development here of overseas ideas to suit Australian conditions rather than much original work. Naturally some pains were taken to keep in touch with overseas organisations but the greatest benefits accrued from personal visits by outstanding overseas scientists. During the war there were visits by three noted foreigners - Professor Oliphant and Sir Henry Tizard from UK, and Dr Compton from USA.

Professor Oliphant

Professor Oliphant arrived here when things were at their worst in mid 1942. He brought a breath of hope from overseas and helped us, at a time when we were completely smothered by local problems, to get a glimpse of the future. He told of the developments of centimeter radar and forecast its use in specialised operations such as landings where it would be employed to direct the landing force from the control ship and by beach control parties ashore. Such techniques were eventually seen in action at Leyte and other places in 1944.

In a paper presented to the Radiophysics Advisory Board on 23rd June 1942 - File 201/14/125, Enclosure 15D - he summarised the overseas developments, compared Australian conditions as he saw them with those in UK, and emphasised

the need for the supply of better information to operational commanders. He felt that operational requirements arose more from the scientists' applications of his equipment to the problems of the commander than from the commander's request for equipment to meet a certain need, and he advised strongly that some simple arrangement should be made by which free exchange of information between Radiophysics and the Allied Command could take place. This advice was followed for a time in that conferences took place between Radiophysics and RAAF Command on several occasions but owing to various difficulties they were discontinued.

Sir Henry Tizard

In the Spring of 1943 Sir Henry Tizard arrived in Australia. Sir Henry, who was scientific member of the Air Council, had played a leading part in the applications of science to the RAF and who led the first UK radar mission to USA, approached the problem from a different point of view. His interest was more operational than detailed and in discussions with the CAS and the Senior Air Staff his suggestions resulted, amongst other things, in the establishment of an operational research section and an Aircraft Performance Unit. In addition he visited Radiophysics Laboratory and took back to England a very favourable impression of the Australian LW/AW.

Dr Compton

In 1944 Dr Compton of MIT visited Australia and the South West Pacific area to examine the general radar situation. As a result of this visit the American Forces embarked on an attempt to provide lightweight radar equipment based on the conversion of airborne equipment to ground use, and several prototype equipments were manufactured

by NSW Railways Annexe. At the same time some attention was given to RCM and a small team of American scientists came to Australia to work with the Radiophysics Laboratory on common problems.

These three visitors were the outstanding ones. On a lower plane numbers of Servicemen and civilians came to Australia from time to time and reciprocal visits were made. Such exchanges are vital to the rapid and successful progress of such an enterprise as radar and should be encouraged in the future.

APPENDIX 'D'

AIRCRAFT FOR RADAR EXPERIMENTAL FLYING

RP Laboratory

Throughout the development of radar, continual arguments took place concerning the provision of aircraft for the RP Laboratory. The first contact of the laboratory with aircraft took place at Richmond in the earliest days of ASV when English ASV Mark I was being fitted to four Hudsons. Even at this stage the elements of the difficulty became apparent. Either the squadron wanted to fly the aeroplane but was hampered by laboratory men working on it, or the laboratory men wanted to carry out air tests and the aircraft was unserviceable. With the removal of the ASV Programme from the laboratory, interest in aircraft waned until 1942 when the problems of temperature inversion arose.

It was found that under certain weather conditions coastal radar stations could detect shipping at ranges very much greater than normal and it was decided that investigation flights should be carried out on the Sydney coast in an endeavour to discover the cause of this phenomenon. After some trouble arrangements were made for an Anson from the Communication Flight at Mascot to do this work but from then on calls for aircraft from the laboratory became more frequent, particularly when it became necessary to test the Army SLC equipment which was being developed. When an American ASG equipment became available towards the end of 1942, a Beaufort was allotted specially for the installation and testing of this equipment and finally two Ansons were attached to Communication Flight Mascot for the special use of the laboratory.

It is now clear that the only satisfactory method of producing air co-operation for the RP Laboratory is to

allot aircraft permanently for the purpose. There is always a feeling on the part of the Service that the scientist is using the aircraft for purposes other than the agreed programme - that is, for purposes which do not appear to have any immediate application, but this must be accepted. A parallel can be drawn from the case of the British TRE where an entire RAF Station - Defford - was allotted for radio experimental purposes. In this case the station was used not only for purely experimental flying but also for the fitment of prototypes and special radio devices which became necessary to meet the rapidly changing tactics of the enemy.

Aircraft Performance Unit

The problems of radar development were finally faced by the RAAF by the establishment of No 1 Aircraft Performance Unit at Laverton about June 1944. This unit, which was a logical development from the test and performance flight, included a radar section and thus for the first time the RAAF had an organisation whose activities were devoted solely to developmental work. An effort was immediately made to build up the radar section of No 1 APU with equipment and suitably qualified personnel and from then on practically all RAAF airborne tests were carried out by APU instead of Radiophysics. It is important to notice here that greater efficiency would have been achieved had APU and the Radiophysics Laboratory been close enough together to allow co-operation. APU aircraft could have been used for RP Laboratory tests and vice versa and better results would have been achieved.

TRAINING

Most of the training problems have already been dealt with chronologically but it is appropriate to summarise the progress of radar training here.

Commencement Training

On my return from the UK in May 1941 we were faced with the problem of providing radar officers and mechanics to service ASV in GR squadrons. Flt Lt M.A. Brown was made available from the signals organisation and he with four wireless mechanics was sent to Radiophysics Laboratory about June 1941 to receive preliminary training in ASV. On completion of their course they formed No 1 RDF School as a lodger unit at Richmond, the first course commencing in July. This school was later enlarged.

About August 1941 Squadron Leader A.E. Mitchell and four RAF radar mechanics arrived from the UK with a COL radar station. I had made arrangements for this with Air Ministry whilst in England, the idea being to train ground mechanics for the RAF. By the time war broke out four radar courses had been started at the school, a batch of ten mechanics had been sent to England in October to join No 10 Squadron which was being fitted with ASV, and four officers and a number of mechanics had been sent to Singapore to assist in the forthcoming ASV project.

University Course

In August 1941, after considerable discussion between Radiophysics personnel and Chiefs of Staff and the Universities, agreement was reached to use Sydney University for RAAF radar officer training. I visited Sydney, Melbourne and Brisbane Universities, selected 50 suitable

personnel, had them enlisted and commenced training by 15th September. We thus had a reasonable number of officers in training although numbers of mechanics available were low.

Technical School Training

In September arrangements had been completed by the Signals people to carry out wireless mechanic training at Melbourne Technical College. Courses were started every month, 50 trainees to each course. The first course completed its training in Melbourne Technical College in February 1942, by which time arrangements had been made to draft half of these to radar school for a two months radar course, after which they would be available as radar mechanics. This arrangement continued for some considerable time and was the main source of mechanics.

Radar Operators

From the beginning difficulties had been experienced in securing suitable operating personnel. These were originally provided from failed aircrew and other personnel unsuitable in their original musterings, but in May 1942 ABO N 399 introduced the trade of Radio Operator Group II, commencing with a trainee radio operator who did four weeks at Radar School and twelve weeks on a Radar Station before remuster. This was followed in July by the commencement of WAAAF training.

WAAAF Training

As has already been explained, very great difficulties attended the introduction of WAAAF Radar operators in that although considerable numbers of WAAAF were available and were trained, objection by the Minister to employment of WAAAF at isolated radar stations and in Northern areas resulted in several hundred WAAAF trainee operators being unemployed for periods up to twelve months or more.

Training in Airborne Radar

In July 1942, with the commencement of No 1 OTU, arrangements were made for all wireless air gunners to receive some ASV training. This training had good results and in January 1943 a special ASV conversion course was started for the purpose of training wireless air gunners already in squadrons before the OTU syllabus commenced. These two courses were later extended to include other aircrew, including pilots and navigators.

The Liberator Problem

The receipt by the RAAF of Liberators from USA produced an outstanding problem, examples of which had been seen in varying degrees in respect to other equipment. The problem has been outlined elsewhere but it can be mentioned here that Liberator crews were first trained in Radar at the Radar School Maryborough, after which an air flavour was added in pre OTU training at Ballarat and finally an attempt was made to give operational training at OTU Tocumwal. Unfortunately equipment available was meagre and the problem was out of all proportion to the facilities, resulting in many Liberator crews being incapable of operating the equipment they carried. The fact that no operational use was available for the equipment was incidental.

Output from the School

Over a period of four years operations, the school produced the following personnel:-

Officers	...	300
Mechanics A	...	840
Mechanics G	...	687
Operators	...	1423

Lessons Learned

The outstanding lesson common to all equipment and nearly all wartime training is the need to have aircrews adequately trained before they are sent into operation with their equipment. This problem, although no doubt fully realised long before the last war, almost resulted in the abandonment of ASV in Coastal Command when it was needed most. It was introduced under the greatest secrecy, no training was given, and this, combined with the unreliable equipment, resulted in no use being made of it. Similar results were found in Australia on the introduction of ASV and the perpetuation of the mistake in the Liberator programme, although partly due to the very serious equipment problems of the time, was probably due in the main to the failure of the Air Staff to learn the lesson.

A further lesson learned was the need for catering for progressively lower standard personnel as the war continued. The original course of six months produced from the material available at the beginning of the war a reasonably capable mechanic. By the end of the war the course lasted more than 18 months and the final product was not as good as the product of the first six month courses. Probably the real solution to this problem lies in increased specialisation. By the end of the war, in spite of an extended training period, it was still necessary to train personnel in one equipment only and to re-train them for any new equipment. It may even be necessary in future to train in specialised parts of an equipment and this matter requires very careful watching.

When the war extends over such a wide area as it did in the Pacific another problem arises in the

transport of personnel to suitable centres for refresher training. The introduction of new radars, particularly ground type, should normally be accompanied by the provision of freshly trained crews to take them into the field; when manpower was scarce this was not always possible and in this case various makeshift means had to be employed such as the introduction of the equipment to the field by special training parties. I do not consider that this is the real answer as new radars are likely to be vastly different from the ones they replace, and the only adequate solution is the withdrawal of personnel to radar school for proper refresher training. The problem will always exist and must be met as the circumstances at the time dictate.

SOME FILES OF INTEREST

File No	Title	Notes
201/28/191	RDF Station, Moresby	
201/19/16	Use of IFF in Aircraft - Policy	
201/14/173	Radio Physics Laboratory - Proposal for re-organisation	Details of dissatisfaction with Radio Physics Laboratory
201/14/67	Submarine Location by RDF	Account of first successful submarine patrol
201/14/7	Training RDF School	
201/14/19	IFF Fitting to Ships - Policy	Discussions with the Navy on IFF
201/18/5	ASV in Hudson aircraft	
201/23/60	RAAF Reports to Radiophysics Advisory Board	History of radar up to September, 1944
201/14/46 201/14/45 201/14/125	Minutes of Radiophysics Advisory Board	Parts 1 and 2. See also later parts for further meetings.
201/23/64	Radio Physics Technical Committee	
201/28/27	RDF Liaison Officer, Sydney	
201/28/64	Radar Organisation in Australia	Criticism of radar and proposal for re-organisation
201/28/65	Radar Stations - Priority of Construction	
201/28/209	Schedule of Radar Stations	Schedules of Stations at various dates up to December, 1944
201/16/218	Transportable AW Sets for Allied Air Headquarters	The inception of transportable AW
201/20/59	Forecast of RAAF and WAAAF Establishments	
201/20/72	Personnel RDF Use of WAAAF Personnel	Story of the WAAAF
201/36/4		Development of LW/AW