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Working party on improvements to Canadian Air Defence System radars: interim report no. 1

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NATIONAL RESEARCH COUNCIL OF CANADA
RADIO AND ELECTRICAL ENGINEERING DIVISION

WORKING PARTY ON IMPROVEMENTS
TO CANADIAN AIR DEFENCE SYSTEM RADARS

INTERIM REPORT NO. 1

Declassified to:
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J. Y. WONG
Authority:
Date: JUL 11 1985

OTTAWA

JULY 1953

NRC # 21926

ANALYZED

NATIONAL RESEARCH COUNCIL OF CANADA
RADIO AND ELECTRICAL ENGINEERING DIVISION

WORKING PARTY ON IMPROVEMENTS
TO CANADIAN AIR DEFENCE SYSTEM RADARS

INTERIM REPORT NO. 1

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OTTAWA

JULY 1953

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SUMMARY

A Working Party from the National Research Council visited ADCHQ and both kinds of radar stations (AN/CPS-6B and AN/FPS-3 - AF/ISG-98) during the late spring of 1953. It is suggested that an RCAF group be formed to co-operate with this Working Party in examining in detail the capabilities of the system of Air Defence Radars as now installed, particularly the ISG-98 as soon as one becomes available for limited operational use. Such a group could arrange for NRC assistance in on-the-job training and in the design of extra test equipment if proved necessary.

No cheap "quick fixes" to improve the capabilities of the system were found. Working from the basic assumption that the present radars will be the backbone of the Air Defence System for many years, a series of possible alterations and additions to the radars are proposed. Generally speaking, full implementation of any one of these proposals would be a fairly expensive proposition and it is not in our province to recommend such changes. However, we believe that design of suitable equipments should be started at once and carried to the prototype stage so that, when a definite operational need arises, no undue delay will occur in meeting it. These proposals include the use of more modern display tubes, a careful watch for better receivers, the modification of antennas to provide more suitable cover or higher gain, the provision of extra or higher power transmitters for the Height Finders, and the design of an S band alternative to the ISG-98 using FPS-502 components. Additionally work should be started to develop other methods of displaying the video information available in V-beam radars in order to achieve better accuracy or greater range through increased visibility or both. Two new radars which may become necessary in the future should be designed. These are a short-range Doppler type set with exceedingly high clutter rejection and gap-filling radar capable of remote display at the present radar sites.

A plea is made for the immediate trial of teleprinter or teleautograph methods of mechanizing some of the telling and plotting functions in order to reduce the present reliance on the memory of operating personnel.

A list of Miscellaneous Comments includes suggestions for improvements through rearrangement of display consoles in the Search rooms, lighting changes, power wiring changes to give better regulation of voltage and frequency, and the use of wired television to repeat the situation maps in the Search rooms and the "blind" cabins of the FPS-3 stations. Additionally references are made to certain changes in operating procedures which could be considered. These points

lie outside the province of the Working Party but are given for completeness and include the careful segregation of personnel working in different coordinate systems (Georef and Polar) and the use of interim track numbers assigned serially within the station with later alteration if desired to system track numbers by the Identification Sections.

NATIONAL RESEARCH COUNCIL

Radio and Electrical Engineering Division

Working Party on Canadian Air Defence
System RadarsInterim Report #1

1. Historical: A Working Party consisting of Messrs. W.C. Brown, H.R. Smyth and E.L.R. Webb and with Dr. R.S. Rattie as coordinator was formed early in 1953 in order to meet a request of the Defence Research Board for a study of the Canadian Air Defence System Radars and to report on possible improvements. Several visits were made to radar sites and to ADCHQ, St. Hubert, in order that the party might become more familiar with the particular equipments in use in the system. Unfortunately, only a short examination of the AF/ISG-98 was possible since none of these equipments are as yet in operational use. This report is being written immediately after "Exercise Tailwind" during which the party split up in order to be able to observe both the AN/CPS-6B and AN/FPS-3 operating under heavy traffic conditions. We have not yet had the opportunity to examine any data collected by the RCAF during this exercise.

It is a pleasure at this point to acknowledge the cooperation and assistance rendered to us by personnel at the radar sites, at ADCHQ, AMCHQ and RCAFHQ, both service and civilian. The interest shown by all concerned made our task much more pleasant than we had anticipated.

2. Scope of this Report: It is possible at this time, we believe, to define some features of the future activities of the working party and to make certain proposals for further action. Some proposals are definite, some indefinite, some are major, many are minor. All are offered with full understanding that the Air Defence Radars are mostly still in a "shakedown" condition, that priority has been given to installation with cleaning up of loose ends following, and that certain deficiencies mentioned, as noticed by us or told to us by one agency, are in fact in the process of correction by some other agency. For reasons such as these we have not attempted to delve deeply into many points raised in this report but offer all for the sake of completeness.

3. Future Activities of the Working Party: N.R.C. proposes that this Working Party should remain in existence, with possible changes of personnel, to continue the studies already commenced. However, it is suggested that certain staff officers of ADC and RCAFHQ be designated as a cooperating group. It is suggested that this group could be charged with the responsibility of ensuring that maximum utility is secured from equipments as installed, and could speak with authority on possible alterations or additions. There should be an operator representation as well as technical personnel in this group. It is, of course, not in our province to suggest the make-up of such a group, nor, as a matter of fact, to ask for its formation.

4. Training in Operating Techniques: In order to get maximum performance from the radars, it is necessary to set the displays up with great care. This is especially difficult in the case of the RHI's. It might well be advisable to form a team to travel from station to station, observing and instructing in operating techniques. Such a team might well be organized under the technical direction of the above-mentioned RCAF group, and N.R.C. would be willing to contribute the assistance of scientific and technical personnel. Certain other aspects of station operation and maintenance such as the use of MFI, swept gain (STC), and differentiation (FTC) might well also come into the scope of such a training unit. It might prove advisable that certain experimental tests be made or certain extra test gear be devised. The facilities of the N.R.C. Ottawa Laboratories could be available for such work. Another phase of this training program might well be periodic visits to N.R.C. by station personnel, including NCO's from maintenance crews as well as technical and control officers.

5. Equipment Capability Studies: The above-mentioned RCAF group and the NRC Working Party should devise certain tests of the capabilities and effectiveness of the stations. We do not have good data, for example, on the high altitude cover of the stations. This might be obtained by controlled experiments with known reduction of sensitivity followed by careful extrapolation to full or normal sensitivity. Similarly tests should be made of the loss of height finding range due to the poorer visibility factor of the RHI compared to a B scan, and of the loss of search range on a highly expanded PPI compared to a B scan.

6. Major Design Studies: In the following list are included new pieces of equipment which we believe should be designed and tested whether or not an operational need arises in the future. The necessary studies could be carried out either in industry or by N.R.C.

(a) Long Range Search: Although the present radars have about reached the useful range limits for conventional aircraft as set by the spherical earth, new receiver techniques based on better crystals may give greater safety factors relatively cheaply. In this field, any developments should be monitored carefully. Depending possibly on the results of the capability studies mentioned above, revised antenna systems (particularly in the case of the FPS-3) may be required. Again U.S. developments should be monitored. This subject will have to be re-examined as soon as more data is available. We understand that a new receiver is being fitted to all FPS-3's. This process should be expedited and best grade crystals should be provided.

(b) Search Displays: One at least of each type of display, B, PPI (FPS-3) and PPI (CPS-6B), should be modified to accommodate newer CRT's, e.g. fluoride types. Extensive tests of these in cooperation with DRML might be extremely valuable.

(c) High Angle Cover: The necessary high-angle modification kit for the FPS-502 should be designed and tested so that if required the FPS-502 can provide supplementary high angle cover for the FPS-3 and CPS-6B.

(d) Short Range Coherent Pulse Radar: A radar of the Coherent Pulse type should be designed in order to provide, if required, supplementary close range cover with extremely good clutter rejection. Such a radar could be based on one of the Pulse Doppler radars recently developed by N.R.C. or Project Lincoln.

(e) Gap Filling Radar: A design, at least, is required for an equipment capable of filling certain gaps in the Air Defence System. This radar we feel, must be so designed that its displays can be sent long distances over video links and reproduced at the main radar stations. It might well be based on the FPS-502 but with a different antenna system.

(f) Height Finder (CPS-6B): It appears that the Height Finding range of the CPS-6B is less than desired.

This is technically not surprising since the antenna gain of the Slant Lower beam is far less than that of the Vertical Lower beam. A design is therefore required which will give higher gain in this beam and this will probably require the addition of a third slant transmitter. At stations where no "third sail" -- long range search -- is to be provided such a process should be quite feasible. At other stations the problem would be more difficult.

(g) Height Finder (ISG-98): Here again and more definitely the height finding range and perhaps more importantly the information rate are inadequate. Two separate programs should be run concurrently. The first affects range only and not information rate but preserves the desirable radio frequency dispersion of the ISG-98 as an anti-jamming feature. In this first program, the development of a higher powered magnetron in the 5 cm. band is required together with the design of a suitable modulator and radio frequency head. Approximately one megawatt is available at X-band and should be easier to obtain at 5 centimetres. Alternatively a travelling-wave-tube or klystron could be considered. A 50% range increase is to be expected.

Provided such a higher powered tube were available, or even without it, an increase of antenna gain of the ISG-98 would be worthwhile. The limit to antenna size would be the 35' radome. A 20' x 4' antenna could probably be fitted to the present mount and use the present feed. A 24' x 4' antenna could be fitted to a revised mount. The 20' antenna should give a range increase of 20%, the 24' an increase of 30%. The higher power transmitter and the 24' antenna together would nearly double the range. The use of a longer pulse length if practical would ensure the double range. It is necessary to retain the 4' dimension in order to cover a reasonable range of elevation angle in each rotation.

The second ISG-98 program should be the design of an equivalent S-band equipment using the modulator and R.F. head of the FPS-502 and again as big an antenna as can be put in a 35' radome. This change could be made in such a way as to cover the required angular sector of elevation with two beams only and not four as at present. Thus the information rate would be doubled. Under these conditions with the FPS-502 head and a 20' x 4' antenna a range increase of about 70% would be obtained and with a 24' x 4' antenna about 85%. It is apparent that this produces a slightly less favourable end result as far as range is concerned than the high power 5 cm. set and the larger antenna but the increased information rate might well be an overriding consideration.

In either program the provision of MTI on the ISG-98 is perhaps necessary at some sites. Any decision might well await operational experience but the second or S band program would use equipments to which an MTI system is being fitted. The S cm. program would require the development of a suitable MTI system. Perhaps this should be done in any case.

The following table using rounded figures presents a summary of these changes.

<u>Wavelength</u>	<u>Antenna Size</u>	<u>Power</u>	<u>Noise Figure</u>	<u>Pulse Length</u>	<u>Range</u>
5 cms.	14' x 4'	250KW	12 db	1.4 μ sec	100%
5	20 x 4	250	12	1.4	120
5	24 x 4	250	12	1.4	130
5	20 x 4	1000	12	1.4	170
5	24 x 4	1000	12	1.4	180
5	24 x 4	1000	12	2.	200
10	20 x 4	1000	9	2.	170
10	24 x 4	1000	9	2.	185

(h) Height Finder Displays: In both the CPS-6B and ISG-98, the HFI's now in use cause some loss of range compared to a PPI or B scan. The magnitude of such a loss is not known as yet. Additionally the accuracy of height readings is poor. A design study is required to find some form of display where one or both of these deficiencies can be improved. Advantage could be taken of relatively exact knowledge of range and azimuth to allow certain forms of signal integration in gated circuits to obtain increased visibility.

(i) Station Radar Information Wiring: It is apparent that extra radar equipment for low cover, high cover, gap filling, increased range, etc. will demand a "radar central" where a "switchboard operator" can route extra information to controllers or trackers as required. The design of such a central should keep pace with other developments.

7. Distribution of Design Studies: The above list of major design studies represents a large load on Canadian development potential. The following is a nebulous proposal for its distribution included only as a preliminary guide and an indication of what part of the load might be taken by N.R.C.

- (a) Antenna design if required - NRC or U.S.
- (b) Search Displays - C.A.L., C.G.E., or N.E., with NRC design supervision
- (c) High Angle Cover - Antenna NRC
- (d) Short Range Coherent Radar - a Canadian manufacturer with NRC design supervision
- (e) Gap Filling Radar - NRC initially
- (f) OPS-6B Height Finder - C.G.E. with aid from NRC on antenna
- (g) ISG-98 Height Finder - High Power Tube by Canadian Westinghouse or RVC. Remaining parts of program shared by Marconi and C.A.L. with NRC design supervision and antenna assistance
- (h) Height Finding Displays - NRC
- (i) Station Wiring - Canadian Industry

It should be noted that no contracts or financial arrangements are necessary with NRC and therefore work can be started immediately assurance is received that the RCAF considers a certain development is urgently required. On the other hand some development funds will be needed to pay for extra more or less complete units for conversion to new units. A reasonable estimate of this would be the total of one FPS-502 basic radar (excluding tower and radome) plus one each PPI display, RHI display, and B scan display. It is possible that these last could be supplied from spares now held by the RCAF but it is reasonable to allocate the funds in any case. Where programs will have to be handled through industry it is difficult to anticipate the charges but it would not be unreasonable to ask that an equal amount be provided for this purpose. These allocations would be for the fiscal year beginning in April 1954.

8. Mechanization of Functions: During exercise "Tailwind" it was apparent that the radar equipments generally speaking could generate data more rapidly than it could be analysed by the present system of telling, plotting, recording and placing on tote boards. It appeared that serious delays were occurring. Incomplete communication facilities contributed but the main cause was inexperienced operators. This last is unlikely to improve greatly especially when reserve forces are employed, as presumably would happen should hostilities break out.

In the distant future one can visualize something like CDS or Datar reducing confusion by simplification of tasks and in the interim future the possibilities of photographic systems being employed to add designations to raw radar data prior to projection on to situation maps, etc.

Since these systems are rather distant, it appears that an immediate easing of the situation should be sought. We would suggest that a trial should be made using equipments of the tele-printer or teleautograph kinds. In the former case, the radar operators or the present recorders would type the data into one of several systems. The output units would feed the plotters, the tote board operators and if required any supervisory personnel. Queries would not be allowed except through supervisory personnel, and would be less frequent since the plotters would rely less on memory. Since data could be allowed to remain idle for a few seconds, independent rates of telling and plotting could be established and it seems reasonable to assume that any small number of tellers could pass data to any small number of plotters. The rate or rates of telling could be adjusted to match the rate or rates of plotting and control could be exercised on individual operators instead of teams which although trying hard do not always pull as a unit.

If the radar operators are not capable of operating the keyboard either through lack of training or an insufficient number of hands, the present recorders, sitting near the displays instead of cluttering up the filter boards, could do the typing. If the radar operators could handle the keyboard, the recorders could be eliminated. Alternatively teleautograph equipment would allow the radar operators to write down the data instead of typing it and, if legible, the recorders could again be eliminated.

A similar system could be usefully employed between the filter room and the operations room. Again cross-telling and forward telling might be facilitated particularly since the data can be allowed to lie dormant until a plotter is free. A judicious use of flashing lights should serve to prevent undue delays. A reasonable elaboration of the system might

allow one teller-typist to feed data to more than one station and a single plotter to find data from more than one station on a single roll of paper.

9. Miscellaneous Comments: There follows a group of items where action may be useful or necessary. In some cases action is in hand. We have not considered these items in detail and offer them only as possibilities. Some are not even radar but strictly operational questions.

(a) Display arrangements: It appears that a rearrangement of the displays in both the CPS-6B and FPS-3 stations to allow the supervisor to see all the displays without leaving his own would make for easier transfer of plots between operators, and would generally speaking ease the supervisor's job or make better supervision possible.

(b) Lighting and clocks: It was noted that in many cases the minimum display room and cabin lighting was so located as to cast annoying reflections on the displays. Clocks were also offenders in this respect. Clocks in addition could not always be seen without turning the head.

The use of rheostats for lighting control is wasteful of power and presents an annoying hazard if left full down. Separate switching of certain circuits to preset levels would be much better and would reduce unnecessary heating of confined spaces. Less general illumination in filter rooms would be beneficial in this respect and could be secured if more contrast were provided by better choice of colours on the maps.

Corridor lighting appeared to be too high in some areas especially near the blind cabins (see below). A general reduction in level together with a change near the entrance door to help the shift into the outside illumination level might be useful.

This whole question of illumination might well be taken up with DRML.

(c) Telephone circuits: As outsiders listening at odd places, we noticed annoying changes of level on various circuits. More training on the use of the microphones might be the cure. We would not be surprised if an intensive study of the system revealed many useful rearrangements. In particular a facility for cross connection of tellers and plotters during a transfer from sector to sector might be very helpful.

(d) Blind Cabins: The blind cabins of the FPS-3 units need either a rearrangement or a light-look on their

doors. The clocks are bad offenders in these rooms. It might be possible in rearranging these rooms to provide by periscopes or other optical means a view of the operations board. Alternatively wired television might be employed. To date it appears that little use has been made of these blind cabins, and some experience in their use should be obtained.

(e) Wired Television: In addition to its possible use in blind cabins, wired TV might well be of value in repeating back information from the boards to the supervisors of display rooms, monitors, and from one board to the other's supervisor.

(f) Changes in Operation of Radar: Provision should be made to warn display operators and controllers of impending changes such as MTI to non MTI, gated MTI position, etc., with an additional feature of an appeal against such changes when a critical situation exists. A Public Address system might work but might prove to be more of a curse than a blessing if too many inputs were available.

(g) Supervisors' Displays: It is possible that a PPI readily available to the filter room supervisors might assist in rapid resolution of complex situations.

(h) Power Distribution: It is our belief that vital parts of the radar system, in particular the MTI equipment, need more protection from voltage and frequency variations and should be fed from a bus carrying only a constant or slowly changing load. A separate high grade regulator might do but this problem needs intensive study.

(i) Pressurization Noise at FPS-3 stations: The radome pressurization systems for the FPS-3 and ISG-98 are excessively noisy. This is not the case in the OPS-6B and the difference lies in the fact that the radome air is recirculated in the bad cases while only losses are made up in the case of the OPS-6B. The reason for recirculation is believed to be avoidance of moisture condensation at night. Since more equipment is inside the radome in the case of the FPS-3 than in the OPS-6B, it may be that the dehumidifying requirement is more stringent. It is urged that the responsible agency study the differences in requirements of the various systems with a view towards reducing the amount of air circulated in the FPS-3 and ISG-98 systems. Alternatively a redesign of ducting, filters, etc., is perhaps warranted. We are not competent to state the extent to which such an annoying background noise affects human operators adversely.

(j) Georef vs. Polar Coordinates: It was observed on one occasion that confusion between radar operator and plotter could be definitely ascribed to the fact that, while the display was in polar coordinates, the plotter was "living"

in a room where Georef was the rule and was also accepting some Georef plots from another station. Some of the previously mentioned auxilliary equipment such as the teleprinter or teleautograph devices or a wired TV link back to the radar supervisor would help to reduce confusion. Similarly a better polar grid on the map would aid together with a rearrangement of plotting duties to keep certain plotters always in "polars" and others in "Georef". On the other hand, the immediate conversion of all data to Georef through the use of video mapping on the displays might be considered. It is, of course, necessary to consider the proposed methods of data handling by automatic means before making any changes in coordinate systems.

(k) Interim Identification of Plots: It was observed that operators and plotters were frequently carrying in their heads more than one "initial plot" for considerable periods of time with resulting confusion. It appears that it would be advantageous to give immediate track numbers to all tracks without reference to the Identification sections. Such track numbers might be for use solely within the station, might be allocated serially, might be removed when a proper identification was found, or might be preserved as a station serial number with the cross reference to the track number of the whole system never appearing on the map but only on the tote board.

10. Priority: We would suggest that immediate attention be given to the formation of an RCAF party corresponding to the NRC Working Party (Para. 3), and to the setting up of an on-the-job-training program (Para. 4). The studies of radar capability would follow the formation of the above group.

Of the Major Design studies (Para. 6), work on the displays (b) (h), should be started immediately and that on the range increases for the Height Finders (f) (g) should get under way as soon as the various agencies concerned can be brought together to produce rough requirements. Certain proposed antenna changes for improved high angle cover (a) (c), may await studies of present cover. The two new radars and video link (d) (e), will have to await firmer requirements although it is possible that certain NRC developments now in hand for other reasons might find themselves being modified in conception.

We regard tests of mechanized telling (Para. 8) as of the greatest importance.

Of the Miscellaneous Comments (Para. 9) we regard the display arrangements (a) and lighting (b) as meriting attention in the near future. Power distribution (h) is expected to cause poor functioning of the radars if action is not taken. Although slightly outside our province, we regard the questions of coordinates (j) and identification of plots (k) as requiring immediate attention.