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RECOMMENDED RESEARCH PROGRAM FOR CARRIER ALL WEATHER FLYING

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RECOMMENDED RESEARCH PROGRAM FOR CARRIER ALL WEATHER FLYING

A. Brodzinsky

April 27, 1949

Approved by:

Dr. R. M. Page, Superintendent, Radio Division III

DEPARTMENT OF THE NAVY OFFICE OF NAVAL RESEARCH

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ABSTRACT

The Carrier All Weather Flying program being prosecuted by NRL is defined in scope and goal. These definitions are derived from three phases of the CAWF problem under active investigation, and the separate steps in the scientific program necessary for attaining the desired goals are indicated. Where possible, schedule dates have been assigned. For all phases beyond the present state of active program research, recommended or intended procedures are presented. The points of co-ordination of this recommended program with other agencies and programs are indicated.

PROBLEM STATUS

This is a first report on this problem; work is continuing.

AUTHORIZATION

NRL Problem R04-42R, CNO Aviation Plan #73

RECOMMENDED RESEARCH PROGRAM FOR CARRIER ALL WEATHER FLYING

INTRODUCTION

An investigation and study of the Carrier All Weather Flying (CAWF) problem, sponsored by NRL under problem R04-20D, lead to an ONR presentation (December 11, 1947) and an NRL report on the results and conclusions reached by that study.[1*] The major conclusion was that the basic method of solution to the all-weather problem should be to "...gather all the data relative to the operation of aircraft in a given area, at one central point, where it can be correlated and interpreted by equipment and personnel not preoccupied with the task of operating the aircraft. When this task of data evaluation is completed..., the data can then be relayed in a directly usable form to the pilot of each aircraft...." From this conclusion and the analyses subsequent to it, NRL problem R04-42R was set up in accordance with Aviation Plan #73[2] covering the experimental research work to be undertaken in order to determine the technical feasibility of such a system and to specify the necessary component parts. In conducting this work it was recognized that many projects of a similar functional nature were being carried on at other government and industrial establishments. Few, if any, however, were directed primarily toward solutions of the Navy's carrier problems from an over-all point of view. It was therefore decided that the activity of the Naval Research Laboratory would be directed solely toward those problems, but that techniques and equipments developed for other uses should be applied wherever possible.

In part, this report outlines the applications that are being made of data relay techniques** to three distinct phases of the CAWF problem. It will in addition cover a program analysis of each of these three phases in order to establish: (1) the extent of each investigation and hence its

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* All references are at end of report.

** These techniques were previously brought to an advanced state of development and operational use in the Airborne Early Warning system under the sponsorship of the Bureau of Aeronautics.

proper culmination insofar as NRL's research activities are concerned; (2) a work flow plan based on projections of the present status and rate of progress; (3) estimated time schedules, also based on present experimental progress; and (4) recommendations for the further prosecution of each phase.

Although obvious similarities of techniques and even identical component parts exist between these three phases (especially since they constitute intended solutions, based on the same basic method, to different parts of one broad problem), the three projects are sufficiently independent to justify separate analysis and prosecution for each, except where indicated. These phases are defined as follows. (For a more detailed discussion see reference 1.)

Data Relay Navigation (DARN) - This basic investigation concerns the navigation of carrier aircraft by means of an airborne PPI visual indicator which displays to the pilot a reproduction of the target information seen by a shipboard search radar. This information is radio relayed omnidirectionally from the ship to all properly equipped aircraft within the range of the relay link. Nonradar information such as commands, intercept vectors, rendezvous points, weather, etc., can be inserted into the PPI display by means of video mapping techniques at the ship base and so received by all aircraft. Self-identification and possible altitude separation of information can be obtained with a coded airborne-beacon response, a technique which may additionally be used for pure beacon detection of aircraft, while the radar echoes are used for detection of nonbeacon-equipped targets, and natural land targets.

Data Relay - CCA - This project is an extension of the DARN system for specific application to the final approach radar AN/SPN-3 used in the Carrier Controlled Approach (CCA) system. Because of the nature of this radar, its operational functions, and the type of display, many of the components developed for the DARN system can be simplified and streamlined for the CCA system. The short range used in the present final-approach radar (4 miles) reduces the complexity of self-identification problems, and the standardized character of the flight maneuver involved permits the video-mapping presentation of only a single course line. For operational use this facility is intended either as a pilot monitor to the present CCA voice link, or as the primary final-approach instrument with a voice-link monitor. It could then tie into the DARN system, which would provide the necessary stacking, traffic control, and feed-in facility to make the over-all operation almost independent of voice channels.

Automatic Landing - Undertaken as a long term project to provide more efficient approach and landing operations than possible with the CCA system, this phase applies the data relay techniques to a "closed loop" system of automatic control of close-range aircraft. The system gathers radar position information of approaching aircraft, compares this actual position with the desired one, and then sends generated error signals via a data-relay link to the aircraft, where it is converted into a correction-control motion of the aircraft.

With these definitions, the CAWF program prosecuted by NRL may be examined, work flow diagrams of each phase may be set up, and the intended goals of each phase explicitly stated. By doing this, it will be possible to make concrete recommendations concerning the further prosecution of the CAWF program by NRL and also to indicate the action necessary to utilize these technical developments as possible solutions to some of the all-weather problems encountered by the operating fleet.

DATA RELAY NAVIGATION (DARN)

The general principles of DARN, as first reported,[3] have been implemented by the experimental development of the various components necessary for its operation as a system. In the development of the components for the DARN system, equipments and techniques currently available have been used as far as possible, and modified only where necessary. This has resulted in a considerable economy of both funds and time. For example the radar is a modified SP-1M, the synchronizing central is a standard part of the AEW system, the airborne indicator is a modified AN/APS-15 remote radar scope, etc. In two cases however, extensive research and development work was required. The first was the airborne decoding circuits and the second was the 1000-Mc video relay transmitter. In addition, as shown in the program flow chart of Figure 1, several studies have been initiated in order to determine possible optimum methods in the solution of some of the more basic problems. However, even the final experimental system used for evaluation will not be considered by NRL to be a production protype. Rather, it will be a research instrument to be used in obtaining the data necessary to specify and recommend the technical characteristics of an operational system.

Ground Equipment

SP-1M Radar - This truck-mounted S-band, one-megawatt radar is used for gathering the long range radar information. The modifications necessary for external synchronization, external antenna drive, video map mixing, and a cosecant-squared antenna pattern in the vertical plane have been incorporated and tested.

Synchronizing Central and Video Mapping - The synchronizing central which provides the basic trigger pulse, rotational (sine and cosine) pulses for PPI orientation, and sweep trigger pulse, in their proper time sequence, is merely a CAEV-60-acy video generator which was designed precisely for such a function for the AEW program. The video-mapping equipment developed at NRL[4] has been completed and, together with the synchronizing central, has been installed in the SP-1M operations trailer. The maps used at present show some outline geography surrounding NRL, but an experimental method for write-in information has been developed. The present experimental method employs photographic negative maps (transparent lines on an opaque background) so that write-in information is accomplished by scratching or etching a completely opaque plate. Although a crude method for doing this has been tested, it is recommended that a more refined method for such "negative take-off" should be developed, or else

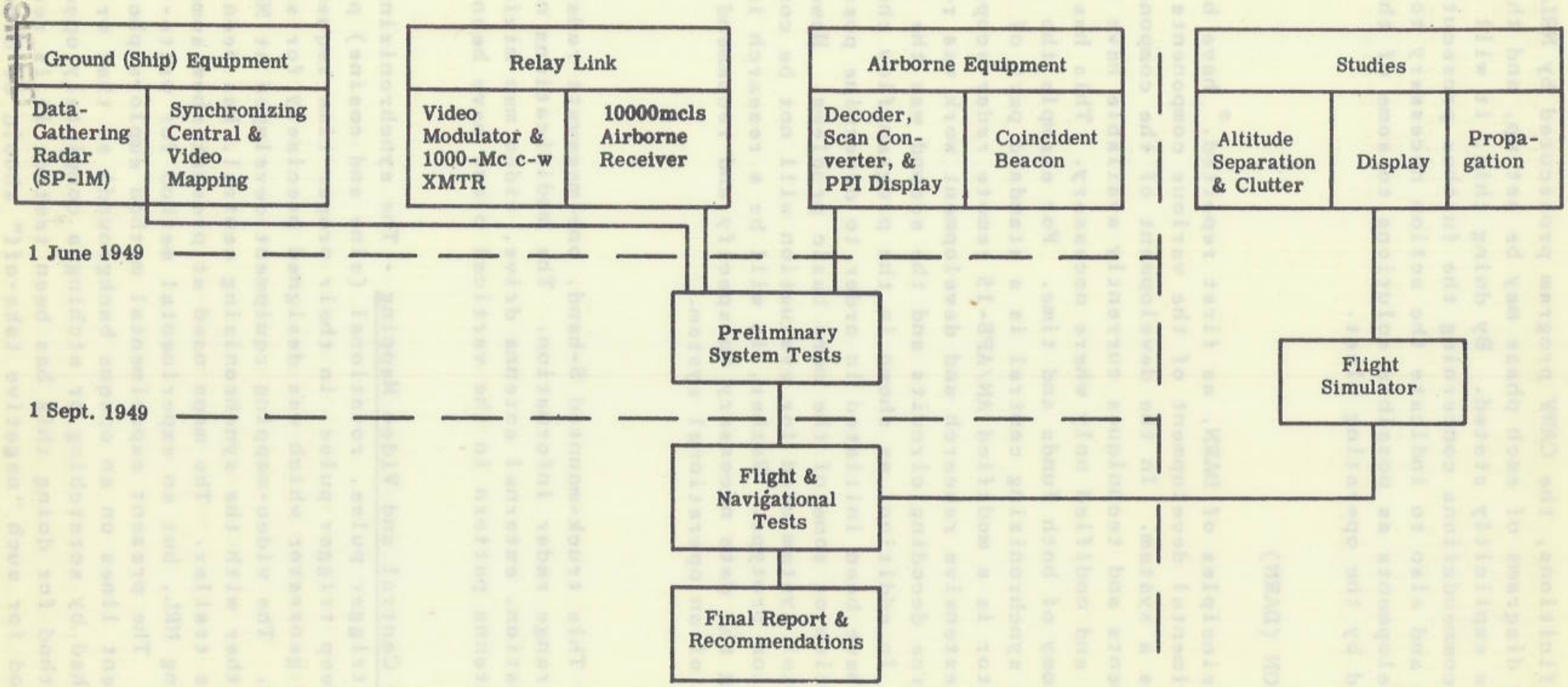

Figure 1 - Data relay navigation (DARN) program flow chart

a complete "positive take-off" method be evolved. This would allow the use of grease pencil writing on a glass or lucite plate. The optimum amount and type of information that should be included by video mapping has not been determined. However, a minimum of information, efficiently arranged, seems an obvious first requirement.[5] It is felt that although some psychological studies have been conducted, only real or simulated operational tests of the whole system will determine this conclusively.

Relay Link

An experimental 1000-Mc c-w transmitter, its associated video modulator and the airborne receiver are being developed to provide adequate omnidirectional coverage to the range limits of the SP-1M radar. Laboratory checks on the equipment developed thus far indicate that this will be possible. Airborne antenna installations and range checks will have to be completed before actual picture video is transmitted. It should be emphasized that the frequency of the relay link is important to the operation of the DARN system only insofar as reliable reception is obtained at the maximum range and the full bandwidth of video information is transmitted and received. A thorough study of the propagation characteristics for various frequencies, including the effects of antenna installation at both the transmitting and receiving terminals must be conducted in order to determine the existence of nulls in the radiation pattern and blind spots in the receiving pattern. Although this study is indicated in the flow diagram, no active efforts are being made as far as this specific application is concerned. It is recommended that this be done by specialists in the field.

Airborne Equipment

The airborne components necessary to display the final radar picture include (1) the pulse decoder and scan converter for obtaining the synchronous PPI rotation and sweep data, (2) the PPI display itself, and (3) the coincident beacon for providing self-identification on the airborne display and a return information path from the aircraft to the ship base. All these equipments are in the final stages of development although their ultimate form is by no means fixed. In order to be useable in the relatively small aircraft types operating from carriers, these equipments must achieve a maximum of compactness and a minimum of weight. Therefore, although NRL does not intend to carry out an extensive "packaging" program, some effort has gone and will continue to go into mechanical and electrical design to meet these ends. The present indications are that the airborne equipment will weigh a total of 50 pounds, enclose approximately 3 cubic feet, and consume under 1 kilowatt of power.

Preliminary System Test

As shown in the program flow chart, the component parts of the DARN system are expected to be experimentally operable approximately 1 June 1949. This will then allow a complete test of the integrated system for determining the performance of the components, and the resolution and reliability factors; and for establishing operational procedures. These tests will involve no flight facilities but rather the relay of the SP-1M radar information from some suitable site to a remote receiving location for display. At present the radar is located near the NRL grounds and the transmission path will be very short (several miles), although facilities exist for installing the experimental receiving gear in a small boat and extending the transmission path some 15 or 20 miles along the Potomac River. It is recommended that, after preliminary tests, the radar site be moved to the NRL Chesapeake Bay Annex at North Beach, Maryland. This will allow range checks of picture receptio to the maximum design range (50 miles). Such tests will undoubtedly uncover some equipment deficiencies or undesirable interactions between components, but it is felt that a 3-month period will suffice to prepare the entire system for flight tests of the airborne equipment and to run navigation courses from the airborne display.

Studies

As already indicated, several separate study programs are necessary in order to be able to optimize the DARN system and to provide a sound technical foundation for the final recommendations. These studies include:

A) A determination of the necessity and means for altitude separation of data so that the airborne display will show only the given air stratum which is of concern to a particular aircraft. Such a presentation would certainly tend to decrease the amount of pictorial information perceived by the pilot and hence to decrease the chances for confusion. Also, fortunately, the attendant increase in system complexity would take place mostly in the ship-based equipment. Such a provision is included in the proposal of other air-navigation systems (e.g. Teleran, by RCA, Navar by FT&R). However, as in all other cases of comparison, it must be kept in mind that of all such systems, DARN is the only one whose entire development is aimed at carrier aircraft problems and their solutions. Hence the need for altitude-layer separation must also be considered solely from that point of view.

B) A study of sea-clutter minimization, either by the use of MTI, or else by utilizing an off-frequency reply from an airborne beacon for the primary echo source. The latter would provide very high target reliability, but would necessitate the continual proper operation of one beacon in every aircraft in the system. By properly coding the beacon reply, it could also be used for altitude-layer information. The additional use of the radar echo as an auxiliary data source would allow the detection of nonbeacon-equipped targets, land masses, etc.

C) An investigation of circuitry for allowing common use of the DARN indicator with other functions such as approach and landing operations, air intercept, flight formation displays, etc. This study will also continue the work begun on the video-mapping project to determine the optimum amount and arrangement of video-inserted information. Also included in this study will be an investigation of heading-stabilized airborne presentation, i.e. making the top of the airborne PPI correspond to the aircraft heading. At present, the system is provided a reference fixed with respect to the carrier base, which obviously will not look the same (relatively) to all aircraft. Such investigations will be carried out in cooperation with the cockpit-presentation studies being conducted at the Special Devices Center.

D) In order to carry on both the component developments and these studies it has become apparent that a simulation of the airborne presentation will be necessary. This may be accomplished, through suitable circuit developments, by using a Link Trainer, with a video-mapping equipment as the radar simulator. This will provide a completely controllable laboratory check point for the various circuit and component developments before integration into the system proper. Although it is probable that this simulator will not be ready before the components of the system have been completed, its utility for the evaluation of this and the developments of other projects will undoubtedly be high.

Navigational Tests (Program Goal)

Since the system is primarily a navigational aid, extensive flights to determine its effectiveness as such must be conducted. The emphasis at this point will not concern the technical details, but the utility of the airborne display of ground radar in aiding flight operations under all weather conditions. The NRL program, at this point, cannot easily include such flight evaluations from an actual carrier using installations in an operational aircraft; nor can it include more than one aircraft. Therefore, the program should call for a shore-based test using the SP-1M radar and an airborne installation in the most suitable aircraft available. Because of the close coordination between NRL and the Special Devices Center on their respective portions of the assignments of Aviation Plan #73, it is expected that a DARN installation will be made in an F7F aircraft which is being modified under SDC cognizance for CAWF instrumentation. The evaluation flights and navigation runs will then be conducted some time after 1 September 1949 with the Chesapeake Bay Annex radar installation as a base. An analysis of the test data obtained from these flights, which will be conducted under simulated conditions, together with the findings of the studies which will have been carried on during the entire component development period, should then supply sufficient information to enable the Naval Research Laboratory to submit a final report containing its recommendations for this project.

DATA RELAY (CCA)

In a letter report[6] to ONR, this laboratory proposed an application of the DARN system principles as a possible solution to some of the known deficiencies of the CCA system, encountered in the evaluation trials conducted by OpDevFor.[7] This proposal covered a comprehensive program for almost all of the operations involved in CCA, i.e. the stacking, marshaling, feed-in, and final approach. In order to expedite the entire proposal, NRL assumed the task of developing only the components necessary to make an application of data-relay principles to the last operation in the CCA procedure, namely the final-approach control involving the precision AN/SPN-3 radar. In addition, it was obvious that any attempt to make an operational system for actual aircraft installation and evaluation would result in a long term project, the ultimate utility of which would always be in doubt until the final evaluation results. Therefore, as a part of its CAWF research activity NRL has restricted the project to the development of the components and simulation equipment needed to display a realistic CCA approach on a radar scope installed in a Link Trainer. As a first attempt, it has been decided to reproduce in the Trainer cockpit precisely the same scope display seen by the CCA operators aboard the carrier. In addition, a video-mapped course line is to be provided for the Link "pilot" to follow. This system will then be used as an evaluation device, to determine the efficacy of an airborne CCA display in providing better coordination between the talk-down operator and the pilot, and in decreasing the volume of information flow on the voice link.

As seen in the program flow diagram of Figure 2, the AN/SPN-3 radar is replaced by a simulator. This provides an echo which drifts in time at a rate corresponding approximately to 90 knots. The azimuthal position of the pulse is controlled by the Link Trainer azimuth drive. This artificial radar echo, a video-mapped course line, and artificial radar receiver noise are then mixed together and transmitted to the Link Trainer over a video cable. In actual operation, this transmission would have to take place over a c-w video

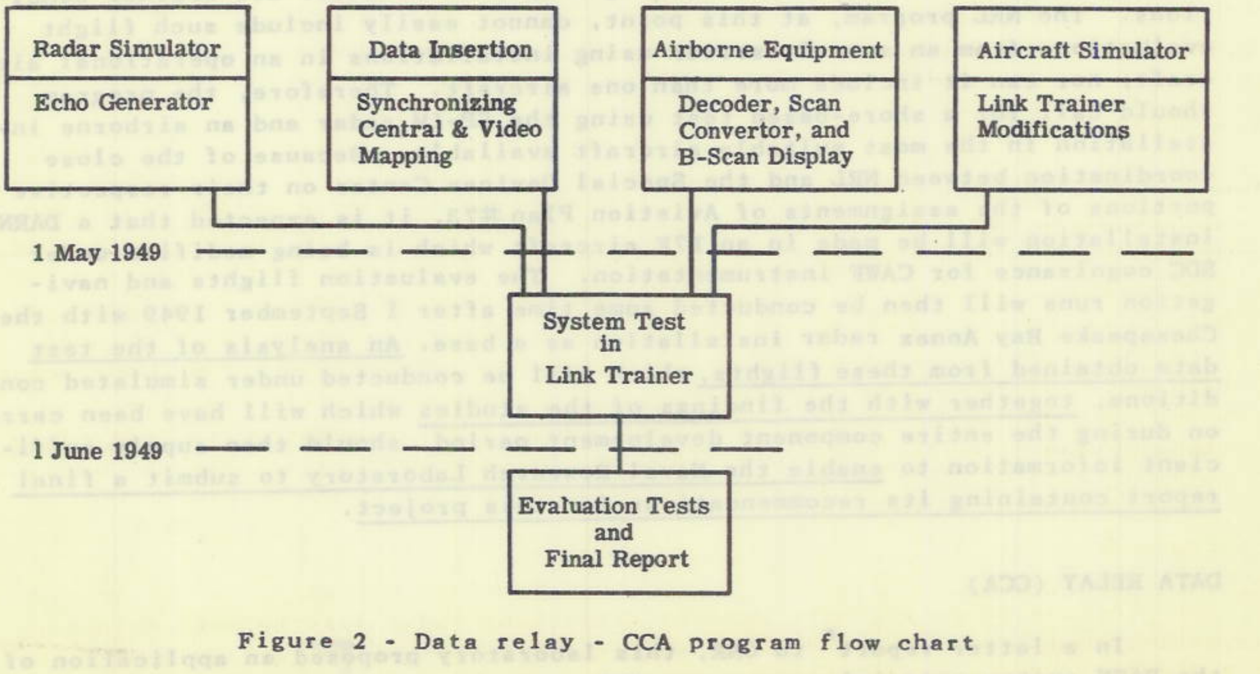

Figure 2 - Data relay - CCA program flow chart

relay link such as that described in the DARN program. However, since such a relay is actually being developed for the DARN system for the same function, it was felt that its use in this simulated installation is not vital to a demonstration of principles. In the Trainer itself, is located the airborne decoding and display equipment, the former being the conversion of sliding-pulse information into scope sweep voltages and trigger pulses, while the latter is merely an airborne remote B-Scan cathode-ray-tube indicator. All these components, in addition to the necessary minor modifications of a standard Link Trainer, have been worked on since September 1948 and, as indicated, are scheduled for completion about 1 May 1949. A short period of system testing of all the components as an integrated unit should then, some time after 1 June 1949, allow successful demonstration in the laboratory of a simulated airborne display for final approach CCA operations. This, together with a comprehensive technical report, would constitute the program goal.

It is recognized that a display of only the final-approach information, no matter how successful, would be of little aid to the over-all CCA system, which includes many more complex operations. The original NRL proposal, however, indicated that these other operations might be solved by use of the DARN system. Using a common switched display, one instrument could alleviate a serious traffic problem and, at the same time, relieve the overcrowded voice communication channels. The validity of this proposal will be determined as a matter of course by the outcome of the evaluations of the Data Relay-CCA, and the DARN projects. If the technical and operational soundness of the proposal is established, a rapid development of the system for fleet use would provide most of the interim solution for short-range (50 mile) CAWF necessary to the fleet. Some reservation must be held on the term "solution" since (1) such a system could not possibly provide the precise information needed for airborne station-keeping, (2) the system would have saturation limits to the amount of information it could disseminate, and (3) problems of multiple carrier (task force) operation might prove difficult, etc.

AUTOMATIC APPROACH AND LANDING

This project was initiated by the analysis of CAWF problems, reported in reference (1). The general method of solution outlined in that reference and in the introduction to this report, is still the one under investigation. The program flow diagram of Figure 3 also corresponds roughly to a component block diagram of the proposed system. An automatic tracking radar is used to obtain continuous range and azimuth-position information for an approaching aircraft. These data are compared with a predetermined flight course from which position error data are derived. This error information is relayed to the aircraft in pulse code form, then decoded and used to actuate the automatic control mechanisms in the aircraft.

Ground Equipment

The use of an airborne automatic-tracking radar for the data-gathering operation was decided on after an analysis made by the Avigation Branch, Radio III. The several distinct advantages it offers in the conduction of

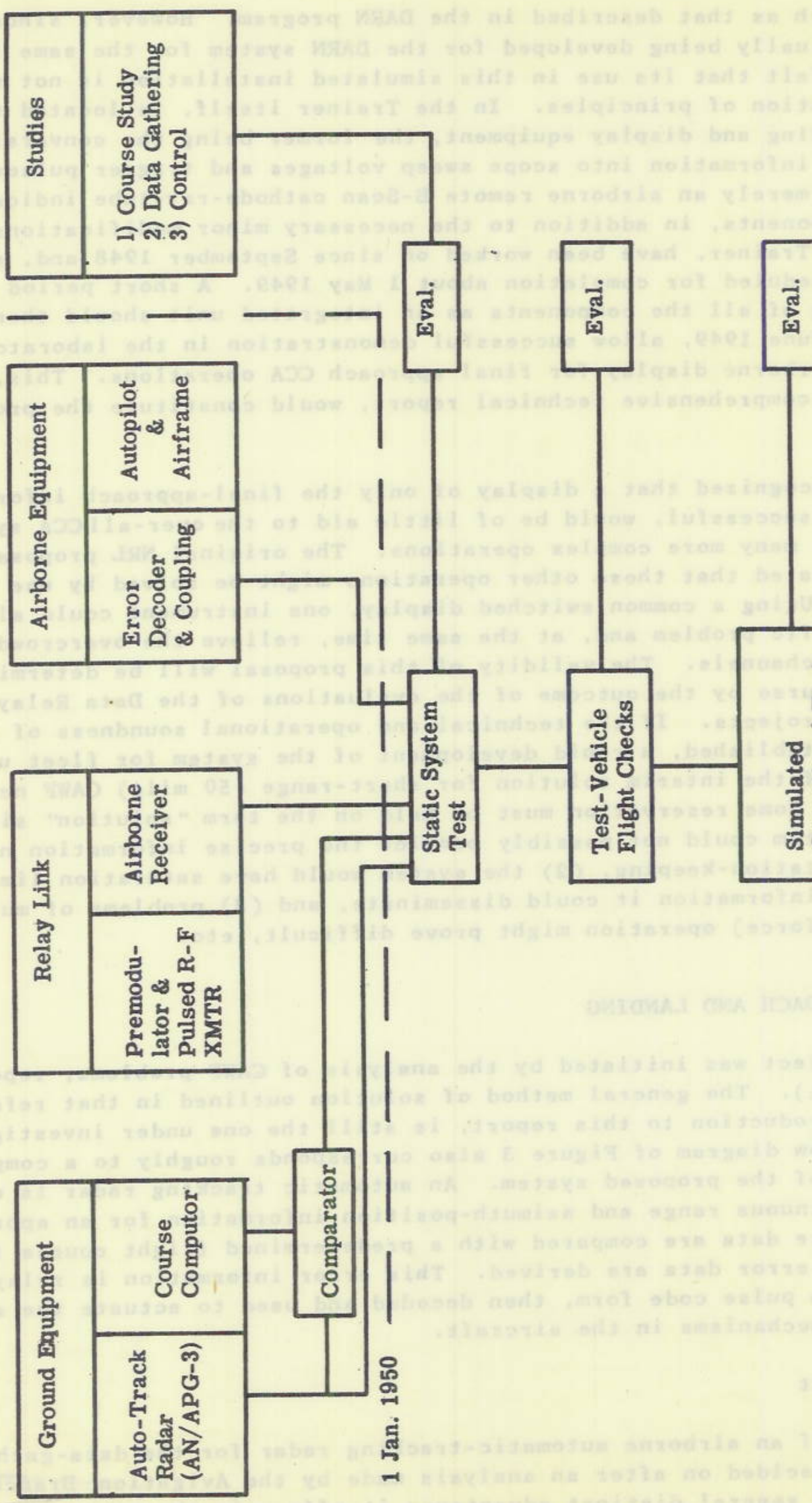

Figure 3 - Automatic approach and landing program flow chart

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the experimental-research portion of this program are:

(a) It is less complex both electrically and mechanically as compared to a ship or shore based radar of the same type (SCR-584, Mk. 25 fire control, etc). Such a typical radar (AN/APG-3) weighs only 300 pounds.

(b) It can be mounted in a single truck with test and recording apparatus, thus providing an extremely mobile field unit.

(c) It occasions no incidental development projects such as tracking-while-scanning circuitry.

The last advantage is especially important since such developments are being prosecuted in other laboratories, and could be applied, ultimately, to this system with practically no modifications. Because an automatic-tracking system will handle only one aircraft at a time per radar, the attention of the NRL activity is directed toward the complete, successful handling of one aircraft. This does not leave the problem of multiple aircraft untouched, since a simple calculation shows that three such automatic tracking radars, requiring a minimum of space (the AN/APG-3, for example, has a 12" dish), could handle a continuous flow of aircraft at 1 minute intervals under automatic control from 3 miles out from the carrier. On the other hand, the successful development of tracking-while-scanning radar systems would allow a simple replacement of the tracking radar by the scanning radar and its associated equipment, with the remainder of the automatic-landing system unchanged. In any event, therefore, the most expedient avenue for experimental purposes at NRL seems to be that of using the airborne automatic-tracking radar for data gathering purposes.

The course computor and position comparator developed for this proposed system are comparatively simple electrically (approximately 12 to 15 electron tubes) and provide:

(a) A flight path which approximates the present landing pattern geometrically except for an expanded range scale which makes the final turn approximately three to four miles in diameter. This makes the final portion of the approach very closely a dead astern course for about 1000 yards astern of the flight-deck ramp. Merely by changing voltage scales, this pattern may be expanded or compressed, although its form will not be appreciably altered. In addition, the technical circuitry is such that any possible instability or circuit change will appear as a change in the entry point (beginning) of the flight path, but the cut-point (end) is rigidly fixed at the proper position.

(b) Error signals of proper polarity which increase linearly with lateral deviation from the flight path up to a certain saturation limit. The comparator is being so designed that the error sensitivity will increase to a certain maximum with decreasing range. This in effect, will control the approaching aircraft along a funnel leading to the touchdown point of the carrier deck.

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Relay Link

The proper error information as determined by the comparator will be converted into variable pulse-spacing data which will then be transmitted on an r-f carrier to the aircraft under control. The method being investigated at present consists merely of an airborne X-band radar modulator and r-f head (magnetron, feed, and antenna) which is keyed by the error data converter, or "premodulator." This is possible because of the restriction, at present, to the control of one aircraft. Therefore, the data is being transmitted at approximately a 40-kw peak level and, by servo-mechanism control, will be beamed in the same direction as the automatic-tracking radar, i.e. at the approaching aircraft. This will insure a maximum of signal strength reliability (a safety factor of at least several thousand). In the aircraft an X-band receiver will detect the control pulses and, after converting them into the usual video form, pass them on to the decoding circuits.

Airborne Equipment

In the decoding equipment, the variable pulse-spacing data will be reconverted into d-c error signals. This decoder, in conjunction with the ground "premodulator" will be designed to carry as many channels of information as is found necessary to maintain the proper control accuracy. At present three channels of information will be provided, which will allow turn control, cut-signal, and any one of a number of other controls desired. In addition, a channel of automatic calibration data will also be transmitted which will provide the correct zero-error reference in the aircraft at all times, thereby preventing any errors due to shifting calibration, voltage, or component or tube variations, etc. Finally, the error information will be applied to the automatic control mechanisms in the aircraft. It is proposed and anticipated that at this point the NRL projects will coordinate with the activities of the Special Devices Center in their developments of automatic pilots and approach control mechanisms, Device 23B[8]. Preliminary discussions with SDC and their contractor have indicated that much of the development work already accomplished will be entirely applicable to the aircraft control problems of the NRL project. The exact technical nature of the coupling between the error output and the automatic pilot input will have to be determined by investigation.

Static System Test

After the completed development of the components, scheduled for 1 January 1950, a series of static tests will be conducted, i.e. laboratory operation of the complete system with the "servo loop" broken at one point. This can be accomplished by feeding artificial tracking information to the radar and recording the final decoded error outputs. From these studies the response characteristics of the system and a knowledge of the expected accuracy of control, limits of stability, noise characteristics, etc., can be obtained. Much similar work for example has been carried on in the

Equipment Research Branch of Radio Division III, Naval Research Laboratory, in conjunction with the Lark Missile guidance project[9]. The experience and knowledge already gained there will profitably be applied to this carrier landing project from this point on to ensure both its early completion and its optimum technical design. The evaluation of these static tests would then be reinvested in the project as corrections or modification in component design, after which the initial flight tests can be undertaken.

Test Vehicle Flight Tests

It would be premature, at this point, to attempt full aircraft control since much must still be learned concerning the system characteristics, since the system now includes the aircraft itself. Therefore, a series of "dry-run" flight test, must be conducted in which the servo loop is broken in the aircraft. The aircraft, manually piloted, will be automatically tracked by the ground radar and by some reference method, say ground theodolite stations. If the aircraft flies a predetermined course which is also setup electronically in the course computor, then the remaining components of the system may function exactly as intended up to the point of the insertion of error signals into the autopilot. Here, instead, recording apparatus will again be used.

By this means, it will be possible to obtain under flight conditions, the performance characteristics of the system including radar-tracking accuracy and reliability, relay-link reliability, error response characteristics, general system stability, etc. An evaluation of these data should reveal whether the final interconnection of the aircraft-control equipment into the system will be possible and also what the probabilities will be for successfully controlled flights. Based on the results of this evaluation and on concurrent theoretical studies of control problems which will have been carried on, the final interconnection of the system into closed loop form will be made, and flights under full guided control will be initiated.

It is not intended, however, even at this point to attempt complete execution of the approach and landing operation because:

(a) The experimental installation will not be made in an operational carrier aircraft but in a test vehicle carrying the necessary test apparatus and other experimental paraphenalia.

(b) It is very difficult to simulate the actual conditions encountered in carrier operations (relative speeds, geometry of landing area and flight paths, surrounding terrain, relative altitudes, etc.) some or all of which may determine the success of the system.

It may therefore be impossible to conduct the final gun-cut and landing operation. Fortunately, however, it will be possible to simulate all except these last operations to a good degree of approximation at the NRL Chesapeake Bay Annex, where a fairly long over-water approach path is available and where the ground equipment may be operated on a 100-foot sheer cliff bordering the Bay. Under judiciously chosen wind conditions, it would then seem possible to conduct simulated approach operations up to a few hundred yards from an imaginary landing point.

The data obtained from these tests will be correlated with the flight course and data-gathering studies to determine the final system design criteria before attempting full automatic control to touchdown.

Studies

As mentioned briefly above, several study projects will be conducted concurrently with the experimental work. These are:

(a) A study of the geometry of carrier landing problems and the electronic-computor problems associated with them. It is desired to obtain a method for deriving a variable flight path with one fixed point (touchdown) so that an approaching aircraft will be guided toward the carrier along a path which depends on: (1) the entry point, (2) the position, (3) the position time derivatives, and (4) possibly the type of aircraft. It would further be desirable to include a means for automatically controlling the landing-time interval and for providing a proper wave-off course.

(b) A study of the various methods for position-data gathering in order to be able to incorporate the optimum design in the system before the final evaluation phase. The two radar methods are (1) automatic tracking of the target by an entire radar and (2) tracking, on a memory basis, the video targets of a continuously scanning radar (tracking while scanning). An informal but inconclusive analysis has been made by the Avigation Branch of Radio Division III NRL.

(c) A study of the control problems encountered in forming a closed-loop system by means of the tracking radar (plane to ground) and the relay link (ground to plane). Such problems have been encountered in the Equipment Research Branch, Radio Division III of NRL, while certain important phases of the problem involving the aircraft control mechanisms alone are under investigation by the Special Devices Center.

SIMULATED OPERATIONAL TESTS (Program Goal)

By the very nature of the problem which any carrier landing system attempts to solve, it is felt that no laboratory simulation methods can prove or disprove the operational feasibility of such a system. Therefore, although it is not under the cognizance of NRL as assigned by Aviation Plan #73, some facility must be made available to provide a conclusive proving ground for a system which will, presumably, be in the very last stages of experimentation. One obvious though very inconvenient facility is an actual carrier, such as might be available through OpDevFor. Another is the simulated flight deck set-up at Patuxent River Naval Air Station. In any event, the facility that will be needed at this point must be capable of actually landing an operational carrier aircraft under carrier landing conditions. Also the landing itself must be "hooked-cable" and not the "free roll" type.

It is therefore felt that the research activities of NRL on automatic carrier landing systems if successfully carried through the component development and test flight stages, should properly include such operational tests, and not terminate until conclusive data has been obtained from such tests. These tests should be a cooperative undertaking between BuAer and NRL. It is also felt that if such tests show the automatic landing system to be successful, it would be logical at this point to evaluate the combination of this system with the DARN system for providing navigational data to carrier aircraft from shipboard search radar range to touchdown. This would be a very desirable step since, on a time schedule basis, the DARN system will have been completed some time prior to the automatic landing tests and will therefore have been considerably improved over the first experimental system.

SUMMARY OF RECOMMENDED PROGRAM

The foregoing program analyses indicate the scope of the Naval Research Laboratory activities which are directly concerned with the Carrier All Weather Flying Problem. They also indicate the stage at which these activities will be considered completed as a research assignment of Aviation Plan #73. In summary, the recommended steps necessary to bring each of the three phases of the NRL program successfully to its stated research goal, include:

A. Data Relay Navigation (DARN)

1. Completion of component developments for ground and airborne installations.
2. Operation of the integrated system for test purposes.
3. Prosecution of the study projects necessary to optimize the system performance and utility.
4. Operation of the system as a navigational aid to one aircraft carrying the airborne display equipment, and receiving the data from some suitable shore base.
5. Analysis of all pertinent data obtained on the system and submission of a final report of evaluation and recommendation.

B. Data Relay - CCA

1. Completion of the component developments and modification necessary to provide a simulated CCA display in a Laboratory Link Trainer installation.
2. Operation of the installed system for test purposes.
3. Demonstration of the simulated display to cognizant agencies and submission of a final technical report.

C. Automatic Approach and Landing

1. Completion of the component developments for the early attainment of an experimental system.

2. Close coordination of the work of NRL with that of other laboratories in order that significant developments in fields applicable to this problem be considered and incorporated where possible.

3. Performance of the various static and dynamic tests of the system in order to obtain the data and information necessary to allow automatic operation.

4. Prosecution of operational tests involving the actual automatic landing of an aircraft under simulated carrier flight conditions.

The attainment and subsequent integration of these separate program goals provide an ultimate CAWF system for fleet use. It will probably solve parts of the broad operational problem, at least on an experimental basis. In order to realize the benefits of these research efforts it will be necessary for the proper cognizant agencies to carry out their development and procurement tasks.

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