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DIGITAL RADAR DATA (DIRAD) SYSTEM.(U)

MAR 75 J W NICKERSON, W G MYERS, S D ELLIOTT

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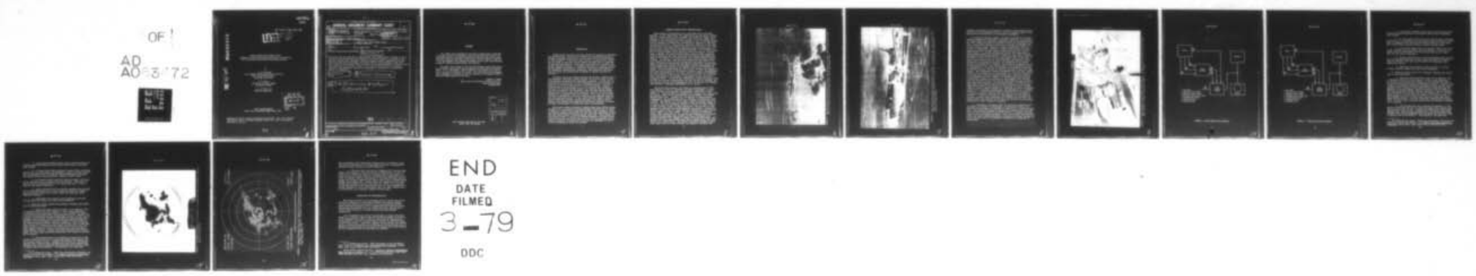

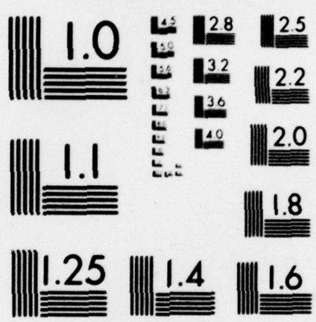
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NWC Technical Memorandum 2504

DIGITAL RADAR DATA (DIRAD) SYSTEM
A Method for Acquiring, Recording, Storing, Transmitting, and Processing Airborne Radar Reconnaissance Data

by

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NAVAL WEAPONS CENTER
China Lake, California 93555, March 1975

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The present document describes a Digital Radar Data (DIRAD) system, already in use in connection with ground-based installations, and readily adapted to existing and prospective airborne radar equipment, which will greatly enhance capabilities for near real-time quantitative assessment and remote display of meteorological radar data. This concept is particularly timely in view of the planned resumption of Project Stormfury activities in the Pacific Ocean in 1977, and the extensive use of airborne analytical instrumentation required for assessment of the effects of modification efforts on typhoons.

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(10) J.W. Nickerson, W.G. Myers, S.D. Elliott, Jr

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FOREWORD

This report was originated by the authors because their experience in the applications of atmospheric sciences has kept them aware of the continuing need for improved techniques of meteorological surveillance. From their combined experience, they present in this report an approach to the development of an advanced prototype digital radar data recording system for improved meteorological surveillance.

The report was written in 1973 and 1974 whenever operational duties of the suthors would permit and was updated for publication in February 1975. It is a preliminary report released at the working level and is not to be used as authority for action. The conclusions and recommendations presented are subject to revision because of the changing requirements of meteorological surveillance.

PIERRE ST.-AMAND
Head, Earth and Planetary Sciences Division
Research Department
10 March 1975

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INTRODUCTION

As Navy ships, aircraft, and shore facilities increase in complexity and sophistication, and decrease in numbers and available manpower, it becomes increasingly important to protect them from the adverse effects of severe weather. To meet this need, efforts to improve the accuracy and the range in space and time of weather forecasts must be supported by improved meteorological surveillance from satellites, aircraft, and surface observing stations. Increasing application of computer analysis methods demands comprehensive, objective, quantitative measurements of the fundamental meteorological parameters, both generally distributed over the world, and concentrated in regions of specific interest or activity.

In recent years, the weather satellite has become a favored tool of the forecaster, providing a global display, in near real time, of the cloud patterns associated with atmospheric processes. A great deal of attention has been directed to the interpretation of these patterns in terms of the structure and evolution of weather systems. A serious limitation upon the usefulness of satellite observations, however, is the fact that as storm systems increase in intensity and development, and thus in concern to the forecaster, their internal details become obscured from view by high-level cloudiness; data for the lower-lying regions must be obtained from other sources. Over land, such information may be provided by networks of observation and sounding stations, and by ground-based radars. At sea, and in coastal regions, where effects of land/sea contrasts, bottom topography, and surface terrain produce rapid changes often aggravating the damage potential of storms, the major reliance must be placed upon aerial reconnaissance.

The present document describes a Digital Radar Data (DIRAD) system, already in use in connection with ground-based installations, and readily adapted to existing and prospective airborne radar equipment, which will greatly enhance capabilities for near real-time quantitative assessment and remote display of meteorological radar data. This concept is particularly timely in view of the planned resumption of Project Stormfury activities in the Pacific Ocean in 1977, and the extensive use of airborne analytical instrumentation required for assessment of the effects of modification efforts on typhoons.

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AIRBORNE METEOROLOGICAL RECONNAISSANCE

Early weather reconnaissance was a collateral duty of military aviation. As its capabilities were demonstrated and developed, however, specific squadrons were formed, equipped, and tasked for weather reconnaissance. This development reached its peak in the late 1960s, with the Navy Weather Reconnaissance (VW) Squadrons 1 and 4 operating WC-121N aircraft (modified Lockheed Super Constellations (Figure 1)) from Guam and Jacksonville, Fla., respectively; similarly tasked WC-130 and other aircraft were flown from several locations by the Air Force, and a variety of aircraft from Miami by the National Oceanic and Atmospheric Administration's Research Flight Facility (NOAA/RFF). All of these groups had as a primary mission the surveillance and investigation of hurricanes, typhoons, and extra-tropical severe storms in their respective areas of operation, and their activities were closely integrated with those of the national civil and military storm forecasting and warning networks. In addition, these and other specialized instrumented aircraft operated by public and private agencies have been active in programs of research in meteorology and weather modification; perhaps most notable among these has been the Navy/NOAA Stormfury experimental hurricane modification program in the Western Atlantic and Caribbean Sea region. With increasing budgetary restrictions, and with the promise of full-time, global satellite surveillance, however, aerial reconnaissance has become de-emphasized in the 1970s. Military weather reconnaissance has been severely curtailed, and the RFF fleet has been cut to two aircraft (with, however, the prospect of replacement by new, specially-configured P3D's). In view of the limitations of satellites noted above, the need for airborne reconnaissance can only continue to increase, and the existing aircraft and instrumentation must be utilized with maximum effectiveness if immediate requirements are to be met.

The WP-3A Orion aircraft, with which the Constellations of VW-4 were replaced in 1971-72, represent the highest development of operational airborne meteorological reconnaissance capabilities to date (Figure 2). These aircraft are equipped with a digital data acquisition and logging system (DALS) developed with the assistance of the Naval Weapons Center, which collects up to 30 channels of meteorological, oceanographic, and navigational data at intervals as frequent as every 5 seconds, and displays it in real time at various stations aboard the aircraft. The data may also be recorded, either in teletype format or on punched tape, and transmitted either as collected or after a delay, to other aircraft, ships, or shore facilities. The aircraft are also equipped for dropsonde and bathythermograph observations. Potentially the most powerful tools for remote-sensing observations aboard the aircraft, however, are their radars. In their original antisubmarine warfare (ASW) configuration, the aircraft were equipped with an APS-80 3-centimeter-wavelength radar system providing a 360-degree plan-position indicator (PPI) display to ranges of 250 nautical miles, with antenna tilt, beam shape modification, ground stabilization, and other sophisticated capabilities. The APS-20 10-centimeter weather surveillance radar from the WC-121N aircraft was adapted to the WP-3s and

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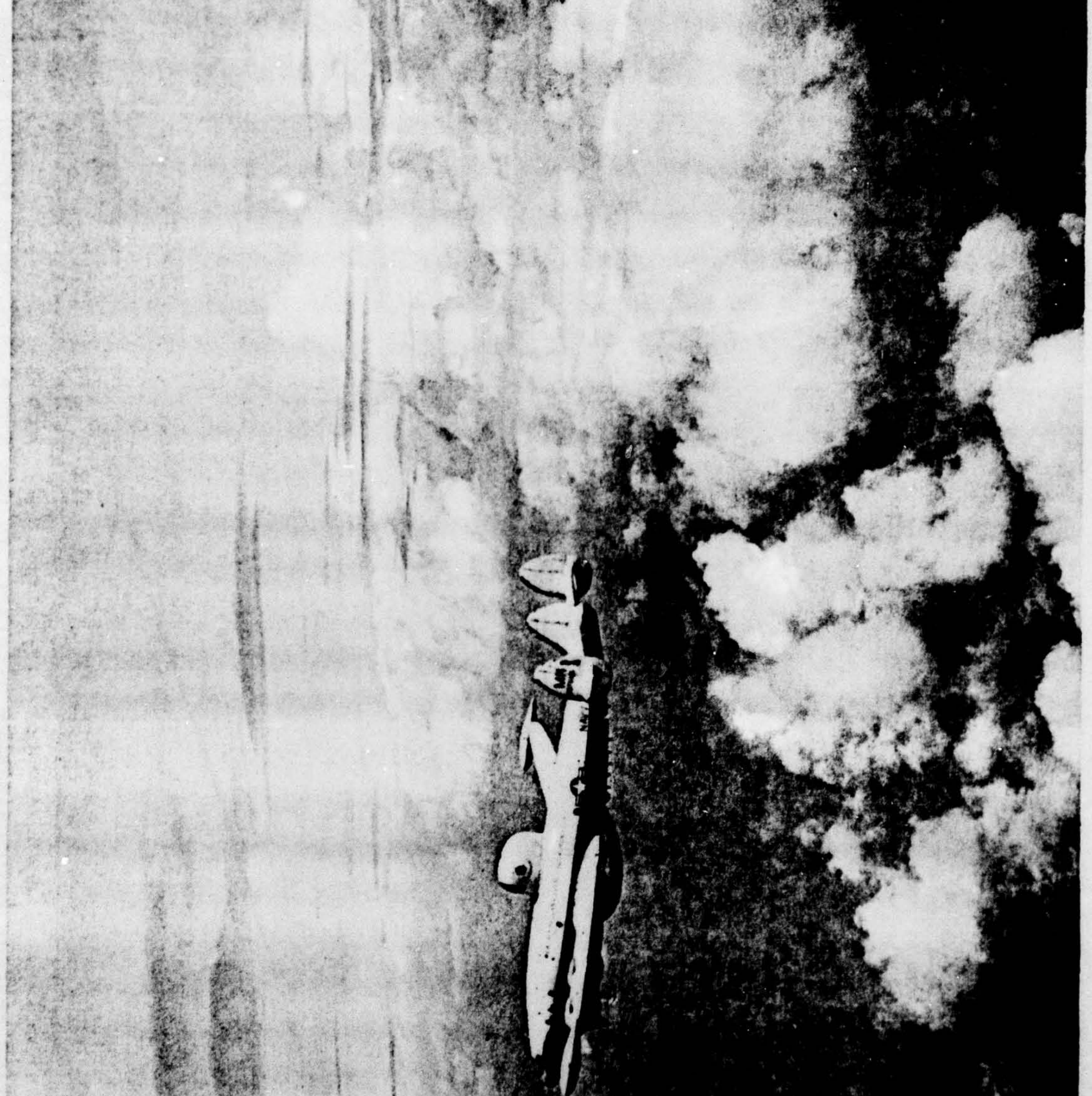

FIGURE 1. Navy WC-121N Super Constellation Weather Reconnaissance Aircraft, Used Through 1971, With APS-20 PPI Radar Antenna Enclosure Below, APS-45 RHI Radome Above.

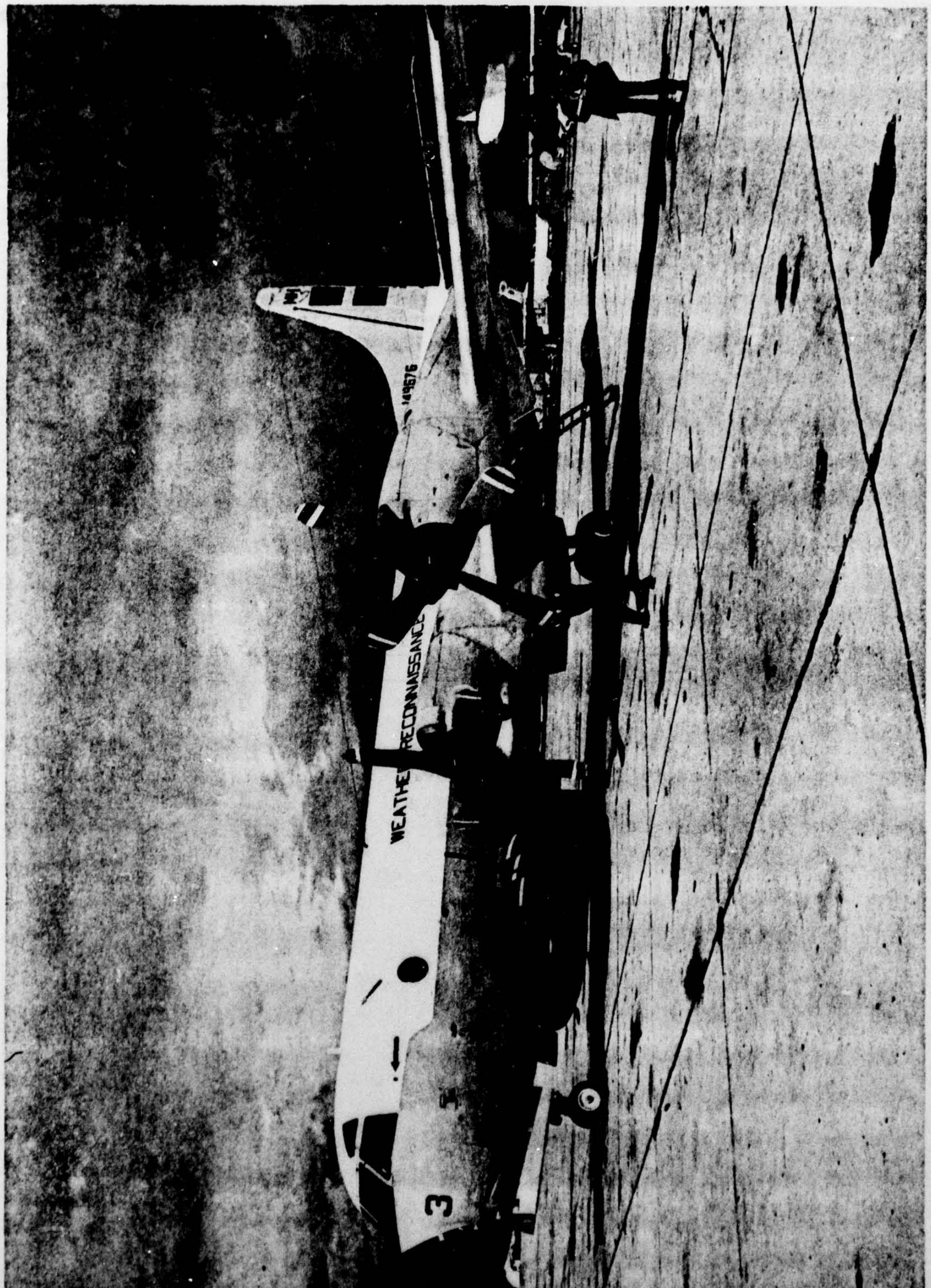

FIGURE 2. Navy WP-3A Orion Weather Reconnaissance Aircraft, in Use Since 1971, With APS-20 Radome Below, APS-80 ASW Radar Antennas in Nose and Tail, and Experimental Seeding Unit Dispenser Under Wingtip.

operates, alternately or concurrently, through the same display system, providing a dual-wavelength capability which can greatly assist in the analysis and interpretation of meteorological phenomena.

As presently operated, however, the great potential of the radar system is inadequately exploited. Although a single PPI scan contains an immense number of information elements capable of quantitative analysis, this information, which if supplied to a suitably programmed computer could provide detailed data on storm structure and dynamics over a large volume of space, cannot at present be adequately collected, stored, or transmitted. Although the radar display aboard the reconnaissance aircraft includes a spare radarscope fitted with a 35-mm camera (Figure 3), and such photography has been used extensively in experimental programs such as Project Stormfury, the results achieved have generally been unsatisfactory. There are several reasons for this situation. First, the 30- to 40-decibel dynamic range of the radar system itself cannot, with the linear amplification employed, be displayed upon the cathode-ray screen of the radarscope at any single setting; the display must, therefore, be continually readjusted for the conditions encountered. The dynamic range of the photographic system, as determined by a combination of exposure and development conditions, is similarly limited, and must be carefully adjusted to match the radar display. Both adjustments require considerable skill and time, careful logging, and a complex set of calibrations, all of which are difficult to provide under realistic operating conditions. Even when these exacting conditions are met, however, the quantitative data the system is potentially capable of providing are not available until the aircraft has returned to base, the film has been developed, and the photographs have been subjected to painstaking analysis. Introduction of a logarithmic amplification stage can provide a solution to the dynamic range problem, and the use of iso-echo contouring, in which specified ranges of returned signal intensity are displayed as discrete brightness levels on the radarscope, can alleviate the requirements for in-flight calibration. Attempts have been made to substitute, for the camera, a videotape system on which the raw video input to the radarscope is recorded. In addition to defects in the equipment thus far employed, for these purposes, these approaches still impose the requirement for delayed replay and analysis, and the data thus obtained are not readily susceptible to rapid treatment by computer.

As a consequence, especially under the conditions prevailing during normal, as opposed to experimental, reconnaissance flights, the recording system—camera or videotape—is used only on a noninterference basis. The radarscope display is adjusted for optimum visual use, and the structure of the storm is described verbally, in largely subjective terms, to the shore-based forecaster. When, as in severe storm penetrations, the radar is employed primarily to guide the aircraft through the storm, even this level of information transmission is infeasible for long periods.

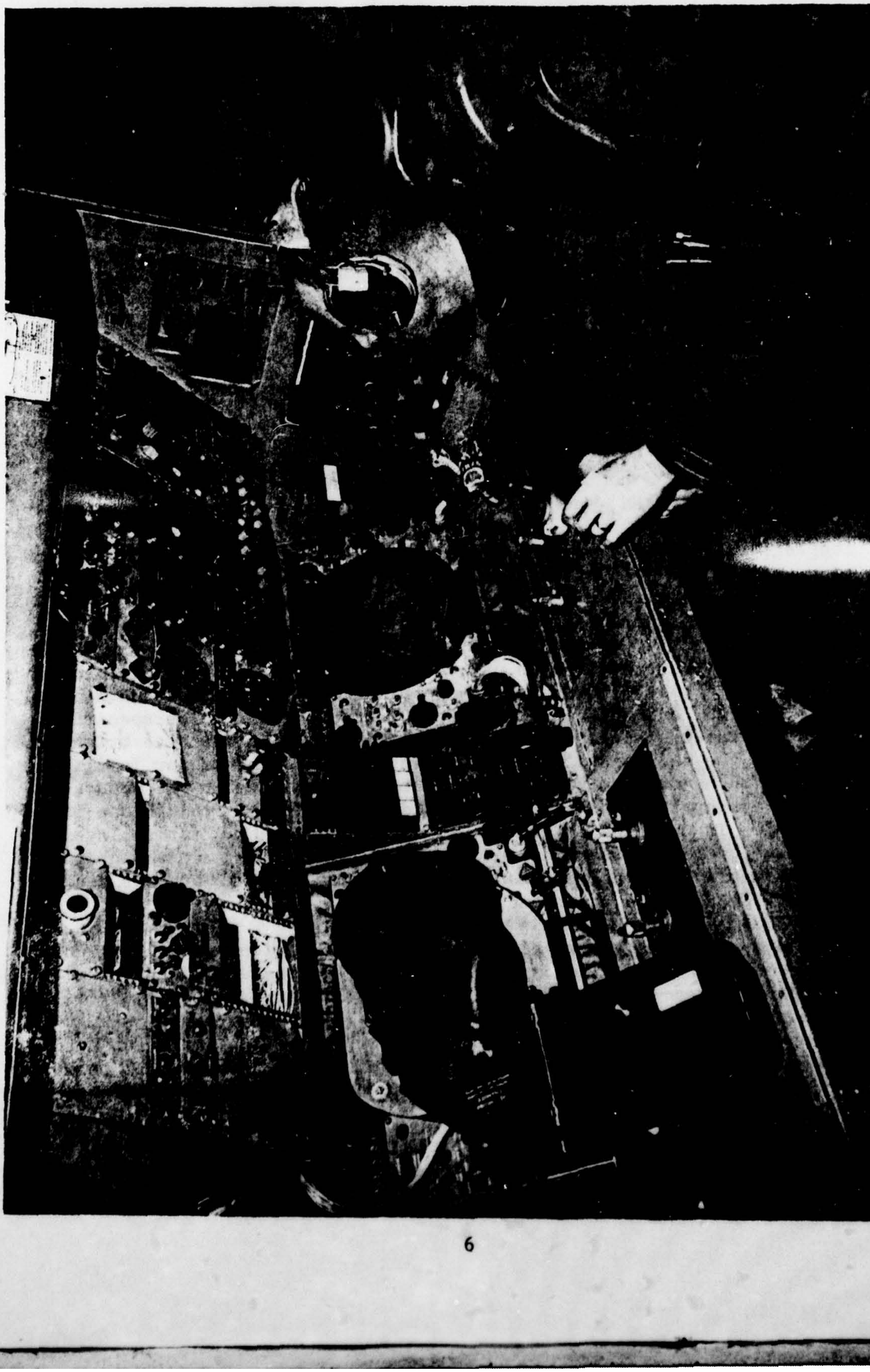

FIGURE 3. Radar Operator Station Aboard WP-3A Showing APS-20/80 Control Console and Main Display Scope in Center, "Slave" Scope With 35-mm Camera to Left.

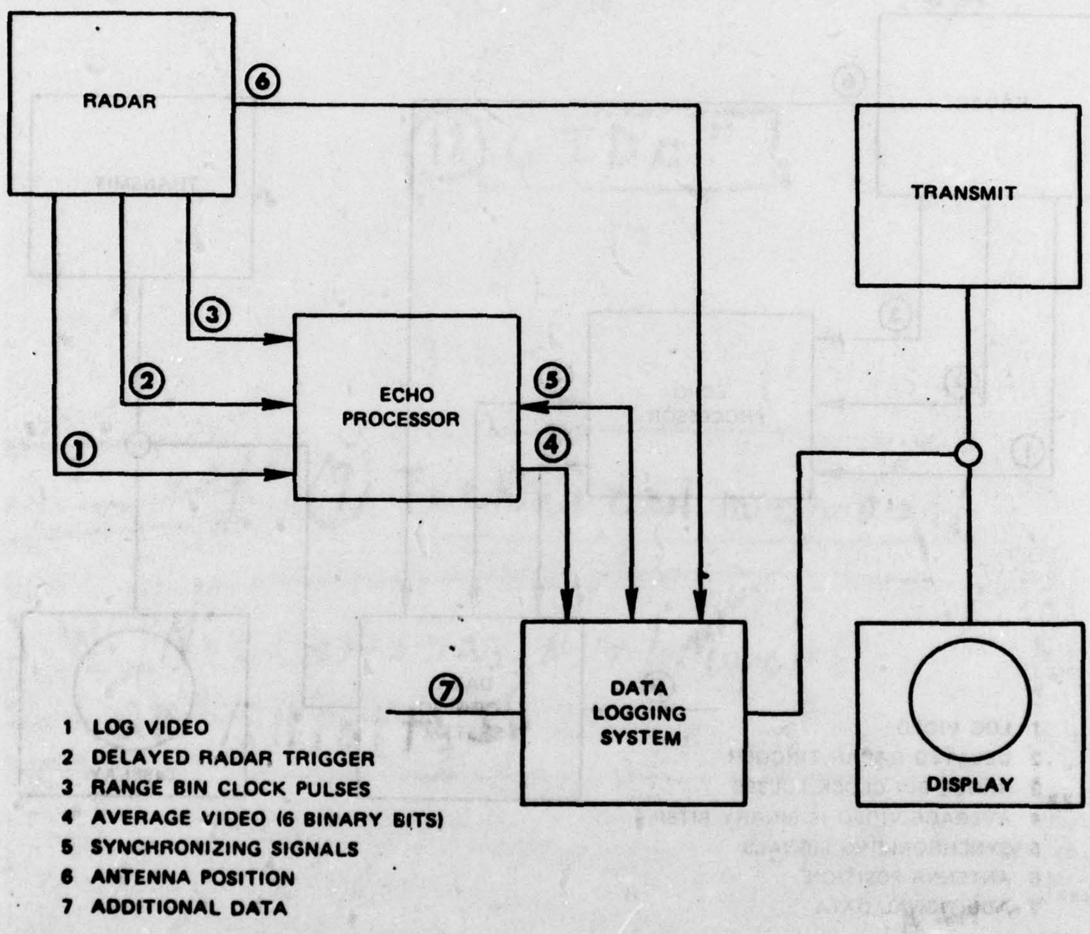

FIGURE 4. DIRAD System Block Diagram.

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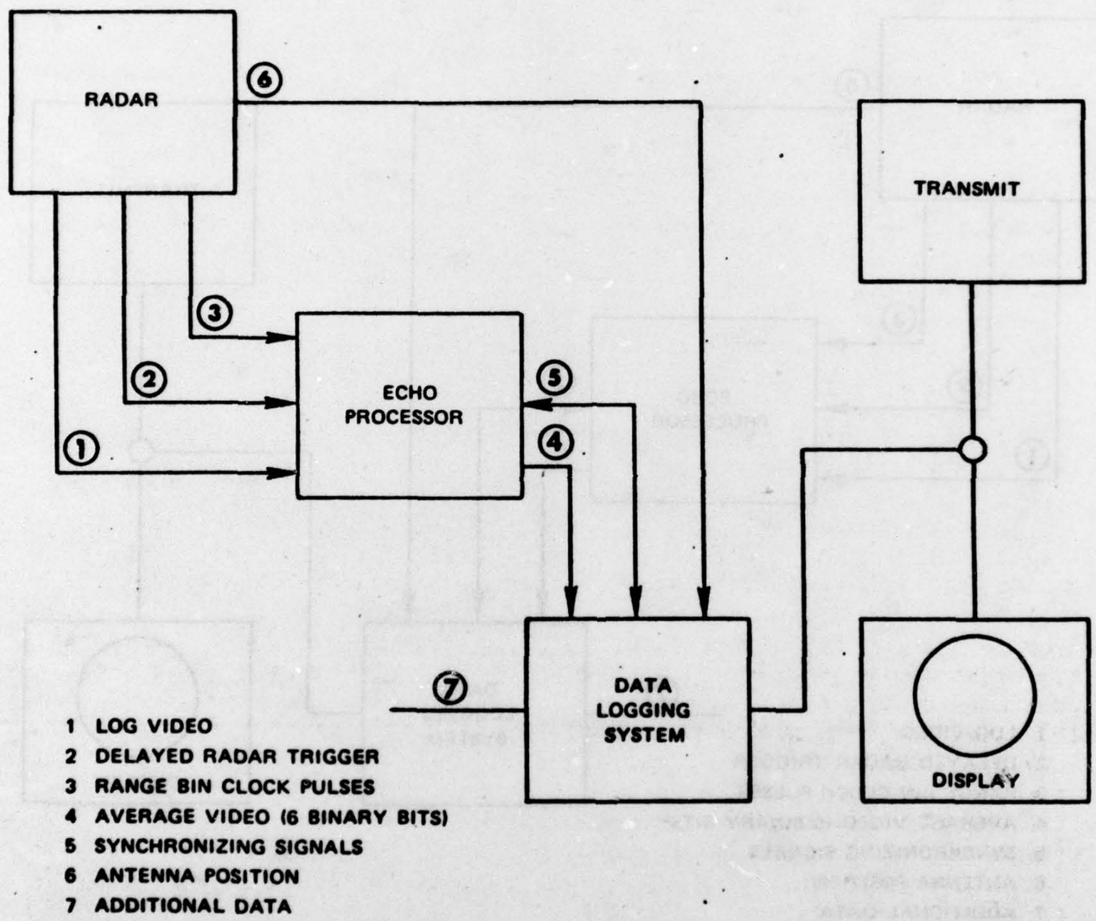

FIGURE 4. DIRAD System Block Diagram.

a. A selectable threshold control will be provided which will eliminate recording portions of the display falling below a specified echo strength.

b. A "range window" mode will also be incorporated, permitting limitation of the recorded data to particular targets or ranges of interest; in conjunction with the range bin interval adjustment, this mode will permit optimum resolution within a specific spatial region.

c. An "azimuth window" mode will similarly permit restriction of the recorded data to an angular sector of interest. (This can, of course, also be accomplished by use of a sector-scan mode, if available with the radar in question.)

d. Antenna elevation will be recorded (assuming that the radar has a pencil-beam capability) for each sweep; successive "on command" scans at different tilts will provide a basis for subsequent three-dimensional analysis.

e. Provisions will be made to allow recording of aircraft altitude, position, speed, and other useful information.

3. There are several options for subsequent treatment and utilization of the recorded data:

a. Relatively simple hard-wired logic can be employed, with a cathode-ray tube or X-Y plot display, or with a spare radarscope, to reproduce the recorded sweep display in a form suitable for quantitative interpretation aboard the reconnaissance aircraft. Figures 5 and 6 compare a conventional radarscope photograph obtained with the type of equipment shown in Figure 3 with a quantitatively coded graphical plot generated at the Environmental Prediction Research Facility (EPRF) at the Naval Postgraduate School, Monterey, California. The plot displays data obtained at the same time, and covering the same area, as the photograph; intensity is indicated by the number of dots (zero to nine, in this example) printed in a square array centered on each range bin/2-degree azimuth junction. Iso-echo contouring, expanded-scale presentations, and other simple analytical modifications can readily be provided for as required.

b. The recorded data can be analyzed and reworked in a wide variety of ways with the aid of a relatively modest-sized computer when the aircraft returns to base. Programs are available for constructing synthetic RHI, constant-level, multiple-level, and various specialized displays where scans at different elevation angles are available, using a computer such as the PDP-8E.[2,3] The analysis of the radar data

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[2] J.H. Boardman and others. "Radar Data Acquisition, Processing, and Display with an On-Line Computer," in Preprints, 14th Radar Meteorology Conference, Boston, Mass., Amer. Meteor. Soc., 1970. Pp. 391-94.

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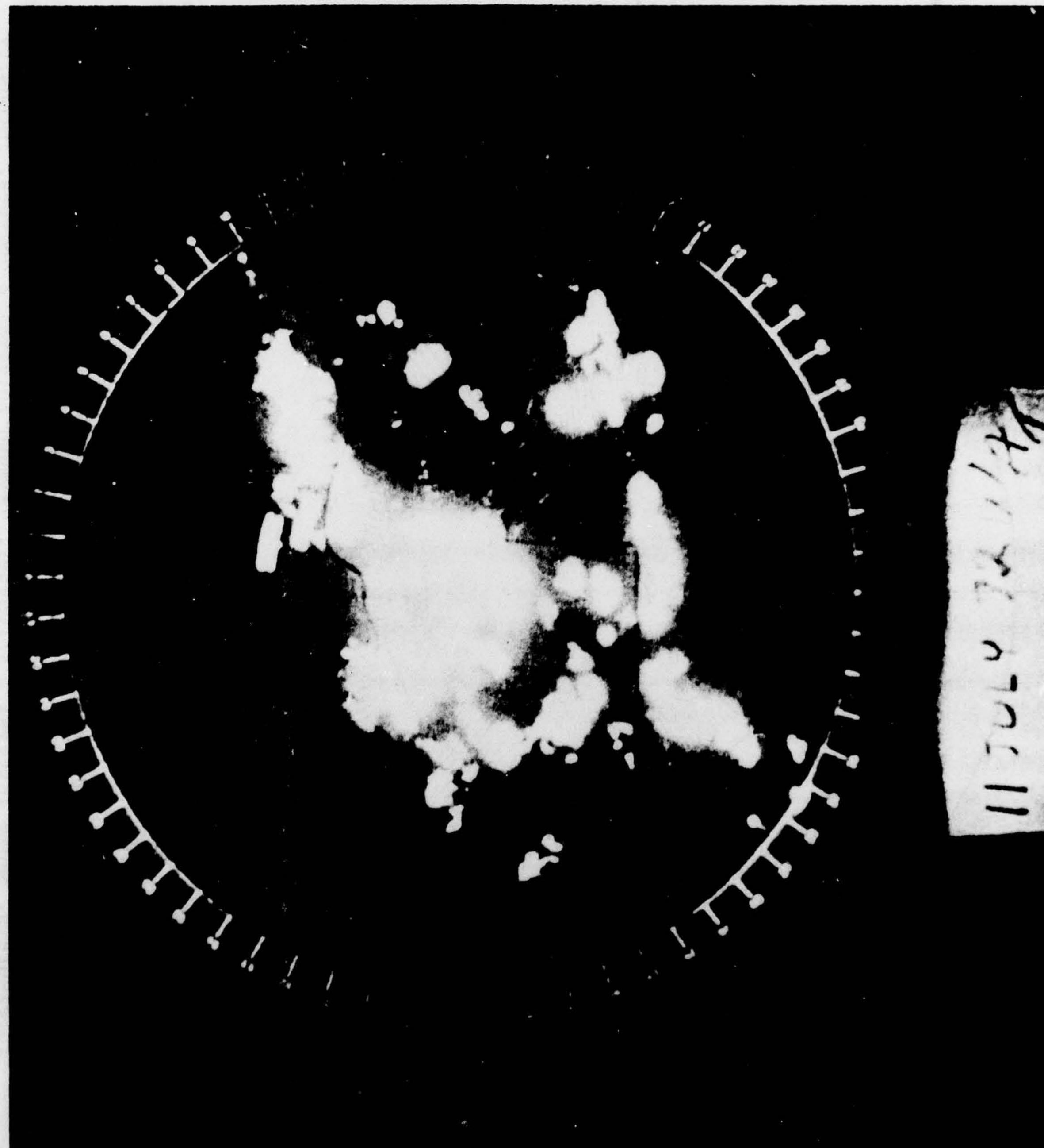

FIGURE 5. IAS/SDSMT Photograph of 10-Centimeter PPI Radarscope Display (Elevation 2 Degrees, Range 125 Kilometers).

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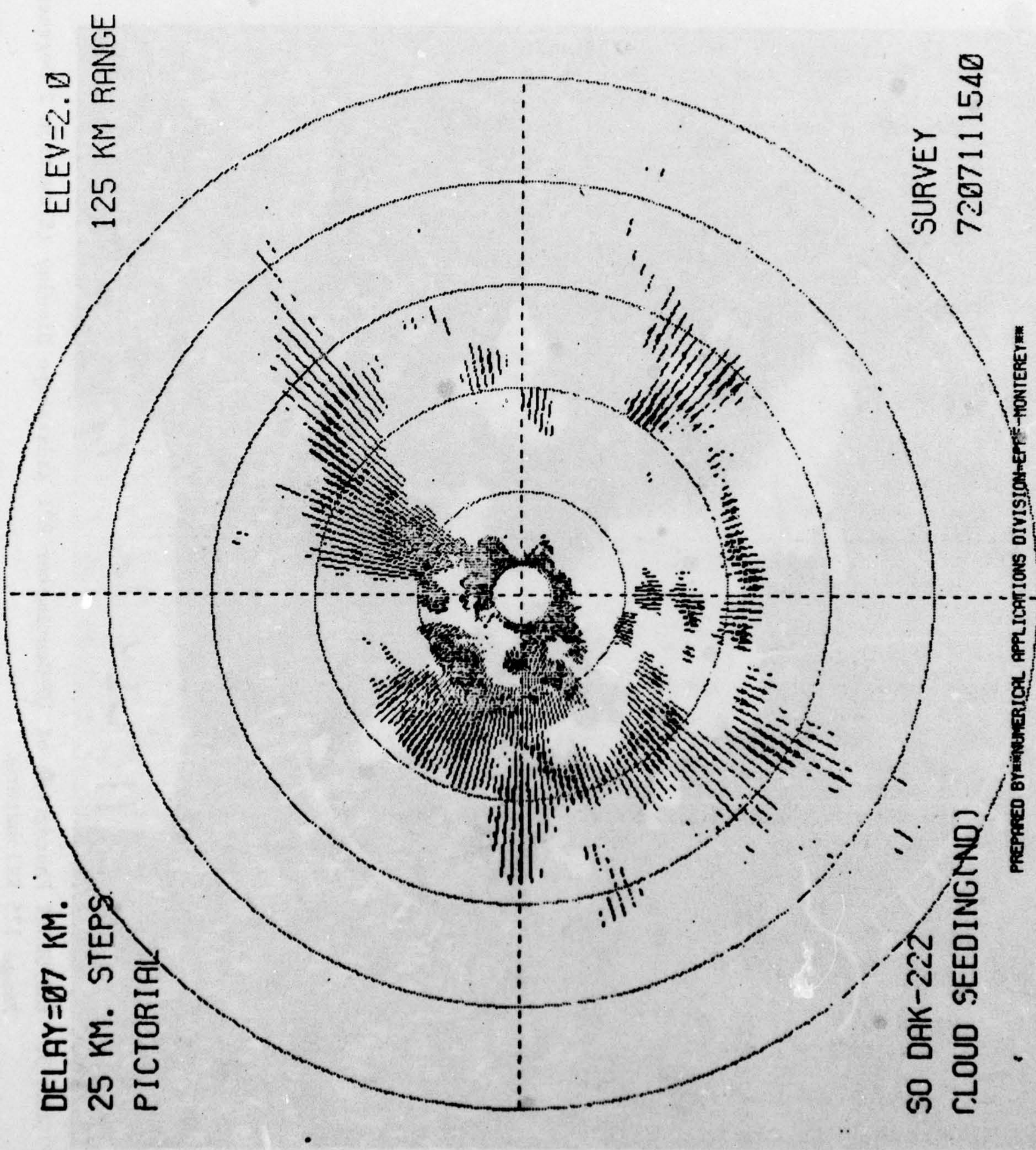

FIGURE 6. Computer-Generated Plot From Digital Record Obtained Concurrently With Photograph in Figure 5. Range interval 1 kilometer, azimuth interval 2 degrees, intensity range (logarithmic) 0–9.

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may be integrated with computerized interpretation of satellite visual and infrared observations, or incorporated as an input to programs for automated synoptic analysis and chart generation.

c. The tape record may also be transmitted for near-real-time display and analysis at shore facilities, or aboard ships or other aircraft; such a capablility would be of special value in the case of an operation such as Project Stormfury, permitting the command/control aircraft to maintain complete surveillance of the target hurricane simultaneously from several viewpoints and levels, and to detect seeding-induced changes almost immediately. Several modes and channels for such transmission are available, and have been reported.[4] Where, as in the case of the DALS-equipped WP-3A reconnaissance aircraft, such transmission is already employed for other meteorological data, the radar records could be incorporated on an automated, regular interval basis.

CONCLUSIONS AND RECOMMENDATIONS

The system described in the preceding section is based upon proven principles, makes use of relatively inexpensive and highly reliable off-the-shelf components and hardware, can be installed and operated aboard existing and planned future reconnaissance and research aircraft with minimal interference with their normal functions, and provides a vitally needed extension of present quantitative observational capabilities.

It is recommended that efforts be undertaken to develop the final design for a prototype digital radar data recording system, to construct it in breadboard form, and to carry out evaluation and demonstration testing aboard a Navy WP-3A reconnaissance aircraft (or equivalent NOAA or Air Force aircraft). Initially, display, interpretation, and analysis would be conducted postflight in the laboratory; as capabilities and requirements are determined, optimum modes and systems for on-board display and for transmission would be specified and developed.

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[3] J. H. Boardman and others. "New Developments in the IAS Weather Radar System," in Preprints, 15th Radar Meteorology Conference. Boston, Mass., Amer. Meteor. Soc., 1972. Pp. 204-11.

[4] Naval Weather Research Facility. Teleplot: A Method of Transmitting Pictorial Data by Teletype, by J. W. Nickerson, Norfolk, VA., NWRF, 1968. (NWRF Technical Paper No. 21-68, publication UNCLASSIFIED.)

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