U.S. DEPARTMENT OF COMMERCE
Environmental Science Services Administration

United States

FEDERAL COORDINATOR FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH

Report on Hurricane Weather Reconnaissance

FCM 69-1

WASHINGTON, D.C.
September 26, 1969

C O N T E N T S

FOREWORD

On August 17/18, 1969, the Mississippi Coast was devastated by the most intense hurricane in history. Winds estimated at over 200 mph and waves 32 feet high wrecked large areas of the coast. Eighty-one thousand persons were evacuated, and the death toll is around 140 with another 76 persons still missing. Damage will approach one billion dollars.

This national disaster prompted a Presidential inquiry, and the Vice President visited the area after the storm. His report indicated some concern with the adequacy of aerial weather reconnaissance.

In the August 26, 1969, meeting of the Environmental Quality Council, the Secretary of Commerce was directed by the President "to make certain that appropriate aircraft with the best available equipment be used on all future occasions."

To respond to this directive, the Federal Coordinator for Meteorological Services and Supporting Research convened an Ad Hoc Group on September 4, 1969. The findings and recommendations of the Group were considered in arriving at the actions presented in this report. Specific items of concern were the ability to penetrate storms to obtain maximum wind and surface pressures, the on-board instrumentation and operating procedures.

BACKGROUND

Hurricane Camille was first discovered south of Cuba on August 15, 1969 by weather reconnaissance aircraft. Aerial weather reconnaissance was subsequently requested of, and provided by, Air Force, Navy and ESSA(RFF)* in accordance with interdepartmental agreements approved by the Federal Committee for Meteorological Services and Supporting Research. Attachment A shows the storm path; Attachment B gives the reconnaissance fix information.

After Camille had caused extensive damage, the Vice President was requested by the President to conduct a survey. The Vice President was informed by the Director, National Hurricane Center (ESSA), that although the forecast service was very good, the aerial weather reconnaissance support on Camille was less than optimum and the Vice President so reported to the President. At a meeting of the Environmental Quality Council, the President requested the Secretary of Commerce to investigate the situation, to insure that appropriate aircraft, with the best available equipment, be used on all future occurrences.

* RFF - Research Flight Facility

FINDINGS

1. AIRCRAFT

The present number of aircraft assigned (14) is based on experience. This has provided adequate coverage to include instances where two storms exist which threaten the coastal U.S. In the rare cases where three storms occur simultaneously, these are covered by extraordinary procedures.

These aircraft have missions other than hurricane reconnaissance during the non-hurricane season. Examples are weather modification, insuring the safety and security of Fleet operating forces, providing oceanographic support, area weather reconnaissance for refueling and photography, air sampling for AEC, and support to manned space-flight missions.

The exact numbers of aircraft required is a function of many variables such as flying hour allocations, air crew status, training, storm locations and characteristics of aircraft.

The specific comments on aircraft currently assigned follow:

- The five AF WC-130 aircraft are considered to be excellent instrument platforms, structurally adequate, and suitable vehicles.
- The six Navy RC-121 aircraft are excellent instrument platforms, are structurally adequate, but are old and difficult to maintain.
- The three ESSA(RFF) aircraft (one DC-4, two DC-6's) are also excellent platforms, but the DC-4 is obsolete and the DC-6's are obsolescent.

2. INSTRUMENTATION

The weather radars aboard Navy and RFF aircraft are operationally satisfactory but old and difficult to maintain. Air Force airborne weather radars are inadequate for hurricane analysis.

Meteorological sensors on AF aircraft are adequate except for the air temperature indicator. Navy and RFF sensor systems are adequate to meet minimal operational requirements.

Neither Navy nor AF aircraft possess on-board visual recorders (visicorders or equal) to allow rapid assessment of rates of change of measured elements with time. The RFF has a device of this capability on the aircraft. It is noted that this requirement is not in the 1969 National Hurricane Plan.

Present instrumentation on weather reconnaissance aircraft is given in Attachment C. A list of desired capabilities for hurricane reconnaissance aircraft, provided by the National Hurricane Center (and appended as Attachment D) indicates that some improvements are necessary. Agency plans to effect these improvements are:

Air Force	- The present modernization program includes a complete aircraft subsystem of weather sensors and an on-board data processor. The procurement of these improved sensors is un-funded, and further, there is a question as to the availability of replacement weather radar. A proposal for contract definition is being let.
Navy	- No funded program - instrumentation excellent (except for the difficulty in maintaining the radar.)
ESSA(RFF)	- A program exists to replace surveillance and Doppler radars, and to install digital data recording units, as well as Omega navigational systems on the DC-6's, in the CY 70, as a supplemental request to the DOC Budget.

3. PROCEDURES

Hurricane reconnaissance is generally performed by the Navy at low-level (700 mb or below) and by the Air Force at 700 mb and above. Navy aircraft, which normally penetrate and maneuver in hurricane eyes at 1500 feet, are restricted (for flying safety reasons) from such an operation when winds of over 120 knots (138 mph) or a radar-measured eye of 15 miles (diameter) or less exists or are forecast at that altitude. However, a fly-through penetration with no maneuvering in the eye can be accomplished by the Navy at 700 mb. With due regard for flight safety, Air Force and RFF aircraft penetrate and transit at 700 mb (approximately 9000 feet) regardless of the wind speed or eye diameter.

ESSA(RFF) aircraft are funded to perform research flights, since inter-departmental agreements specify that operational flights will be conducted by Air Force and Navy aircraft. In certain instances - specifically when overflight of Cuba is required, - ESSA(RFF) conducts operational missions, but in the general case, funding allocations limit this type of mission.

Procedures for existing plans for obtaining data in regenerating, dissipating or developing storms do not include sufficient provisions for obtaining profile data (winds versus distance from center) considered necessary by forecasters. This specific requirement is not included in the 1969 National Hurricane Plan.

CONCLUSIONS

In the evaluation of immediate and future courses of actions, the actions taken in connection with Hurricane Camille were reviewed. This review resulted in three conclusions:

- Ample and timely warnings based on adequate forecasts were provided to persons and organizations in locations deemed to be endangered by the storm as it moved from the Gulf on-shore.

- There was no significant effect on the issuance of warnings and forecasts as a result of the failure of aerial weather reconnaissance aircraft to provide certain data in this particular case. However, there was a delay in obtaining information on the intensity of the storm.

- Data provided to forecasters from weather reconnaissance aircraft was less than optimum. This was traced to four primary factors:

  - Procedures which limited eye penetrations at 1500 feet, as applied to U.S. Navy aircraft, for flight safety reasons.

  - Inherent instrumental limitations, specifically in USAF airborne weather radars. Information is degraded in heavy precipitation conditions on the fixed wave length used, and radar data were consequently not available at critical periods in Camille's history.

  - Insufficient post-flight liaison between NHC and flight crews to obtain data not received from aircraft in-flight.

  - With advancing technology, there are now a number of requirements for data which are not reflected in the 1969 National Hurricane Operations Plan.

ACTIONS

1. To insure that appropriate aircraft with the best available equipment are used on all future hurricane occurrences, the following actions are being taken:

a. Procedures

Starting immediately, aircraft operating and flight procedures (to include Navy RC-121 aircraft penetration and transit of hurricane eyes at 700 millibars) as well as ground communications procedures will be revised as necessary to insure that critical information is provided.

b. Aircraft

The U.S. Navy will take action to replace the present weather reconnaissance aircraft, with instrumentation to meet the requirements. This action is programmed for FY-72.

c. Instrumentation

o The USAF will take action to modernize the present USAF weather radar. Technical evaluation is underway to determine the most effective weather radar for Air Force aircraft. This equipment will be obtained and installed as soon as possible; however, since this is a development item, availability for the next hurricane season is improbable.

oo The USAF will take action to modernize the other instrumentation aboard the reconnaissance aircraft. The temperature measuring equipment will be available by the next hurricane season. A study contract will be let for the remainder of the equipment.

ooo ESSA will take action to update the instrumentation aboard the two DC-6 aircraft. Flying hours for operational back-up of the DOD aircraft will be added. This action is reflected in the current supplemental budgetary request.

d. Data Requirements

Advances in the state of the art of hurricane forecasting have generated new requirements for data. The requirements will be included as a matter of urgency on the agenda of the next annual hurricane conference. The conferees will be directed to address this problem and to incorporate the results in the National Hurricane Operations Plan at the next meeting scheduled for February 16, 1970.

2. Costs involved All of these actions have been programmed by the agencies. Following are the estimated costs and status of programming:

Item	Prior Status	Present Status	Estimated Cost $M
U.S. Navy replacement of WC-121 aircraft, with required instrumentation	Programmed and unfunded	FY-72	68M*
USAF Weather Radar	Programmed but unfunded	Programmed and now funded	5 **
USAF Remainder of hurricane reconnaissance instrument improvements	Programmed but unfunded	Development funds now available	4.2
ESSA - Update DC-6 instrumentation and add flying hours	FY-71	Current supplemental (FY-70)	1.35

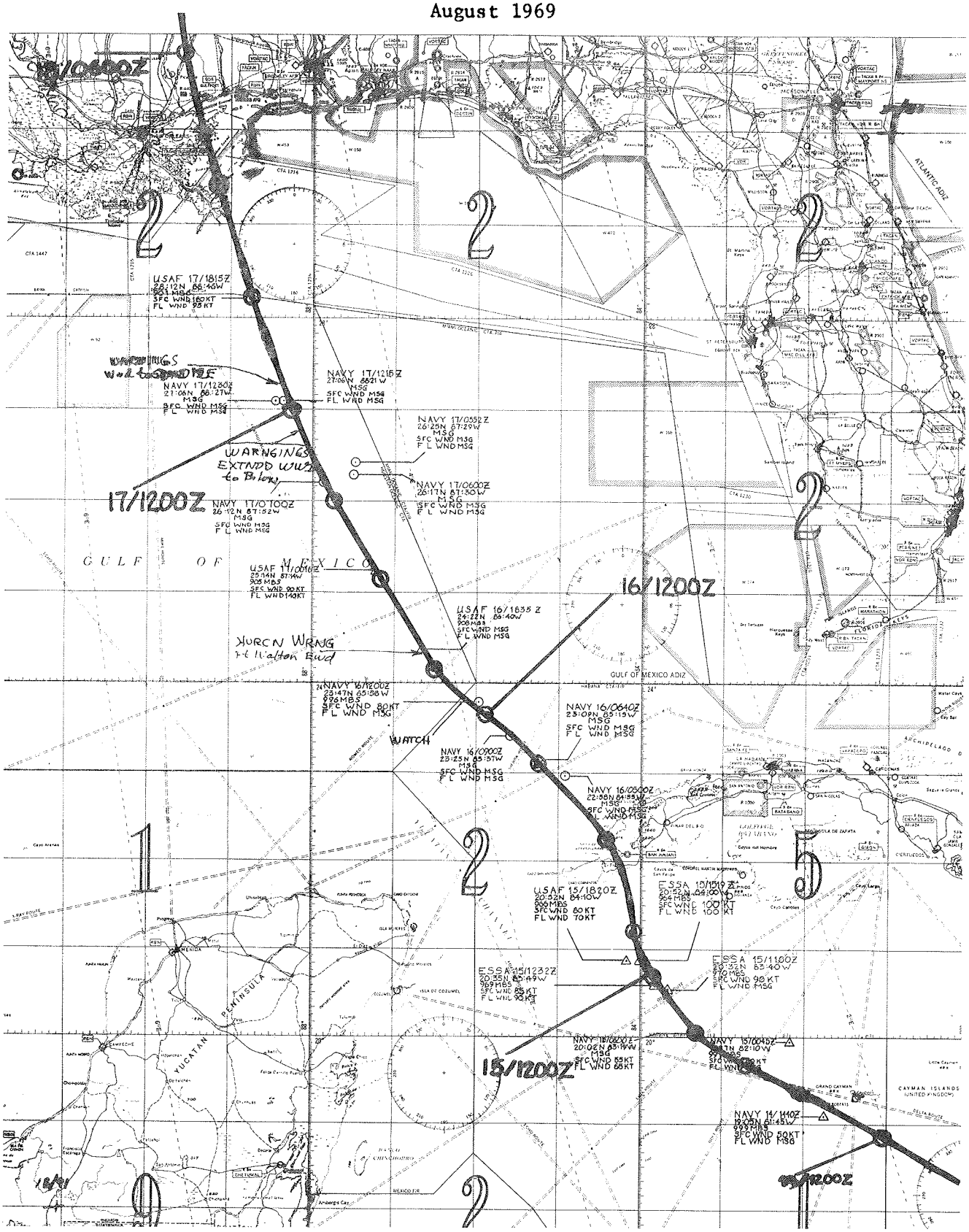
3. The cost of these programs is 78.55M. The net effect is to provide required improvements earlier by accelerating the time schedules of plans which had already existed.

4. Continuing Action - The replacement for the U.S. Navy aircraft, now programmed for FY-72 in this report, has not been specified. The options which are available, including transfer of existing resources within the DOD, complete overhaul and modernization of existing aircraft, and additional procurement of current aircraft (WC-130 or WP 3D), cannot be explored in the time available to complete this report. A direct evaluation of aircraft is underway by the U.S. Navy. With funding in FY-72, complete investigation of these options can be accomplished by the Department of Defense.

* Includes flyaway, initial spare support, and instruments based on a six plane buy. Cost of modernizing present aircraft not estimated.

** Does not include development costs.

HURRICANE "CAMILLE"
August 1969



Attachment A

Z-4 hrs = EDT

HURRICANE CAMILLE
WEATHER RECON FIXES
14-17 AUGUST 1969

FIX	DAY	TIME	FIX MADE BY	CENTRAL PRESSURE MB	SFC WIND KNOTS	FLT. LEVEL WIND KNOTS
1	14	1440Z	Navy	999	50	Msg.
2	15	0045Z	Navy	997	60	Msg.
3	15	0600Z	Navy	Msg.	55	65
4	15	1100Z	ESSA	970	90	Msg.
5	15	1232Z	ESSA	969	85	90
6	15	1519Z	ESSA	964	100	100
7	15	1820Z	USAF	966	80	70
8	16	0500Z	Navy	Msg.	Msg.	Msg.
9	16	0640Z	Navy	Msg.	Msg.	Msg.
10	16	0900Z	Navy	Msg.	Msg.	Msg.
11*	16	1200Z	Navy	996	80	Msg.
12	16	1835Z	USAF	908	Msg.	Msg.
13	17	0016Z	USAF	905	90	140
14	17	0552Z	Navy	Msg.	Msg.	Msg.
15	17	0600Z	Navy	Msg.	Msg.	Msg.
16	17	0700Z	Navy	Msg.	Msg.	Msg.
17	17	1215Z	Navy	Msg.	Msg.	Msg.
18	17	1230Z	Navy	Msg.	Msg.	Msg.
19	17	1815Z	USAF	901	180	95

* Not a penetration

Attachment B

ATTACHMENT C

PRESENT INSTRUMENTATION OF RECONNAISSANCE AIRCRAFT *

ELEMENT		USAF	NAVY	ESSA
Weather Radars	PPI	AN/APN-598 (3 cm)	AN/APS-20 (10 cm)	DC-6's AN/APS 20 E (10 cm) Collins WP 101 (5-6 cm)
				DC-4 AN/APS-42 (3 cm)
	RHI	NONE	AN/APS-45 (3 cm)	DC-6's Bendix RDR- ID (3.2 cm)
				DC-4 None
WINDS Flight Attitude	Compass type	N-1	CGRS	N-1
	Accuracy	± 2°	± 1°	± 0.2°
	Airspeed type	M-1A	AX-606	A-2
	Accuracy	± 5 kts	± 3 kts	± 5 kts
	Doppler radar type ground speed	APN - 147	APN - 153	APN - 82
	Range	70-1000 kts	70-500 kts	70-700 kts
	Accuracy	± 5 kts	± 5 Kts	± 2.1 kts
	Drift Range	± 40°	± 60°	± 45°
	Accuracy	± 0.25°	± 1°	± 0.15°
	Wind Error (rms)	3°/7 kts	Unknown	3 kts to 15 kts 2% > 15 kts

*WC-130 , WC-121, DC-6 = Only

ELEMENT		USAF	NAVY	ESSA
Flight Level Temperature	Sensor Type	Rosemont 102	D4 2801 A	Vortex AMQ-8 Rosemont 102
	Range	-85° to +50°	-40° C. to +99.99° C	-80° C to +50° C
	Accuracy	± 1° C	± 0.1° C	± 1° C
Sea Surface Temperature	Sensor Type	None	PRT - 4A	PRT-5
	Range	---	-40° C to +40° C	+10° F to +110° F
	Accuracy	---	± 1° C	± 2° F
Humidity/ Dewpoint	Sensor Type	None	Cambridge Systems 137-C3	IR Hygromater Cambridge Systems
	Range	---	-50° C to +50°C	IR: 0-20 gm/m^3 Cambridge: -50°C to +50°C
	Accuracy	---	± 1° C	IR ± 5% Cambridge: ± 1° C
Liquid Water Content	Sensor Type	None	None	Johnson-Williams
	Range	---	---	0-6 gm/m^3
	Accuracy	---	---	± 30% EST

		USAF	NAVY	ESSA
Attitude	Pressure Type	MA -1	FA-112 Rosemont	555 T I
	Range	0-50 K'	0-20 K'-FA-112 1050-500 mb - Rosemont	1050-50 mb
	Accuracy	50' + 0.25%	± 0.5 mb - FA-112 ± 0.5 mb - Rosemont	± 0.5 mb
	Radar Type	SCR-718	SCR-718 APN-159	APN-159
	Range	0-30 K'	0-30K' SCR-718 0-70K' APN-159	0-10 K'
	Accuracy	50' + 0.25%	50' + 0.25% SCR-718 8' or 1% APN-159	8' or 1%
	Pressure Height at 10 K' Accuracy	± 106'	± 77' - FA-112	± 77'

SONDES

	AN/AM T-6 USAF, NAVY, & RFF
Temperature Range	-60 to +40 C
Accuracy	
Accuracy	± 1.2 C
Sampling Interval	Continuous every other 20 mb
Response Speed	Good
Performance	Fair
Pressure Accuracy	± 6.0 mb
Sampling Interval	650'
Performance	(Long extrapolation at S.L.)
Humidity Accuracy	7% RH for 1 cycle only - then undefined
Sampling Interval	Continuous every other 20 mb
Response Speed	2 sec. at +40 C to 2 min. at -30 C
Performance	Poor - washes out, deteriorates in atmosphere, very slow response
Sonde Fall Rate (f/m)	1500 (after 6 sec free fall)
Cost	$71.
Failure rate	27%
Performance	Fair
Potential	Poor

ATTACHMENT D

Desired Capabilities of Hurricane Reconnaissance Aircraft
As Viewed by the National Hurricane Center
September 1969

1. A capability to penetrate, at 10,000' or below, all hurricanes which threaten a coastline: to obtain maximum winds at flight level in the strongest sector and the central pressure.

2. In a developing, regenerating or dissipating hurricane, a capability to measure sub-cloud layer winds along a profile from the storm center into the strongest pressure gradient (usually north or east of the storm), or-

3. In lieu of 2, above, a capability to obtain equivalent potential temperature profiles at an elevation just below the outflow level and along a track from the center outward through the strong sector.

4. An in-flight visual recorder, from which maximum gradients of critical elements (wind, D-value, temperature and humidity) can be reported in-flight.

5. A Doppler radar wind-finding system with minimal attenuation due to rain beneath the aircraft. As an alternative, inertial navigation should be available as a back-up system.

6. Temperature measurements, free of wet bulb effects, should be accurate to 0.5° C. Dewpoint depression (humidity measurement) should also be accurate to 0.5° C.

7. An S-band weather radar, PPI mode, with a beam width less than three degrees and a range of at least 200 miles.

8. A radar, in the RHI mode, X or K band, for measuring cloud tops,

9. An infrared temperature sensor for measuring sea-surface temperature gradients.

10. A system operating radius of 2,000 miles.