# CHAPTER 2

# RECONNAISSANCE

## A. GENERAL

In past typhoon annuals this chapter has traditionally been allotted to aircraft reconnaissance with little or no mention of the other reconnaissance platforms--satellite and land radar. All three platforms have been given individual attention in this report.

The three reconnaissance platforms are considered by JTWC to be complementary tools. Each has unique advantages and disadvantages not common to the other two. For example, the satellite has the capability of observing vast areas simultaneously, providing data which allows the typhoon forecaster to immediately identify suspect disturbances. On the other hand, once a disturbance is located, its precise state of development can only be determined by aircraft penetration. Only the aircraft can reliably locate the outer limits of the 100, 50, and 30-kt wind envelopes. The land radar site is not plagued by navigational or gridding errors like the other platforms but has the disadvantage of not being able to provide quantitative estimates of intensity. The land radar and satellite platforms have the ability to monitor tropical cyclones when they move within restricted areas such as the no-fly area surrounding China. In short, it is desirable to have all three platforms contributing to the overall reconnaissance data-base.

## B. AIRCRAFT RECONNAISSANCE

From the standpoint of flexibility, the aircraft is an outstanding reconnaissance tool. As a mobile meteorological platform, it can provide, by direct measurement, data on a storm's periphery and interior. An assessment of the storm's intensity can be derived on penetration by obtaining a central pressure and profile of maximum winds. By conducting profiles thru the storm, the aircraft can provide data for determining the extent of destructive winds. The airborne platform can remain on station for a 6-hour period enabling it to monitor changes in track movement, intensity and radius of damaging winds and providing this information on a timely basis for input into warnings issued by the appropriate warning center.

### 1. RECONNAISSANCE REQUIREMENTS

During 1971 JTWC reconnaissance requirements for investigations, fixes, and/or synoptic tracks were relayed to the Tropical Cyclone Reconnaissance Coordinator (TCRC) at Andersen AFB each day about 0300Z for the following day's missions. This message included the area for

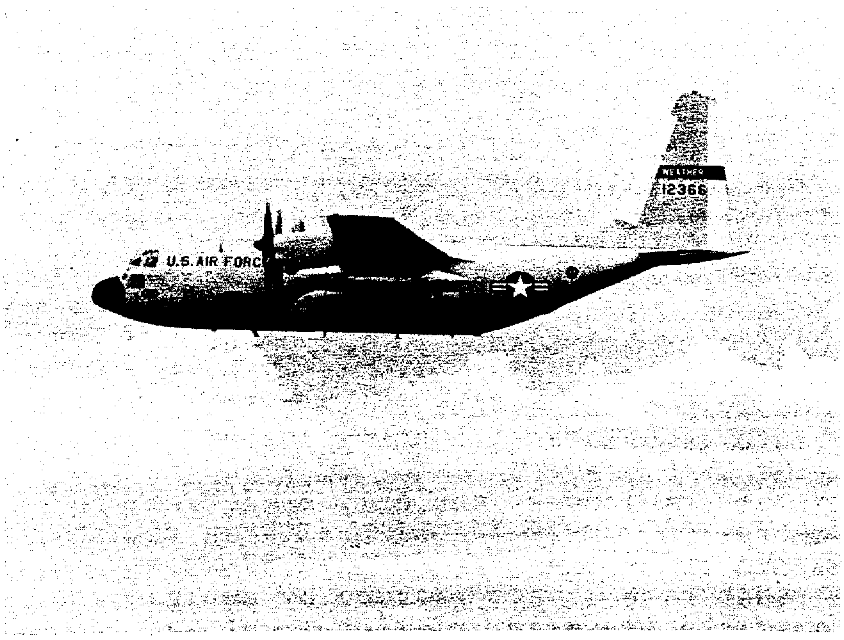


FIGURE 2-1 WC-130 AIRCRAFT FLOWN BY THE 54th WEATHER RECONNAISSANCE SQUADRON LOCATED AT ANDERSEN AFB, GUAM.

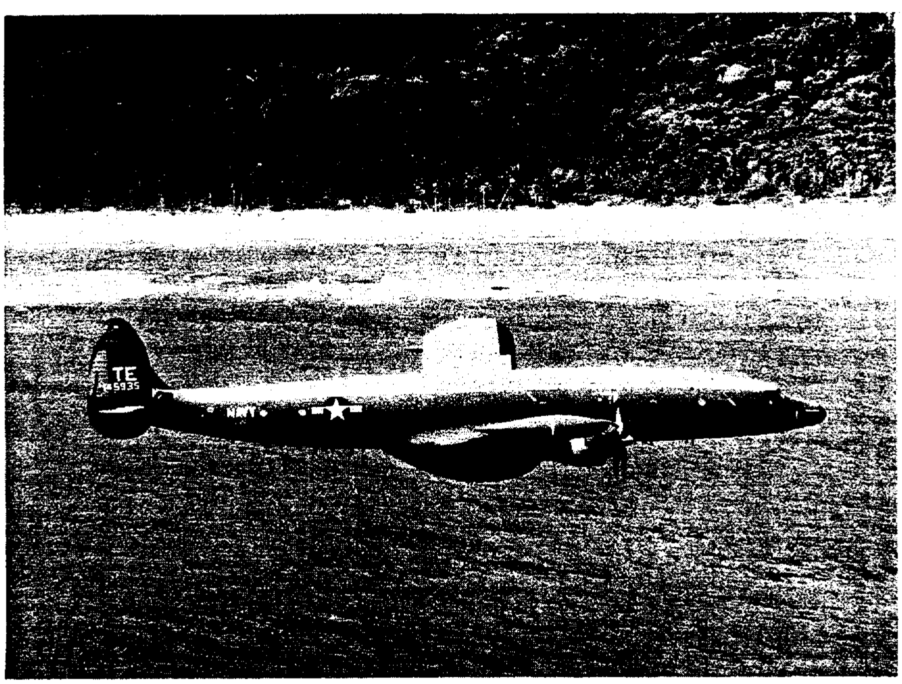


FIGURE 2-2 WC-121 AIRCRAFT FLOWN BY THE FLEET AIR RECONNAISSANCE SQUADRON ONE (VQ-1) LOCATED AT NAVAL AIR STATION, GUAM.

investigation, forecast position of the cyclone at levied fix times, and/or a standard synoptic track. The TCRC then assigned the missions to the Air Force's 54th Weather Reconnaissance Squadron (54 WRS) operating WC-130 aircraft (Figure 2-1) and/or the Navy's Fleet Air Reconnaissance Squadron ONE (VQ-1) operating WC-121 aircraft (Figure 2-2). Both squadrons were based on Guam but often staged from other bases according to the relative location of the reconnaissance area and available assets. Unfortunately, support from VQ-1 was terminated on 1 November due to deactivation of their weather reconnaissance mission. During the peak of the season, aircraft from the 55th and 53rd Weather Reconnaissance Squadrons periodically augmented the assets on Guam.

A change in the levying procedures this past season involved tasking by TCRC of the individual squadrons on the basis of availability of resources, as opposed to the previous fifty-fifty sharing of requirements. A similar system has been in effect for Atlantic hurricane reconnaissance since 1965. Also during 1971 the TCRC, on request from JTWC, provided a crew and aircraft on alert from one of the squadrons for launch within 4 hours, if it was determined that fixes might be levied on a suspect system within the next 24-48 hours. This provided the warning center with increased flexibility in committing reconnaissance assets to a given area. As a result, many investigative flights were canceled based on satellite data just prior to launch of the mission.

Four fixes per day are levied on all tropical cyclones within the JTWC primary area of responsibility (Figure 2-3). Two fixes per day are levied in the secondary area. Reconnaissance aircraft are not allowed to fly within the restricted zone depicted in Figure 2-3. Fixes are levied at six-hourly intervals for two hours before warning time in the primary area and normally at twelve-hourly intervals for three hours before warning time in the secondary area. Additional fixes and other information may be requested by operational commanders through JTWC when such additional information is needed to make operational decisions. These requests are honored as resources permit.

## 2. INVESTIGATIVE MISSIONS

After detecting a disturbance, by using satellite and conventional data, an aircraft is dispatched to thoroughly investigate the suspect area. Two investigative procedures are used--a point investigative or an investigative pattern. If the disturbance appears to be well

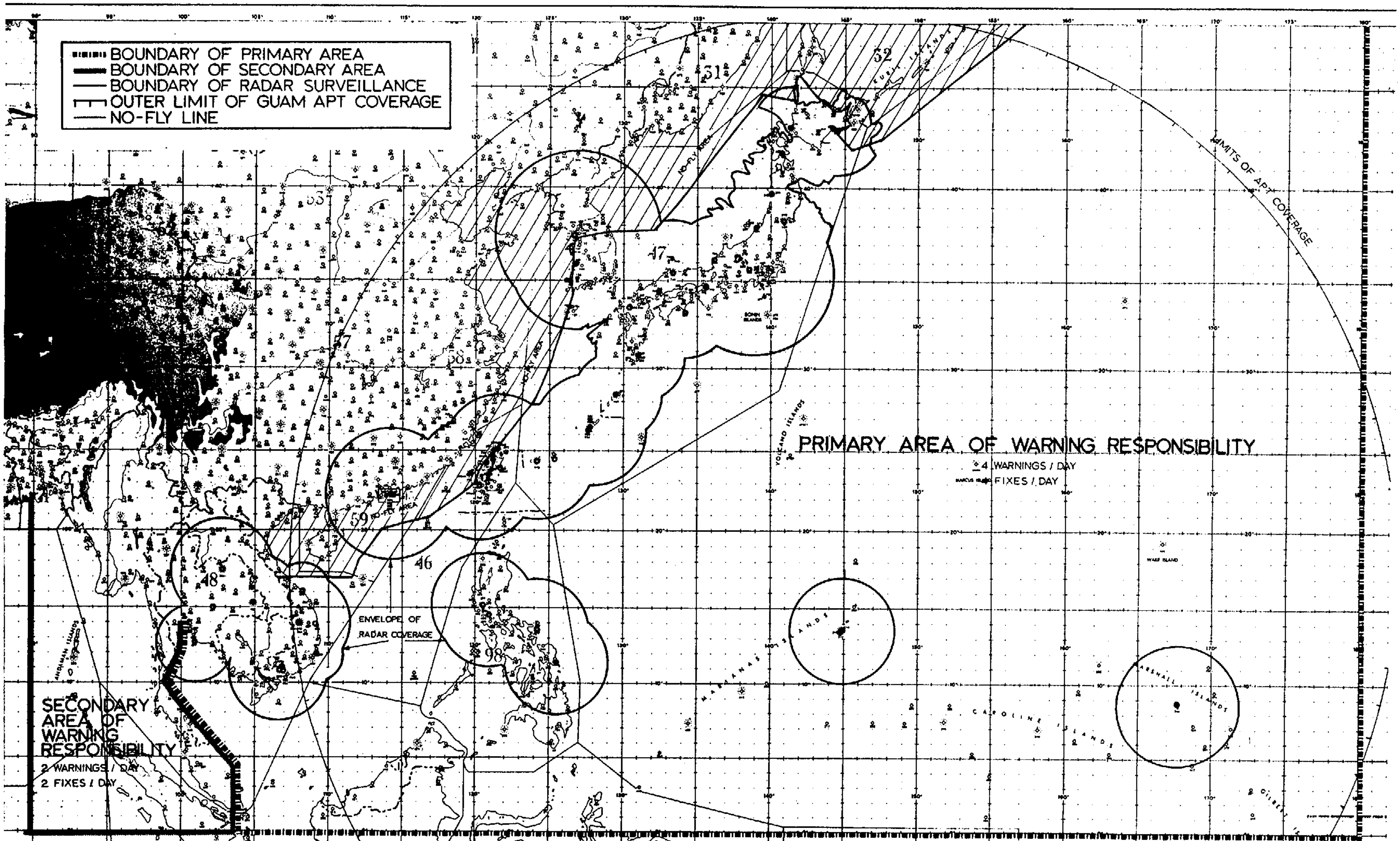


FIGURE 2-3. JOINT TYPHOON WARNING CENTER AREA OF WARNING RESPONSIBILITY. RECONNAISSANCE AIRCRAFT ARE CAPABLE OF FLYING ANYWHERE IN THE AREA EXCEPT THE RESTRICTED ZONE ALONG THE COAST (NO-FLY AREA). LAND RADAR AND SATELLITE COVERAGE ARE OUTLINED FOR REFERENCE.

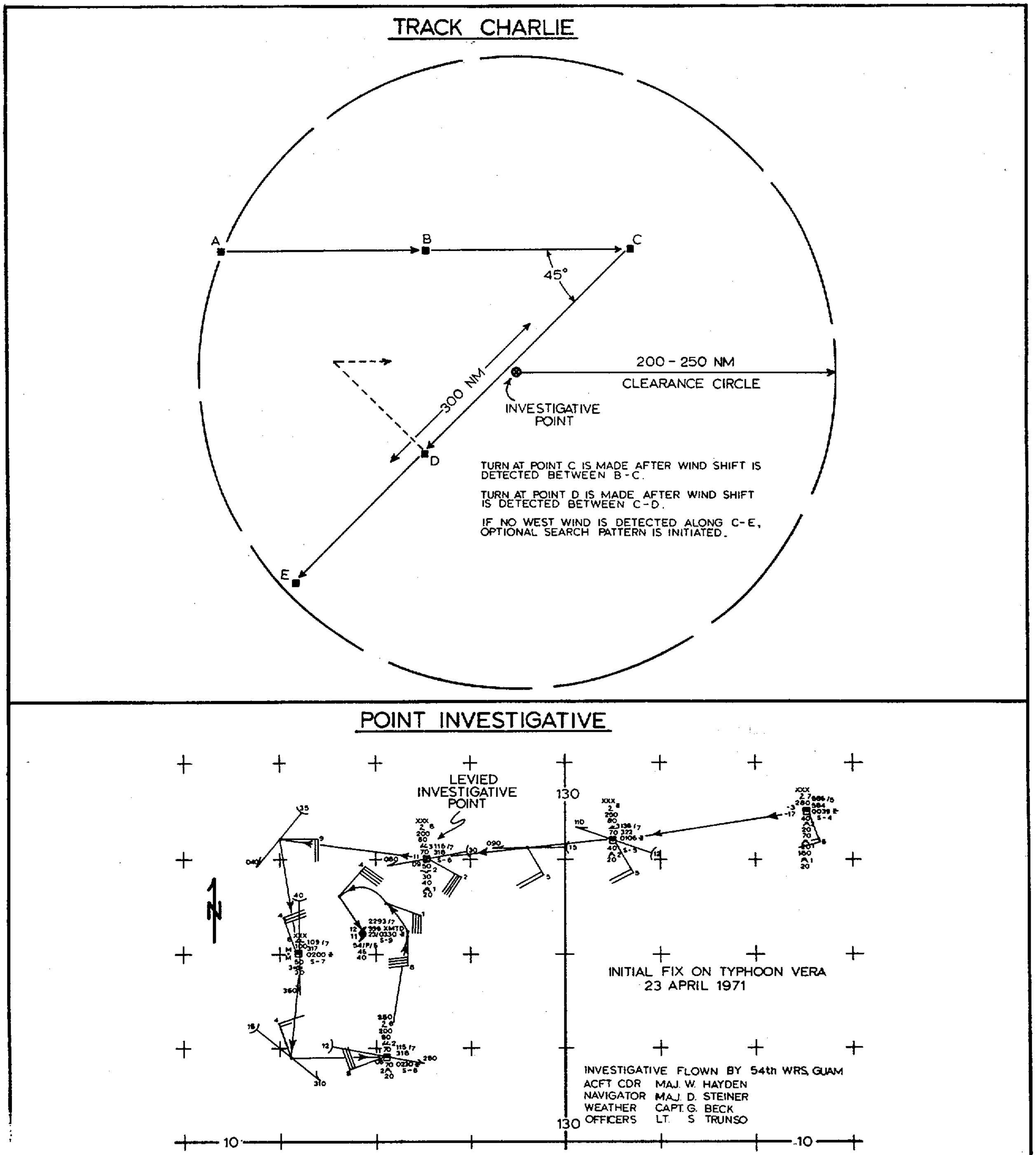


FIGURE 2-4. INVESTIGATIVE TRACK CHARLIE (ABOVE) AND EXAMPLE OF A POINT INVESTIGATIVE (BELOW). CHOICE OF METHOD DEPENDS ON ESTIMATED INTENSITY OF STORM.

developed with little doubt as to the presence of a well-defined circulation, a point investigative is levied. The aircraft flys from the staging base directly to the investigative point and begins a search pattern from there. If the measured wind field and/or radar presentation indicate the levied point is "off", it is up to the meteorologist aboard the aircraft to alter the flight path accordingly in order to fly directly to the center of the disturbance. Figure 2-4 is a good example of a well-executed investigative mission using the point method.

On the other hand, if the precise stage of development is unknown due to the lack of data or the disturbance is obviously not yet well defined, an investigative track is levied (Figure 2-4). This allows the aircraft to fly one latitude degree north of the investigative point until a windshift is detected, then predetermined turns are executed until the circulation is "closed off". The location of the center of circulation (if it exists) is transmitted as soon as available to JTWC. Regardless of the method used, observations are taken and transmitted every 30 minutes with mid-point wind observations in between. Most investigatives are requested to be flown at the 700-mb level (FWC/JTWC, 1970).

3. STORM FIX-MISSIONS

Eye data from tropical cyclones are provided by low-level penetration, intermediate-level penetration, or radar fixes taken from outside the center of the storm. Figure 2-5 shows a radar photograph of a well-developed typhoon taken from the APS-20 scope of the WC-121 aircraft. Some radar fixes are made using the "hole-in-sea-return" as illustrated in Figure 2-6. A discussion of this phenomenon is contained in a report by Senn (1961).

Penetration fixes are preferred since they provide a measure of the storm's intensity. Parameters such as the minimum sea level pressure, minimum geopotential height at standard level, maximum observed wind, and internal temperature of the vortex are used to measure the present intensity of the storm and to identify intensifying or weakening trends. Penetration fixes are made whenever possible but occasionally the small size of the eye combined with the intensity of the winds prohibit penetration. Less than 15% of 1971 fixes were made by radar.

New peripheral tracks were begun in July 1971 (Figure 2-7). These tracks are patterned after those which appear in the National Hurricane Operations Plan. They differ from previous peripheral tracks of past years

FIGURE 2-5 APS-20 RADAR PHOTOGRAPH OF TYPHOON BESS (120 KTS) OVER THE PHILIPPINE SEA 19 SEPTEMBER 1971.

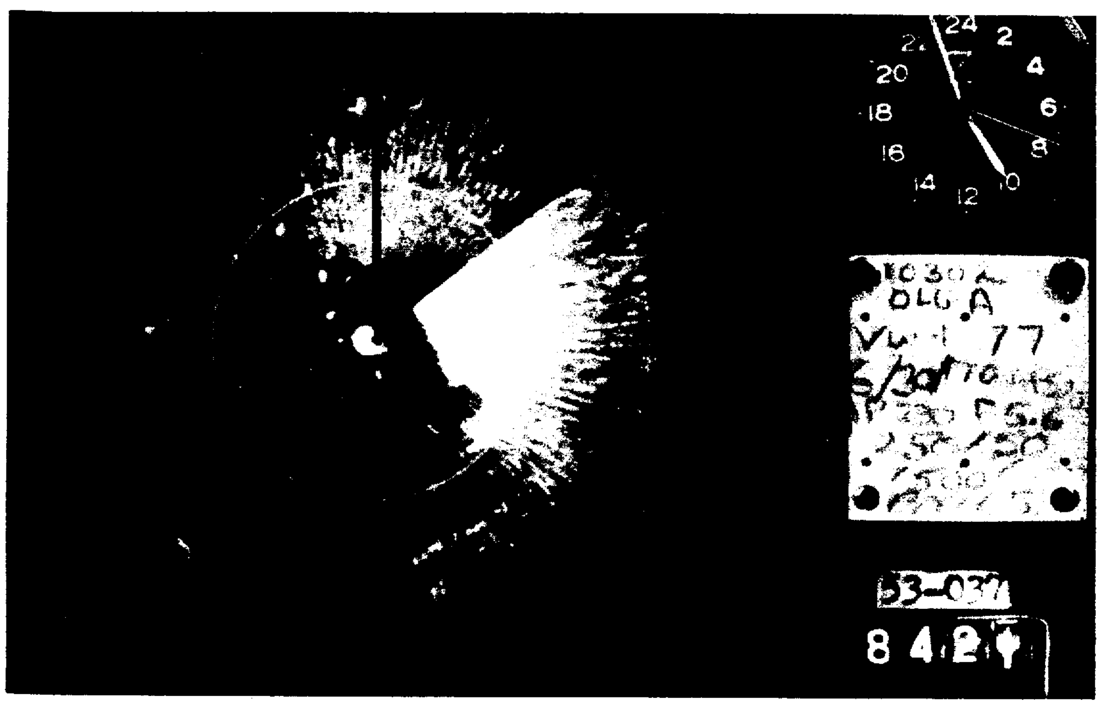

FIGURE 2-6. EXAMPLE OF THE HOLE-IN-SEA-RETURN PHENOMENON WHICH IS USED TO PINPOINT THE CENTER OF THE WIND EYE OF A TROPICAL CYCLONE. THIS APS-20 RADAR PHOTOGRAPH OF TYPHOON OLGA WAS TAKEN 30 JUNE 1970.

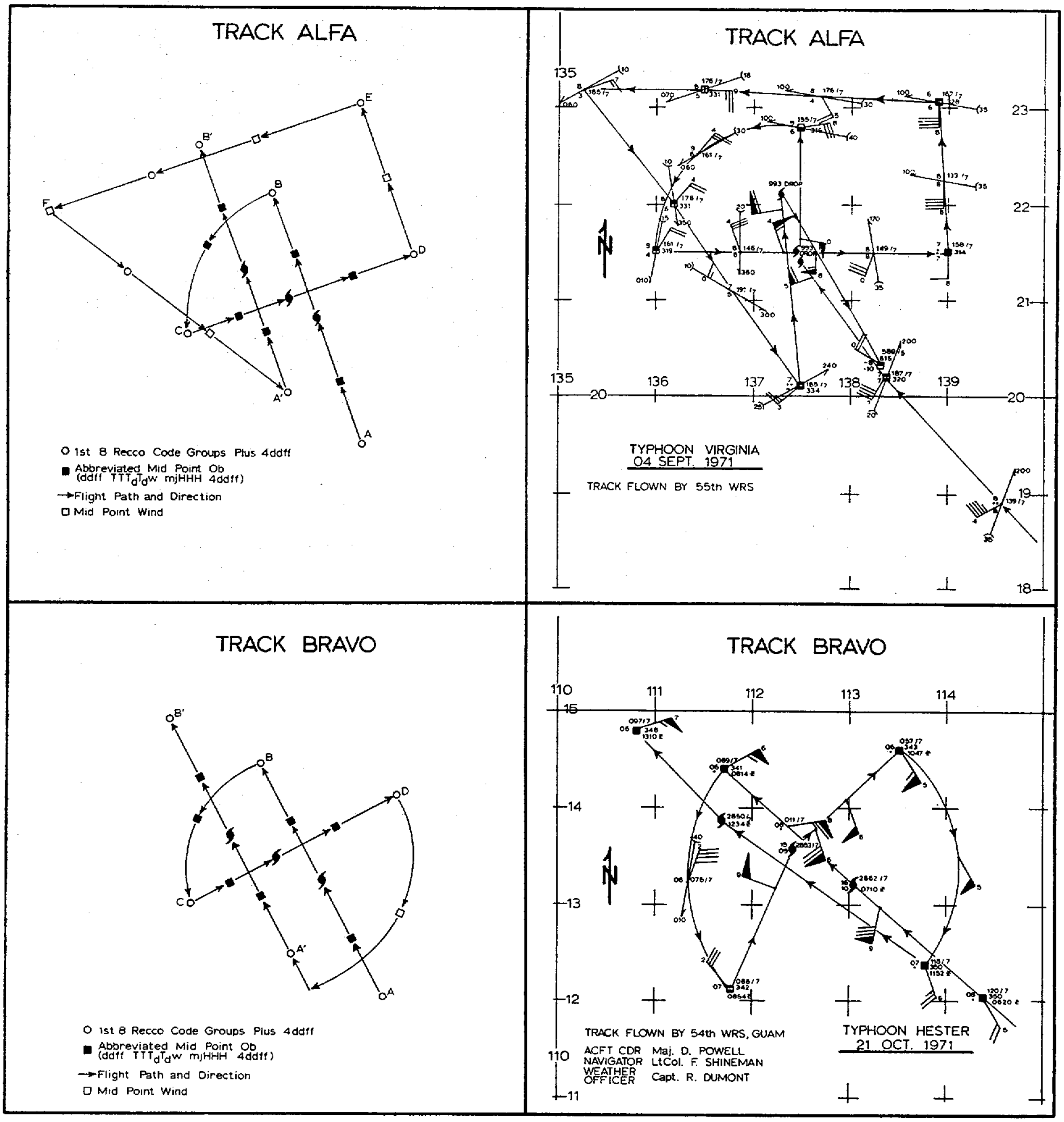


FIGURE 2-7. PERIPHERAL TRACKS FLOWN BY RECONNAISSANCE AIRCRAFT. TRACK ALFA IS USED FOR SIX-HOURLY FIXES AND TRACK BRAVO FOR THREE-HOURLY FIXES.

in that they consist of several radial traverses through the storm center which supply "radial profiles" of parameters such as wind, temperature, and geopotential height. Track ALFA is used for six-hourly fixes and Track BRAVO with three-hourly fixes. JTWC recommends a track to be flown but the ultimate decision as to peripheral track rests with the aircraft commander after arrival on the scene.

4. AIR/GROUND COMMUNICATIONS

The primary method for relay of the eye/center message from the aircraft to JTWC is by means of a direct phone patch with the aircraft. The primary route, as indicated in Figure 2-8, is through the Andersen Aeronautical Station. The weather monitor at Andersen checks the fixes as well as other reconnaissance data for meteorological and technical accuracy and prepares them for transmission to JTWC and on to the Fuchu ADWS for further distribution. If a reliable radio contact cannot be made through Andersen Airways, the message is passed through one of the other designated Aeronautical Stations.

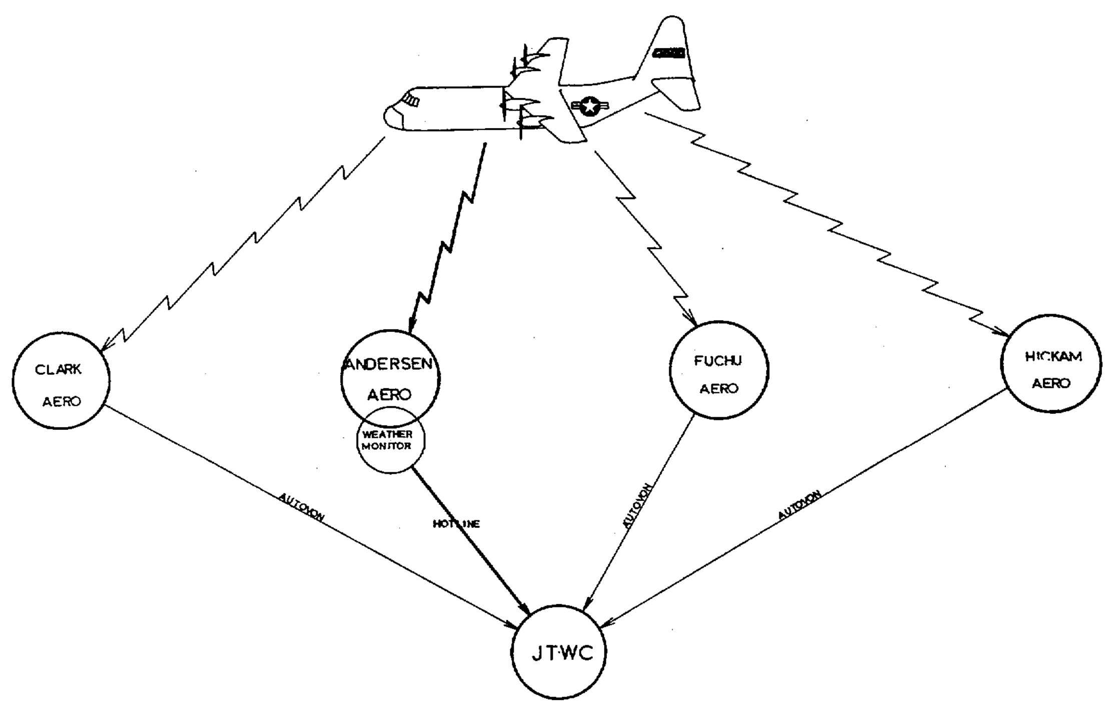


FIGURE 2-8. AIR TO GROUND COMMUNICATION ROUTES. PRIMARY ROUTE IS VIA ANDERSEN AERO.

TABLE 2-1. AVERAGE DELAYS
FOR FIXES RECEIVED DURING 1971 BY METHOD

| | AREAS OF RESPONSIBILITY | | | |
|---|---|---|---|---|
| | PRIMARY | | SECONDARY | |
| | NO. FIXES | AVERAGE DELAY TIME | NO. FIXES | AVERAGE DELAY TIME |
| PHONE PATCH | 720 | 27.5 MIN. | 3 | 61.7 MIN. |
| PHONE RELAY | 18 | 49.7 MIN. | 0 | |
| TELETYPE | | | | |
| A. POINT TO POINT | 8 | 45.9 MIN. | 1 | 135 MIN. |
| B. AIR TO GROUND | 2 | 32.5 MIN. | 0 | |

AVERAGE DELAY FOR ALL FIXES - 28.7 MIN.

Delay times (defined as the difference between the time of the fix and the time of receipt of the completed message) for receipt of fix data are shown in Table 2-1. Ninety-six percent of all fixes were received by phone patch with an average delay time in the primary area of responsibility of 27.5 minutes and about 62 minutes in the secondary area. Phone relay of fix data (only 2% of total cases) was accomplished if the aircraft's signal was not of patch quality. This method averaged 22 minutes slower than phone patches. Transmission via teletype was also much slower although the number of cases has been kept to about 1% of the total. The two fixes received by the Navy's direct air-to-ground teletype were very early in the season. The average delay for all fixes was 28.7 minutes.

Table 2-2 shows a slight increase in the percent of fixes delayed more than one hour. Here again, the larger number of multiple-storm situations last year than in 1969 or 1970 is a probable explanation due to the inability of the warning center to simultaneously copy two or more eye/center messages. Table 2-2 also shows the percent of fixes received after warning time, the value for this year being just above 2%. Further computations show that 4.5% of all six-hourly fixes arrived in the forecaster's hands less than 30 minutes prior to warning time. The fact that 3.5% of our warnings had to be amended due to non-receipt of fix

TABLE 2-2. 1971 DELAY STATISTICS COMPARED TO PREVIOUS YEARS

| | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 |
|---|---|---|---|---|---|---|
| % Fixes Delayed Over One Hour | 38% | 16% | 4% | 3% | 5% | 6% |
| % Fixes Received After Warning Time | 5.4% | 3.1% | 0.7% | 0.6% | 0.9% | 2.1% |

data by release time (normally about 30 minutes before the hour) convincingly demonstrates the importance of these six-hourly fixes in establishing accurate warning positions and intensities.

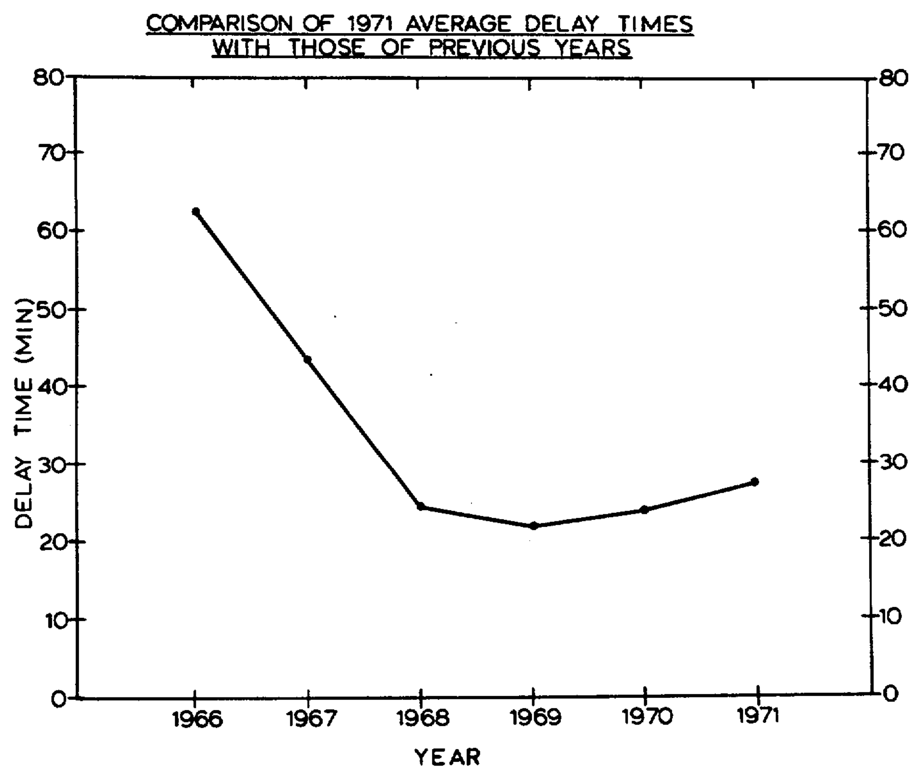


FIGURE 2-9 COMPARISON OF 1971 DELAY TIMES WITH THOSE OF PREVIOUS YEARS.

Figure 2-9 compares average 1971 delay times for all fixes with previous years. During the last three years there has been a slight increase. The greater number of multiple-storm days in 1971 than in 1969 and 1970 could well account for all of the increase.

## 5. SUMMARY

The extremely active typhoon season last year heavily tasked the available reconnaissance assets. As shown in Table 2-3, the two squadrons were tasked with almost 45% more fixes and investigatives than the long-term average of 675.

TABLE 2-3. COMPARISON OF FIXES AND INVESTIGATIVES LEVIED IN 1971 TO LONG-TERM AVERAGE

| | |
|---|---|
| Levied Fixes | 802 |
| Levied Investigatives | 179 |
| TOTAL | 981 |
| Average Levied Fixes/Invest (1962-1970) | 675 |

In response to decisions made at the 1971 typhoon conference, the concept of three-hourly fixes was operationally introduced in April. Fixes were levied on a three-hourly basis when tropical cyclones came within 300 n mi of key DOD installations. This amounted to 182 additional fixes being levied or about 23% of the total levied fixes for the year.

TABLE 2-4. DISTRIBUTION OF REQUIREMENTS AMONG RECONNAISSANCE SQUADRONS

| | Fixes | Investigatives |
|---|---|---|
| 54 WRS | 58.7% | 89% |
| VQ-1* | 41.3% | 11% |

*Deactivated 1 November 1971.

A. <u>FIXES</u> - TO BE COUNTED AS <u>MADE ON TIME</u>, FIX MUST SATISFY FOLLOWING REQUIREMENTS:

(1) WITHIN 1 HR BEFORE OR NLT 1/2 HR AFTER LEVIED FIX TIME.

(2) RADAR FIX MUST BE WITHIN 75 NM.

(3) FIXES WHICH FALL UNDER CLASS 2 OF OLD SCORING SYSTEM WILL BE COUNTED AS MADE.

(4) LATE/EARLY IS DEFINED AS OUTSIDE TIME FRAME IN A(1) BUT WITHIN 3 HRS (OR WITHIN 1/2 FIX INTERVAL, WHICHEVER IS LESS) OF LEVIED FIX TIME.

B. <u>INVESTIGATIVES</u> - TO BE COUNTED AS <u>MADE ON TIME</u>, FOLLOWING REQUIREMENTS MUST BE SATISFIED:

(1) IN INVESTIGATIVE CIRCLE BEFORE SPECIFIED NLT TIME.

(2) SPECIFIED FLIGHT LEVEL FLOWN.

(3) FULL RECON OBS EVERY 1/2 HR WITH MID- AND TURN-POINT WINDS REPORTED WHEN INSIDE INVESTIGATIVE CIRCLE.

(4) ADEQUATE COVERAGE ALL QUADS UNLESS CONCENTRATED EFFORT IN ONE OR MORE QUADS HAS BEEN SPECIFIED.

(5) SPECIFIED TRACK FLOWN (IF LEVIED).

(6) CONTACT WARNING CENTER BEFORE TERMINATION.

FIGURE 2-10. CRITERIA FOR EVALUATING RECONNAISSANCE EFFECTIVENESS. ALL FIXES AND INVESTIGATIVES ARE EVALUATED AS MADE ON TIME, LATE, EARLY, OR MISSED.

Of the fixes made, the 54th Weather Reconnaissance Squadron accounted for 59% while VQ-1, or Fleet Air Reconnaissance Squadron ONE, contributed 41% (Table 2-4). This is the same ratio for the number of aircraft which were available for tropical cyclone reconnaissance between the squadrons, however support from VQ-1 was terminated on 1 November due to deactivation of their weather mission. The Air Force squadron, as shown in Table 2-4, was responsible for the majority of the investigative missions.

Aircraft reconnaissance of JTWC's secondary area of responsibility began in October accounting for four levied fixes. The first mission on a Bay of Bengal tropical cyclone occurred on 28 October by an aircraft of the 54th Weather Reconnaissance Squadron operating out of Udorn, Royal Thai Air Base.

## 6. EFFECTIVENESS

A new scoring method which measures the combined effectiveness of the total reconnaissance force was introduced last season (Figure 2-10). This system is considered simpler and more efficient than its predecessor the "J Factor" which had been in effect since 1965. Another change which occurred last year was the adoption of a hardnose stand on relinquishing levied requirements. Because of the uncertain influence of this change in policy, the statistics of past years are not directly comparable.

TABLE 2-5. RECONNAISSANCE EFFECTIVENESS FOR 1971

| | ALL | 6HRLY | 3HRLY |
|---|---|---|---|
| Completed on Time | 698 | 540 | 158 |
| Early | 6 | 5 | 1 |
| Late and Missed | 98 | 75 | 23 |
| Total Levied | 802 | 620 | 182 |

Table 2-5 shows a breakdown of the reconnaissance effectiveness for last season. Of a total of 620 fixes levied for six-hourly intervals, 75 or 12% were late or missed. The late and missed fixes are purposely grouped together since they represent a penalty which is introduced into the typhoon forecast. Late fixes reduce the time available for proper evaluation of the fix and preclude the use of objective techniques. Fixes made after warning time cause a delay in release of a warning or an amendment to the most recent warning. Of course a missed fix degrades the forecast significantly since the initial position is more uncertain. Late and missed fixes affected 10% of the 747 warnings released during the 1971 season.

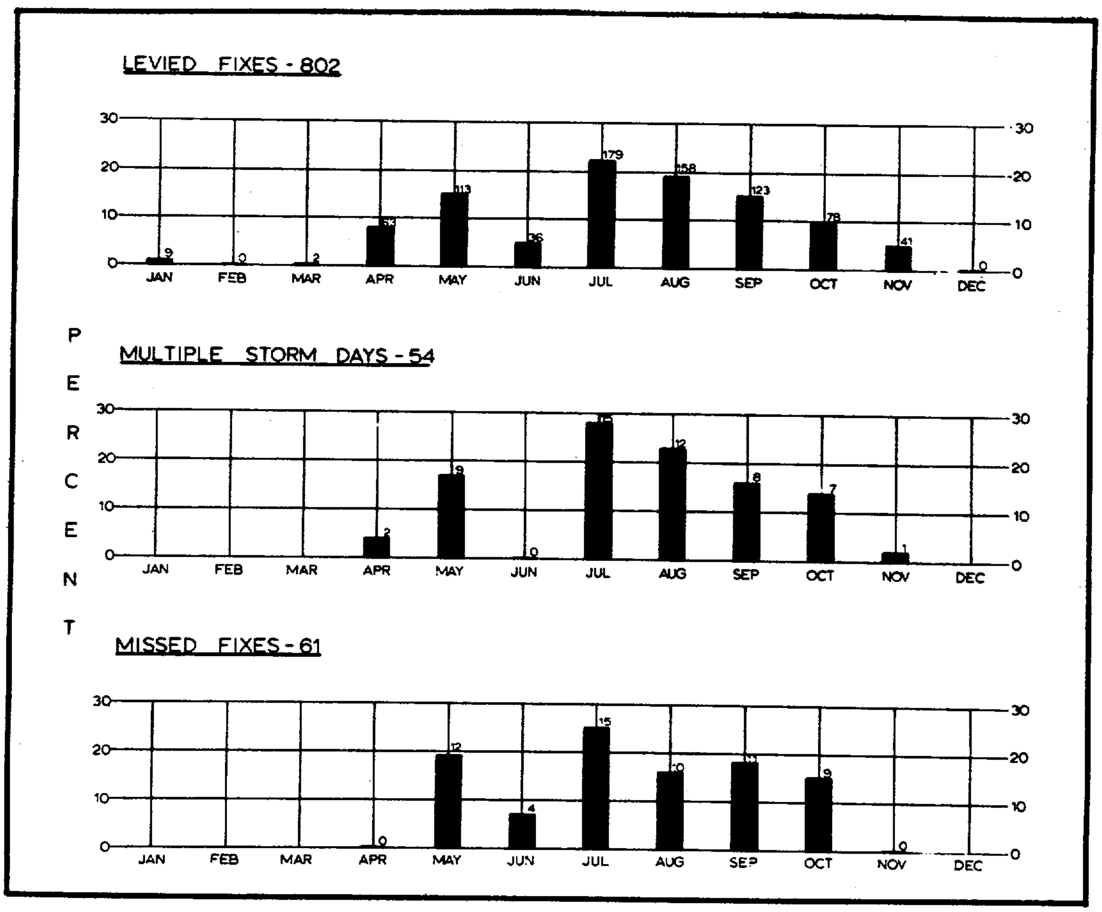


FIGURE 2-11. MISSED FIXES FOR 1971 COMPARED TO MONTHLY FIX REQUIREMENTS AND MULTIPLE-STORM DAYS.

Figure 2-11 sheds some light on why there was an increase of late and missed fixes last year. The top graph shows the monthly distribution of levied fix requirements for 1971. Two obvious peaks stand out in May and the period July through September. This past year had a total of 54 multiple-storm days and was distinguished as having the largest amount of levied fixes--almost equaling the combined total of 1969 and 1970.

The middle graph shows the monthly distribution of the multiple-storm days. It is by no coincidence that a majority of missed fixes occurred during the period of multiple storm occurrences. Fifty-four percent of all missed fixes occurred during these periods, thus illustrating the strain on assets to complete missions during periods of peak storm activity.

## C. SATELLITE RECONNAISSANCE

The weather satellite has revolutionized surveillance techniques over the vast areas of the tropical oceans where tropical cyclones form. With daily coverage over these areas it is virtually impossible for a disturbance to go undetected. In most cases pre-storm disturbances are tracked for several days before the first warning is issued. Satellite pictures provide first-guess estimates for the location of disturbances which are to be investigated by aircraft reconnaissance. Infrared passes during early morning hours are especially useful for briefing purposes. After a storm attains a visible eye, the satellite picture of the storm represents a useable "fix" for locating the storm provided that the information is available to the forecaster on a real-time basis.

### 1. SOURCES OF DATA

During the major portion of the typhoon season, ESSA-8 was the primary and only direct readout satellite as both ITOS-1 and NOAA-1 systems were shut off due to overheating in the momentum wheel assembly of the spacecraft (Figure 2-12). ESSA-9 was reactivated and performed as the primary stored-readout spacecraft.

The ATS-1 satellite provided valuable information for storms east of 150E last season. The data from this satellite are not copied at Guam, but relay of this information by telephone has been invaluable on occasion especially when the disturbance or storm is outside Guam's area of acquisition of APT data (Figure 2-3).

| SATELLITE | TYPE OF DATA | LOCAL TIME | REMARKS |
|---|---|---|---|
| ESSA 8 | APT (DIRECT) | 0940 | PRIMARY APT SPACECRAFT JUL - DEC |
| ESSA 9 | AVCS (STORED) | 1445 | PRIMARY AVCS SATELLITE JUL - DEC |
| ITOS-I | APT (DIRECT) | 1535 | REAL TIME TRANSMISSION SYSTEM |
| | DRSR (DIRECT) | 0335 | TURNED OFF 16 MARCH DUE TO TEMP |
| | AVCS (STORED) | 1535 | RISE IN SPACECRAFT MOMENTUM WHEEL |
| | SR (STORED) | 0335 | |
| NOAA-I | APT (DIRECT) | 1520 | REAL TIME TRANSMISSION SYSTEM |
| | DRSR (DIRECT) | 0320 | TURNED OFF 22 JUNE DUE TO TEMP |
| | AVCS (STORED) | 1520 | RISE IN SPACECRAFT MOMENTUM WHEEL |
| | SR (STORED) | 0320 | |

APT - AUTOMATIC PICTURE TRANSMISSION
AVCS - ADVANCED VIDICON CAMERA SYSTEM
SR - SCANNING RADIOMETER
DRSR - DIRECT READOUT SCANNING RADIOMETER

FIGURE 2-12. WEATHER SATELLITES WHICH PROVIDED DATA DURING THE 1971 TYPHOON SEASON. LOCAL TIME COLUMN DENOTES AVERAGE EQUATOR CROSSING TIMES.

During the past season attempts were made to pass APT data via AUTOVON from Clark AB but due to numerous communication problems this method never proved successful. Relay of APT data from FWC Pearl Harbor is done routinely on request. Further, verbal descriptions or eye "fixes" are passed by AUTOVON or message from APT sites in WESTPAC which are outside Guam's area of acquisition in accordance with CINCPACINST 3140.1K (1971).

Problems arise when a disturbance is outside the APT acquisition area of JTWC. In these cases the forecasters at the warning center must rely on a verbal description of the area by another meteorologist at the remote site. Many disturbances are quite deceptive in their initial stages in that the clues to development or even the presence of a disturbance may be so subtle that only an experienced tropical cyclone forecaster can properly interpret the picture. Something that appears insignificant to one person may be a very important clue to the trained tropical meteorologist. For this reason it is imperative that the warning center be supplied with real-time access to satellite data for its entire area of responsibility. This is not the case at present. Attempts to obtain the information via AUTOVON have not proven successful. Real-time coverage of the entire area will probably not be a reality until a geostationary satellite is positioned over the area.

Infrared data are particularly valuable since they allow for delineation between high and low clouds. On all satellite pictures the forecaster is looking for signs of organization in the cloud mass. The direction and magnitude of cirrus blowoff from thunderstorms are sometimes useful in determining the nature and degree of organization of upper-level outflow patterns. Evidence of low-level banding into the disturbance is also helpful in determining present and forecast intensities depending on the degree and strength of the inflow.

The Analysis Branch at the Environmental Satellite Service (NESS) reviews Advanced Vidicon Camera System (AVCS) pictures each day to locate tropical disturbances. Upon detecting a disturbance, a bulletin is issued and is relayed to JTWC which gives the position of the system and an estimate of its intensity based on a system of stages and categories of development.

Of 253 classifications made during 1971, 63% were verified as a tropical storm or typhoon, 24% were related to pre-storm development stages while 12% of the disturbances sighted failed to generate into a tropical storm. The remaining 1% were decaying or extratropical stages of tropical storms.

These bulletins are used by JTWC forecasters as late fixes if the storm is well developed or as an indication of the state of development if the disturbance is new. ESSA-9 is a stored-readout satellite not copied at Guam, thus the bulletins represent data from an independent source which can be compared to the ESSA-8 data received locally. The bulletins are especially helpful for disturbances which occur outside Guam's area of acquisition.

NESS supplied JTWC with valuable information from the ATS-1 satellite on occasion. Typhoon Mary formed north of Wake Island in an area which was beyond local APT coverage. The coordinates of the storm as given to the reconnaissance aircraft were uncertain due to an expected acceleration in forward speed. A call from NESS provided an up-to-date position of the storm based on ATS-1 data (Figure 5-23) in time to redirect the aircraft which allowed a penetration-fix of the storm. Without the call the

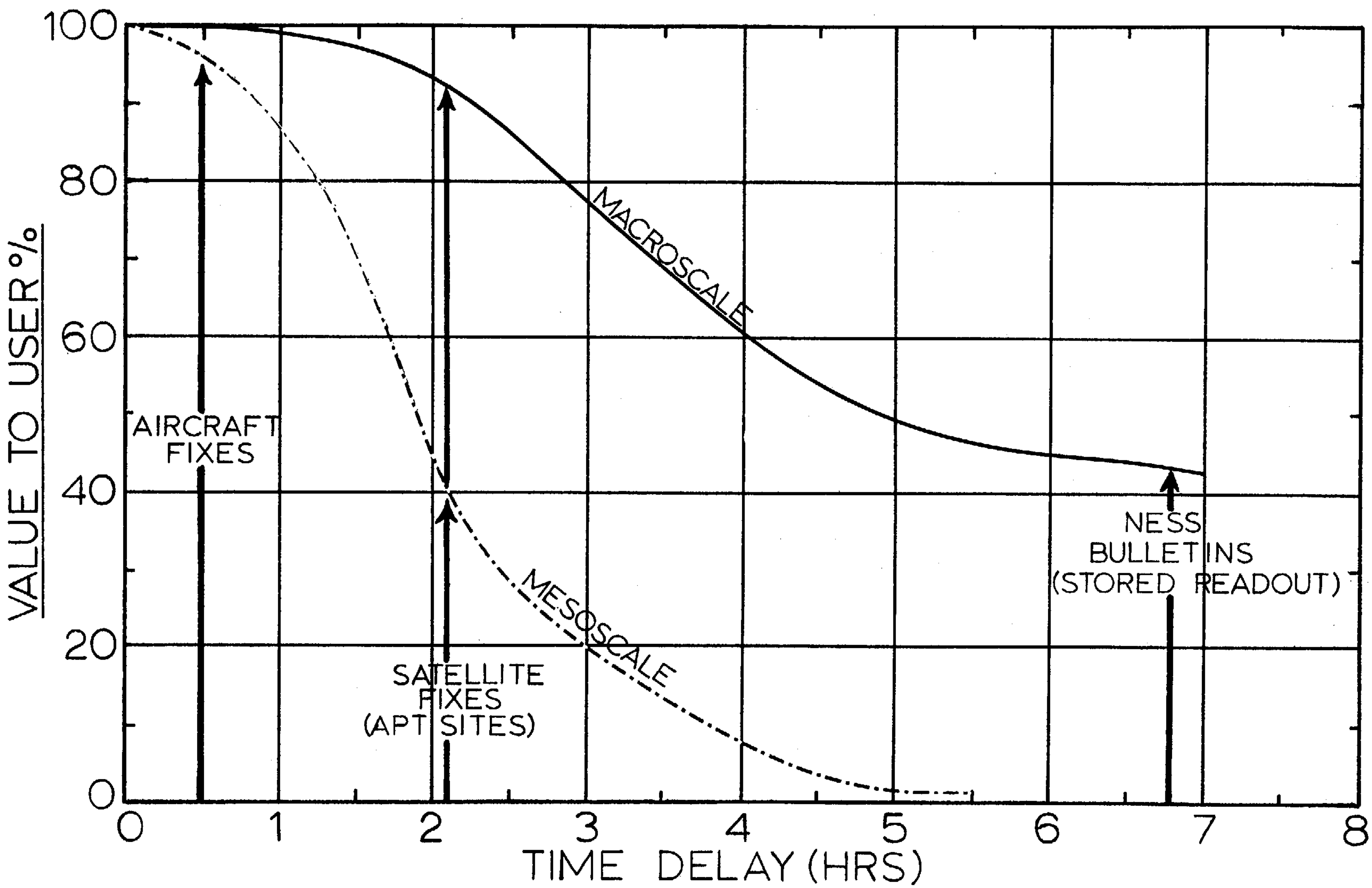


FIGURE 2-13 . VALUE OF DATA AS A FUNCTION OF TIME.

mission would have been fruitless since the estimated coordinates were in error by hundreds of miles.

Figure 5-41 is another example of the use of ATS-1 data in storm positioning. All of these data are mailed to JTWC for post-analysis purposes.

2. COMMUNICATIONS

JTWC, like all operational forecast centers, operates within a rigid time frame. In order for data to be used in a tropical cyclone warning, it must be current. Figure 2-13 illustrates the perishability of satellite data. This graph is based on a survey by the Systems Development Office of the National Weather Service and the Mitre Corporation (1969). The average time delays for aircraft fixes are indicated for reference. The curve marked macroscale refers to large scale, slowly changing information such as size and relative state of development of a storm. The mesoscale curve refers to information such as the fix position and intensity of the storm. This type of data perishes more rapidly with time as it is critical to each warning. The average time delays of just over two hours for bulletins sent from other APT sites reduces the value of the mesoscale data to below 40% of its original worth. Even larger delays, averaging nearly seven hours, are associated with bulletins from NESS.

Satellite data received live at the warning center is normally available for operational use within a half hour of the nodal crossing time. The warnings must be released to the communications center at 0530, 1130, 1730, and 2330 GMT. Taking into consideration time for receiving the satellite pass, gridding of the picture plus required interpretation, the availability of satellite information for real-time input into the warnings is restricted to satellite passes east of Guam. For disturbances west of Guam, the problem is compounded since satellite coverage is not available until 30 minutes to 2 hours after the time the warning has to be released. Of course this information can be used for verifying the accuracy of the last warning and can be the basis for an amendment in some cases. It should be pointed out here that a geostationary satellite would eliminate this problem since data would be available over the entire area every half hour.

### 3. POSITIONING VERIFICATION

A detailed breakdown of positioning errors* using satellite fixes is provided in Section B of Chapter 3. Table 2-6 summarizes the errors for 1971. Errors are given in nautical miles.

TABLE 2-6. POSITIONING ERRORS USING SATELLITE FIXES

| STAGE | B | C | C+ | X |
|---|---|---|---|---|
| CASES | 21 | 31 | 20 | 97 |
| MEAN | 85 | 52 | 30 | 24 |
| MEDIAN | 66 | 34 | 27 | 23 |
| RMS | 100 | 71 | 34 | 29 |

It is obvious from the data in Table 2-6 that positioning accuracy is dependent upon the stage of development--the stronger the disturbance the more accurate the fix. The most accurate fixes are derived from storms with visible eyes. For the 58 such cases which occurred during 1971 there was a mean deviation of 22 n mi and a median error of 19 n mi. Unfortunately, an eye is visible only about 25% of the time during the lifetime of a storm (1971 statistics).

### 4. INTENSITY VERIFICATION

JTWC forecasters routinely derive estimates of a storm's intensity from satellite pictures by stratifying by stage (Dvorak, 1968) and further classifying the systems into categories (Hubert and Timchalk, 1969). These derived values become critical pieces of information when a reconnaissance aircraft is not in the area.

All of the NESS bulletins received during 1971 were compared to the best track maximum winds.** The results

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*Position error is defined to be the magnitude of the vector from the fix to the corresponding position in time along the JTWC best track.

**Best track winds are determined after a careful post-analysis and are probably within $\pm$ 10% of the actual maximum wind.

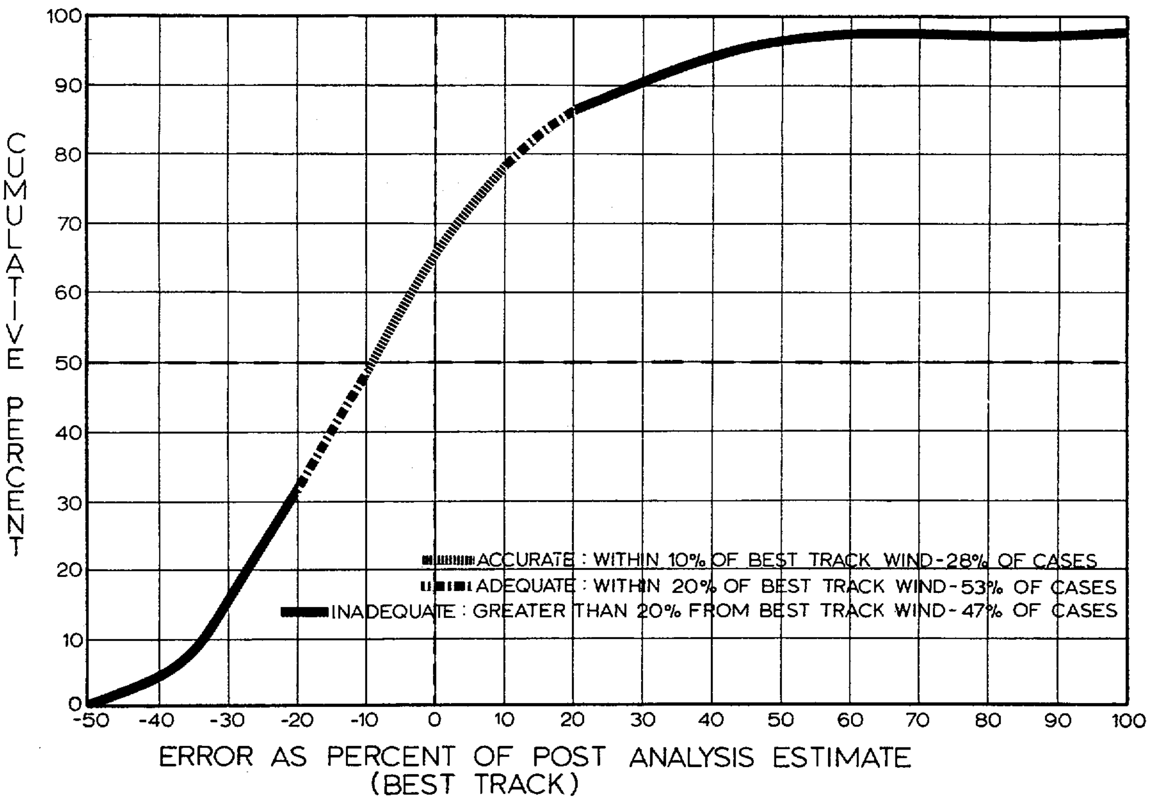


FIGURE 2-14. VERIFICATION OF SATELLITE WIND ESTIMATES. PERCENT ERROR IS COMPUTED BASED ON BEST TRACK POST-ANALYSIS. THE GREATER AREA UNDER THE CURVE TO THE LEFT OF ZERO THAN ABOVE THE CURVE TO THE RIGHT OF ZERO INDICATES THAT THE SATELLITE ON THE AVERAGE TENDS TO UNDERESTIMATE THE ACTUAL WIND SPEED.

are shown in Figure 2-14. Derived winds within 10% of the best track wind are considered accurate and any wind within 20% is considered adequate for input into the warning. Only 53% of last year's satellite-derived winds were considered adequate. The remaining 47% were not acceptable estimates.

A technique aimed at improving the present intensity classification system is now in the experimental stage. Developed by a member of the Analysis Branch at NESS, the system is based on seven classes of development. This new technique appears to overcome some of the deficiencies of the system, however, any conclusion at this point would be premature. Hopefully, by the end of the 1972 typhoon season, a complete evaluation of the system will be available.

It should be pointed out that any classification scheme has exceptions. These anomalies can become nightmares to the tropical cyclone forecaster if satellite data are all that is available. As a case in point, Figure 2-15 is an ESSA-9 view of typhoon Rose on the 16th of August, within hours of striking Hong Kong. Since the storm was past the restricted no-fly line, an aircraft penetration was impossible. The NESS classification system determined the

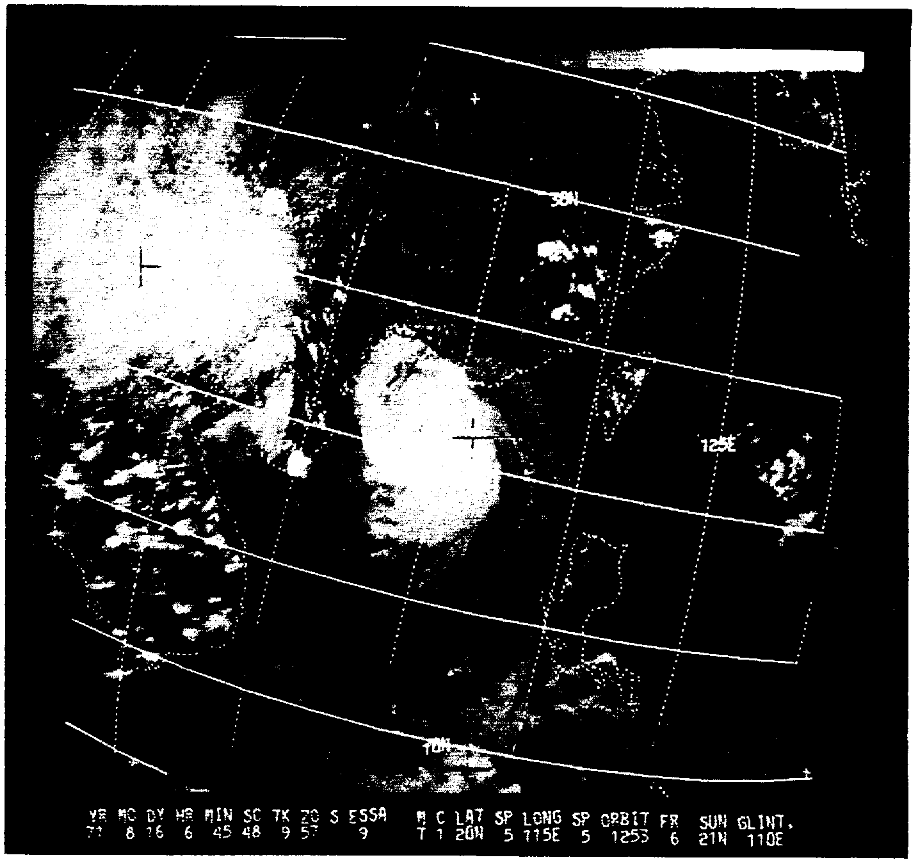


FIGURE 2-15 TYPHOON ROSE MOVING ON A NORTHERLY COURSE TOWARD HONG KONG 16 AUGUST 1971.

intensity of Rose to be 75 to 80 kt. Post analysis of Rose using ship data close to the eye and one ship which passed through the eye* indicated maximum sustained winds of 115-120 kt--a 50% error in the satellite estimate. This is all the difference between a moderate blow and a disaster.

## D. LAND RADAR RECONNAISSANCE

Over 600 storm fixes from land radar sites were received during 1971. This reconnaissance tool provided hourly fixes to the JTWC when a storm was within the envelopes of radar coverage indicated in Figure 2-3. In one instance (typhoon Irma as she approached Okinawa) three-hourly fixes levied by an operational commander were canceled by the warning center when the storm entered the area of land radar coverage thus saving one complete aircraft reconnaissance mission for that particular day. This is an excellent example of the symbiotic relationship which is desired among the available reconnaissance tools.

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*None of these data were available at the time of the forecast.

1. SOURCES OF DATA

Radar reports are received from over 50 different sites in the western Pacific and Southeast Asia. Past annual reports list these stations by name and give characteristics of the radars (FWC/JTWC, 1970). The most timely and reliable data are received from the excellent network which exists in Japan and the Ryukyu Islands and is administered by the Japanese Meteorological Agency. Figure 2-16 is an example of the radar presentation of typhoon Billie as seen by the radar located at Naze, Anami-o-shima Island in the Ryukyu chain.

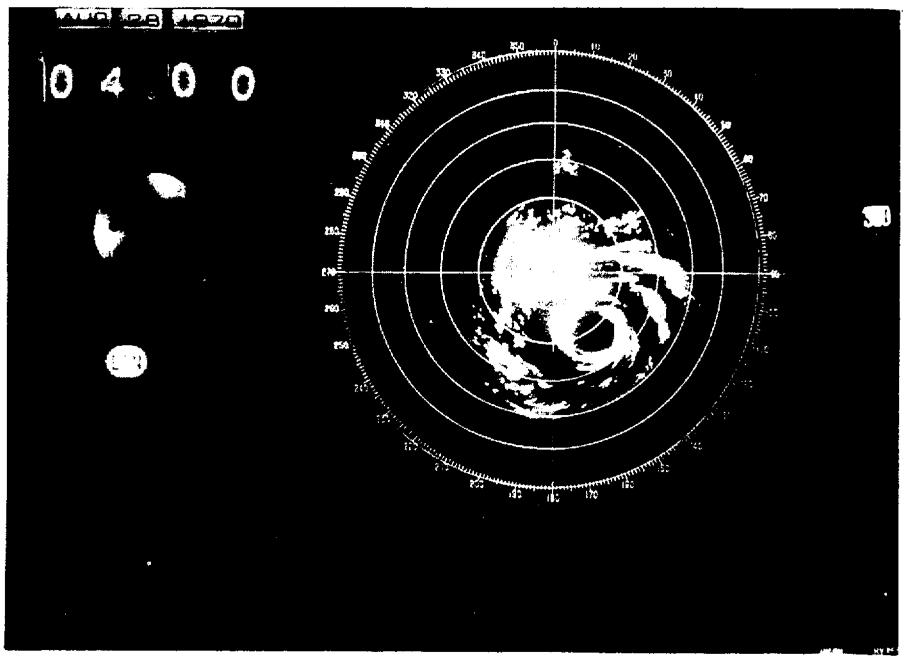

FIGURE 2-16 THE EYE OF TYPHOON BILLIE ON 27 AUGUST 1970, 1900 GMT AS VIEWED BY THE NAZE RADAR (10.4) ON AMAMI-O-SHIMA ISLAND RANGE MARKS ARE AT 100 KM INTERVALS (PHOTOGRAPH COURTESY OF JAPAN METEOROLOGICAL AGENCY.)

Many reports are telephoned to JTWC by other weather agencies throughout the area. The personnel at OL B, 1WWg, Taipei AS provide excellent relay service via AUTOVON when a storm is nearby. Similar service is provided for storms approaching the coast of Vietnam by the personnel of the SEA Weather Central in Tan Son Nhut. The Naval Weather Service Environmental Detachment (NWSED) at Cubi Point, Republic of the Philippines acts as coordinator for relay of all radar fixes received from Philippine radars including ADCC sites. The forecasters at Kwajalein have also provided valuable information on many occasions.

The 10-cm radar located at the Royal Observatory in Hong Kong is critical for warning residents of the colony since the no-fly line prevents aircraft from entering the coastal waters. The last aircraft fix on typhoon Rose was made when the storm was still over 120 n mi from the coast. The sharp turn toward the north was not indicated by fixes up until this time. Only after the Royal Observatory began tracking the storm was it clear that Rose was making a hard turn toward Hong Kong.

## 2. UTILIZATION OF DATA

Radar fixes are normally received at one-hour intervals. In many cases fixes from more than one site are available, especially in the vicinity of Japan. Normally an estimate of the accuracy such as good, fair, or poor is given. These provide guidelines in assigning weights to fixes when more than one is available. If the accuracy of the fixes are the same then normally the station nearest the storm is given more weight.

Because of the short-term oscillations of speed and direction of movement about the mean patch of the storm, speed and direction determinations on a fix-to-fix basis are notoriously unreliable. Instead, the movements from the positions 6 and 12 hours ago to the latest radar fix are used as measurements of current speeds.

Another problem sometimes arises when a storm is on the outer limits of a radar's range. In these cases the radar can observe only the highest clouds near the wall cloud, and a complete presentation of the eye is not always possible.

## 3. POSITIONING VERIFICATION

Based on 1971 data for typhoons only (412 cases), land radar is able to fix a storm with a mean error of 12 n mi, a median error of 10 n mi, and rms equal to 14 n mi. These values are only slightly greater than those associated with aircraft fixes. Unfortunately, the critically needed measurements of intensity can only be obtained by aircraft penetration. For a more complete error analysis of land radar fixes refer to Chapter 3.

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