

CHAPTER II — RECONNAISSANCE & COMMUNICATION

1. GENERAL

The Tropical Cyclone Warning Service depends on reconnaissance to fix the location and determine the intensity of tropical cyclones. Due to the vastness of the warning area and the scarcity of reporting stations, land and ship reports are not sufficient for these determinations. In the past, aircraft reconnaissance was used almost exclusively to determine position and intensity. With the increasing satellite capability during the last several years, satellite derived data have assumed greater importance. During the past season Defense Meteorological Satellite Program (DMSP) data were used for positioning and intensity estimates approximately one-fourth of the time.

2. RECONNAISSANCE RESPONSIBILITY AND SCHEDULING

Aircraft weather reconnaissance is performed in the JTWC area of responsibility by the 54th Weather Reconnaissance Squadron (54 WRS). The squadron, equipped with nine WC-130 aircraft, is located at Andersen Air Force Base, Guam. The JTWC reconnaissance requirements are sent daily to the Tropical Cyclone Reconnaissance Coordinator. These requirements include areas to be investigated, forecast position of cyclones to be fixed, and standard synoptic tracks to be flown.

Four fixes per day, at six-hourly intervals, are required (CINCPACINST 3140.1L) on all significant tropical cyclones in the JTWC primary area of responsibility (see inside front cover). Two fixes per day are required in the secondary area. During the past season, extensive use was made of the Selective Reconnaissance Program (SRP) to fulfill these requirements.

The SRP was implemented in 1972 to alleviate pressure on overtaxed aircraft reconnaissance assets. The SRP attempts to optimize the entire reconnaissance system by using each reconnaissance platform (aircraft, satellite, and surface radar) under optimum conditions whenever possible. Various factors are considered in selecting which reconnaissance platform to use for any warning, e.g., the cyclone's location and stage of development, the DMSP satellite times and areal coverage, availability of land radar reports, the cyclone's threat to specific U.S. interests, aircraft operational limitations (e.g., one fix versus two fix missions), etc.

Aircraft reconnaissance continues to be the best method for determining tropical cyclone position, intensity, and structure (i.e., radius of wind speeds of various intensities). Only the aircraft can provide direct measurements of height, temperature, and wind at flight altitude, sea level pressure, and other parameters. The aircraft also provides much greater flexibility in time and space compared to the other platforms. DMSP satellites provide day and night coverage of the JTWC area of responsibility. DMSP satellite imagery provides

estimates of cyclone positions and, for day-time passes, estimates of intensities using the Dvorak technique (NOAA TECHNICAL MEMORANDUM, NESS-45). In addition, satellite data used in conjunction with conventional data can provide estimates of the radii of various wind speeds. The primary disadvantages of satellites is that the coverage is often not timely for warning purposes and the satellite provides no direct measurements of parameters closely related to tropical cyclone intensity. Land radar provides useful positioning data when tropical cyclones are located near the Republic of the Philippines, Hong Kong, Taiwan, or Japan (including the Ryukyus or other islands). It does not, however, provide measurements or estimates of tropical cyclone intensity or structure. The following sections summarize the JTWC utilization of the various reconnaissance platforms during 1973.

3. AIRCRAFT RECONNAISSANCE EVALUATION CRITERIA

The following criteria are used to evaluate aircraft reconnaissance support to the JTWC.

a. Six-Hourly fixes - To be counted as made on time, a fix must satisfy the following criteria:

(1) Made not earlier than 1/2 hour before to 1 hour after scheduled fix time.

(2) Aircraft in area requested by scheduled fix time, but unable to locate a center due to:

(a) Cyclone dissipation; or

(b) rapid acceleration of the cyclone away from the forecast position.

(3) If penetration not possible due to geographic or other flight restriction, radar fixes are acceptable.

b. Levied 6-Hourly fixes made outside the above limits are scored as follows:

(1) Early - fix made within the interval from 3 hours to 1/2 hour prior to levied fix time. No credit given for early fixes made within 1 1/2 hours of the previous fix.

(2) Late - fix made within the interval from 1 hour to 3 hours after levied fix time.

c. When 3-Hourly fixes are levied, they must satisfy the time criteria of paragraph one in order to be classified as made on time. Three-Hourly fixes made that do not meet the above criteria are classified as follows:

(1) Early - fix made within the interval from 1 1/2 hours to 1/2 hour prior to levied fix time.

(2) Late - fix made within the interval from 1 hour to 1 1/2 hours after levied fix time.

d. Fixes not meeting the criteria of paragraphs one, two, and three are scored as missed. Requirements levied with less than 24 hours notification, if missed, are counted as unfulfilled. If the squadron is in an alert posture, the fix is scored as missed vice unfulfilled.

e. Levied fix time on an "as soon as possible" fix is considered to be:

- (1) Sixteen hours plus estimated time enroute after an alert aircraft and crew are levied; or
- (2) Four hours plus estimated time enroute after the DTG of the message levying an ASAP fix if an aircraft and crew, previously alerted, are available for duty.

f. Investigatives - To be counted as made on time, investigatives must satisfy the following criteria:

- (1) Aircraft must be within 250nm of the levied investigative point by the specified time.
- (2) The specified flight level must be flown.
- (3) Reconnaissance observations are required every half-hour in accordance with AWSM 105-1. Turn and mid-point winds shall be reported on each full observation when within 250nm of the investigative point.
- (4) Observations are required in all quadrants unless a concentrated investigation in one or more quadrants has been specified.
- (5) Specified investigative track must be flown.
- (6) Aircraft must contact JTWC before terminating the investigative.

g. Investigatives not meeting the time criteria of paragraph f. will be classified as follows:

- (1) Late - aircraft is within 250nm of the investigative point after the specified time, but prior to the specified time plus 2 hours.
- (2) Missed - aircraft fails to be within 250nm of the investigative point by the specified time plus 2 hours.

h. Requirements levied as "resources permitting" are not evaluated.

4. AIRCRAFT RECONNAISSANCE SUMMARY

There were 362 required six-hourly fixes in 1973, representing a record low since establishment of the JTWC. Of the 362 required fixes, 227 or 62.4% were levied upon aircraft. The remaining required fixes were satisfied by satellite, radar, extrapolation, or synoptic data. The SRP made it possible, when there was a choice between aircraft, radar, or satellite, to reduce the aircraft levy. By employing SRP, 45 fixes were levied upon satellite or radar, a savings of 16.5% in the use of aircraft. In addition to the 227 fixes, 28 investigatives were also levied on aircraft.

This total aircraft levy is only 38% of the average levy from 1965 through 1973. The mean deviation from the best track for all aircraft fixes was 16nm. This is a 2nm decrease from the average deviation for the past 3 years.

The total of 227 fixes levied does not include intermediate fixes, which averaged 131 for the past two years. The decrease in the number of intermediate fixes -- 182 in 1971, 81 in 1972, and none in 1973 -- and investigatives -- 179 in 1971, 81 in 1972, and 28 in 1973 -- during the past three years resulted from a CINCPAC request to reduce intermediate fixes and the application of the DMSP satellite data (Section 6).

Table 2-1 summarizes reconnaissance effectiveness. Using the scoring criteria in Section 3, the 13 missed plus unfulfilled fixes, or 5.7% of the total levied fixes, represent a significant decrease from the previous two year average of 13.9%. The percentage of late and early fixes rose from 10.6% in 1972 to 15.3% in 1973.

	NUMBER OF LEVIED FIXES	PERCENT
Completed on time	179	79.0
Early	4	1.7
Late	31	13.6
Missed	11	4.8
Unfulfilled	2	0.9
	227	100.0

	LEVIED	MISSED	PERCENT
AVERAGE 1965 - 1970	507	10	2.0
1971	802	61	7.6
1972	624	126	20.2
1973	227	13	5.7

Figure 2-1 relates the number of fixes missed/unfulfilled to the monthly fix requirements and multiple-storm days, i.e., a day when two or more storms were active at the same time. The 82 levied fixes in October account for 36% of the total levied fixes. October also included 42% of the multiple storm days and 30% of the missed fixes as compared to August which had 22% of the storm days, but 46% of the missed fixes. August, however, had only 21% of the levied fix requirements.

Figure 2-2 compares the percentage of fixes and investigatives missed/late versus the number of storms per day. The 26 days with 2 or more storms represents only 35% of the calendar days of warning; however, they encompass 75% of the missed/late fixes and investigatives. This indicates, that even in a light season, concurrent storms can overtax current aircraft reconnaissance capabilities.

5. RADAR RECONNAISSANCE SUMMARY

A total of 419 radar reports of tropical cyclones were received during the 1973 season, 409 from land stations, 3 from ships, and 7 from aircraft. This is a significant decrease from 1972 when over 700 radar reports were received. There are two primary reasons for this decrease, the large decrease in tropical cyclone activity from 1972 to 1973 and the significant reduction of military activities in the western North Pacific and South China Sea areas.

To evaluate the 1973 data in terms of quality, the land radar reports received were grouped into three accuracy categories, a method provided for in the WMO code. The categories used are defined as good (less than 6nm), fair (6-20nm), and poor (greater than 20nm). Using this stratification, 32% of the reports were classified as good, 40% as fair, and 28% as poor. In addition to the above accuracy classifications which are derived from the radar operations, all land radar reports were compared to the JTWC best track positions and deviations computed. The mean deviation was 12nm, a 29% decrease from the average of 17nm for the previous three years.

The radar sites that provide some of the most significant coverage to JTWC are those whose surveillance borders within the Air Weather Service no-fly zone. The Royal Observatory at Hong Kong provided valuable positioning information on 7 tropical cyclones during 1973 in which geographical restrictions existed to reconnaissance air-

craft. Other locations which play similar roles are those situated on western Taiwan and Korea, although by the time a tropical cyclone reaches the latitude of Korea its radar presentation is often quite deteriorated. A key station for tracking tropical cyclones in the northwestern South China Sea during the Vietnam conflict was the Monkey Mountain site at Danang. The loss of observations from this site last season proved quite critical during typhoon Anita's trek into the Gulf of Tonkin this past July, adversely affecting units of the 7th Fleet.

The receipt of land radar reports from national meteorological and AC&W sites in the Republic of the Philippines was greatly improved in 1973 compared to previous years. This improvement is attributed to recent improvements in the radar network, better communications, and closer liaison between U.S. military and Philippine officials.

Of 17 tropical cyclones which came within the surveillance range of the Far East radar networks, four typhoons Ellen, Billie, Nora, and Dot accounted for the majority of radar reports. Each of these storms was characterized during periods of observation by slow movement allowing for numerous position reports. Billie while passing through the southern Ryukyus was under coverage of 6 radars simultaneously for a 12 hour period. Radars of National Meteorological Services accounted for 70% of the 419 observations received at the JTWC for tropical cyclones during 1973. AC&W sites furnished 23% and Air Weather Service radars, contributed 8%.

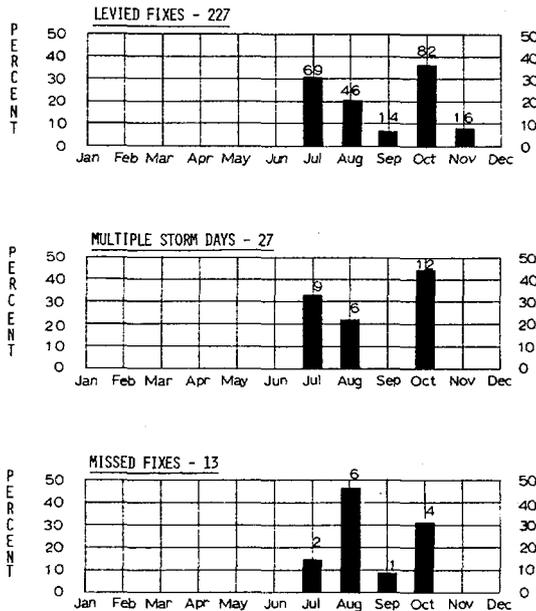


FIGURE 2-1. Missed fixes for 1973 compared to monthly fix requirements and multiple storm days.

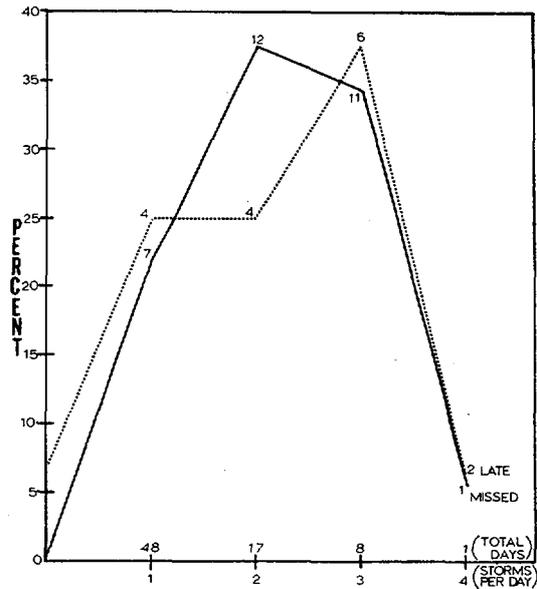


FIGURE 2-2. Percentage of fixes and investigatives missed/late vs. storms per day.

6. SATELLITE RECONNAISSANCE SUMMARY

Satellite reconnaissance information is provided to the JTWC by the Air Force Defense Meteorological Satellite Program (DMSP) site collocated with the JTWC. This site was established in May 1971. During the 1971 storm season, DMSP data were available to the JTWC forecasters but were not authorized by CINCPAC as a substitute for aircraft fixes. Coincident with the site's establishment was the implementation of a Technique Development Program (TDP) designed to determine the potential of DMSP data as an alternative reconnaissance platform. This was necessary as aircraft resources were being reduced and it was possible that the remaining reconnaissance fleet would be subject to further reductions. Hence the SRP concept was introduced. Under the SRP, the JTWC would selectively levy reconnaissance requirements on aircraft, high resolution satellites and land radar with the satellites expected to fulfill an increasingly important role.

By the end of 1971, the TDP had established the viability of satellite derived storm positions and intensity estimates. Plans were then made to implement the SRP. During 1972, techniques used to position tropical cyclones and estimate their intensities from DMSP data were further refined. An organized approach to daily decision making on the use of DMSP data in lieu of aircraft was implemented beginning with Typhoon Phyllis in July 1972. Factors such as satellite coverage of the storm, timeliness of the DMSP data, and quality of the position were considered in this decision process. During the remainder of 1972, satellite fixes were levied in lieu of aircraft 12% of the time. During 1972, the Guam site provided the majority of satellite data used operationally by the JTWC. Data were received from other Pacific DMSP sites and the Air Force Global Weather Central (AFGWC) but there was no formal program to rely on these data.

Prior to the start of the 1973 season, an SRP network was established consisting of Guam; Fuchu, Japan; and Nakon Phanom (NKP), Thailand (primary sites); and Kadena, Okinawa; Osan, Korea; and AFGWC serving as backup sites. The network was designed to provide timely DMSP data to the JTWC through the Guam site which served as clearing house and quality control monitor. The Guam site was also responsible to the JTWC for forecasting which of the primary sites or combination of sites would receive usable fixes. Regardless of whether such fixes were levied in lieu of aircraft, the sites affected would be notified by message to pass the required information to the JTWC. As the data were received, processed, and analysed, data were first passed by phone to the Guam site and followed up by message to the JTWC.

There are six position classes referred to by Position Code Numbers (PCN). The PCN identifies the method of gridding and the type of circulation center; it also has associated with it a set of statistics related to its accuracy. Table 2-2 provides the methods of center determination and gridding for each PCN. The mean error,

standard vector deviation, and sample size are given for the 3 major classes i.e. eye, well-defined circulation center, and poorly-defined circulation center. While no statistically significant difference presently exists between geographical and ephemeris gridded positions, it was decided to retain the gridding method as part of the PCN stratification to provide a check on the accuracy of ephemeris gridding and to isolate any problems growing out of either geographical or ephemeris gridding in the future.

TABLE 2-2. GUAM DMSP SITE TROPICAL CYCLONE POSITIONING STATISTICS, 1973 (1972)

PCN	METHOD OF CENTER DETERMINATION/GRIDDING	MEAN ERROR (NM)	STANDARD VECTOR DEVIATION (NM)	SAMPLE SIZE
1	Eye/Geography	15.5 (14.7)	17.8 (17.3)	40 (357)
2	Eye/Ephemeris			
3	Well Defined CC/Geography	18.9 (21.0)	22.9 (26.3)	86 (159)
4	Well Defined CC/Geography			
5	Poorly Defined CC/Geography	59.8 (30.2)	54.2 (36.6)	46 (294)
6	Poorly Defined CC/Geography			

NM = Nautical Miles
CC = Circulation Center

The 1972 figures which serve as the standard are given in parentheses. Table 2-3 shows corresponding 1973 figures for NKP and Fuchu respectively. Only PCN's of 1 through 4 are considered as quality fixes, i.e. location accuracy comparable on the average to that expected from the aircraft. It should be noted that only 31% of the positions made during 1973 by the primary DMSP sites were of PCN's 5 or 6, a significant reduction from 1972 when 50% of the positions were classified in the poorly defined category.

With only one operational satellite during the early part of the 1973 season (July and August), satellite coverage during the period 5 1/2 hours before to 1/2 hour after warning time was available for 52% of the warnings. However, during the last part of the season (September, October, and November) with two functional satellites, 87% of the warnings had satellite coverage available during the same time

TABLE 2-3. DMSP TROPICAL CYCLONE POSITIONING STATISTICS 1973

NAKON PHANOM, THAILAND			
PCN	MEAN ERROR (NM)	STANDARD VECTOR DEVIATION (NM)	SAMPLE SIZE
1&2	16.8	20.0	47
3&4	19.1	25.4	62
5&6	48.1	66.3	85
FUCHU, JAPAN			
PCN	MEAN ERROR (NM)	STANDARD VECTOR DEVIATION (NM)	SAMPLE SIZE
1&2	15.4	17.7	37
3&4	20.9	25.0	75
5&6	36.2	51.4	26

period. For 24% of the 390 warnings issued by the JTWC, both satellite coverage and timeliness of the data were met simultaneously. In this context, timeliness is defined as having DMSP satellite data with nodal times of 1 1/2 to 3 hours (descending node) or 1 3/4 to 3 hours (ascending node) prior to warning time. When quality PCN's are also stipulated, it was found that for only 14% of the warnings were coverage, timeliness, and quality PCN forecast to occur. When the three criteria given above are anticipated, the forecast is referred to as SRP quality. The verification rate for SRP quality forecasts during the season was 90%. The actual use rate of satellite as the basis for warnings was considerably larger than the 14% which were forecast to be of SRP quality. Altogether, 27% of the JTWC warnings were based on satellite data. Of the forecast SRP quality fixes, 25% were levied equating to 13% of the satellite fixes used for warnings. The remaining 87% of the satellite fixes for warnings consisted of non-SRP quality and some additional SRP quality which were forecast, not levied, but subsequently used. A summary of these SRP statistics is given in Table 2-4.

There were a wide variety of satellite products available from the SRP network during the 1973 season both for real-time analysis by the individual sites and post-analysis conducted by the Guam site and the JTWC. Historically, the types of data from

the DMSP satellites have remained essentially unchanged during the past three years. Satellite meteorologists at the SRP network sites had available Very High Resolution daytime and nighttime infrared (VHR), and High Resolution daytime and nighttime visual (HR) and infrared (IR). Table 2-5 provides the imagery data characteristics.

During daytime, VHR along with IR are the primary data used for positioning and intensity analysis. In addition, visual and IR data enhancement techniques have been developed which often permit the analyst to locate the circulation center when the primary data alone would result in a poorly defined center. Likewise, nighttime position can often be classified as eye fixes or well defined centers as a result of having HR data from moonlight available. Marginal eye centers or well defined centers not visible on VHR can frequently be determined with as little illumination as that provided by a half-moon.

Satellite data are playing an increasingly larger role in tropical cyclone reconnaissance. For example, the operational use of DMSP data has produced a significant decrease in the number of aircraft investigative flights flown. For the two years preceding the establishment of the SRP network (1970 - 1971), the ratio of investigative flights flown to the number of storms was 5.5:1, while for 1973 this ratio was reduced to 1.2:1.

TABLE 2-4. SELECTIVE RECONNAISSANCE PROGRAM SUMMARY

PARAMETERS	RATIO	PERCENT
Number of cases where there was DMSP coverage of storm and timeliness for use in warning/total number of warnings issued	95/390	24
Number of cases where there was coverage of storm, timeliness of data, and PCN < 4 (SRP Quality forecasts made)/total number of warning issued	56/390	14
Number of SRP quality forecasts levied/number of SRP quality forecasts made	14/56	25
Number of SRP quality forecasts used as basis for warnings/number of warnings based on satellite	14/107	13
Number of warnings based on satellite/total number of warnings issued	107/390	27

TABLE 2-5. DMSP IMAGERY DATA CHARACTERISTICS

PARAMETER	VISUAL		INFRARED	
	VHR	HR	WHR	IR
Resolution (nautical miles)	0.33	2.0	0.5	2.0
Bandwidth (micrometers)	0.4-1.1	0.4-1.1	8.0-13.0	8.0-13.0
Equivalent blackbody temperature (°Kelvin)			217-307	210-310

7. COMMUNICATIONS

a. AIR TO GROUND

Aircraft reconnaissance data are normally received by the JTWC via direct phone patch through Andersen, Clark, or Fuchu aeronautical stations. Under degraded propagation conditions, data can be intercepted by a weather monitor located near these stations and relayed by AUTOVON or teletype to the JTWC.

Average communications delays for the preliminary and complete center data messages for past years are compared with 1973 delays in Figure 2-3. Delay times are defined here as the difference between the fix time and the time of message receipt at the JTWC. The preliminary fix message was introduced in 1972 to reduce delays in the receipt by the JTWC of vital position and intensity information. After two years of use, it has proved its effectiveness and permits a significant amount of extra time to be spent in forecast preparation. The 48 minute average delay in the complete center data message during 1973 shows an increase of about 14 minutes over 1972. This increase is attributed to several circumstances which prevailed during the 1973 season: (a) more emphasis was placed upon receipt of the preliminary message during 1973, lessening the need for passing the complete center message to the JTWC as quickly as before, (b) messages were more carefully prepared, and (c) a larger share of the messages were passed through Clark aeronautical station than in previous years due to location of cyclone tracks. This routing of phone patches through Clark places more stringent requirements on radio-telephone quality and has been

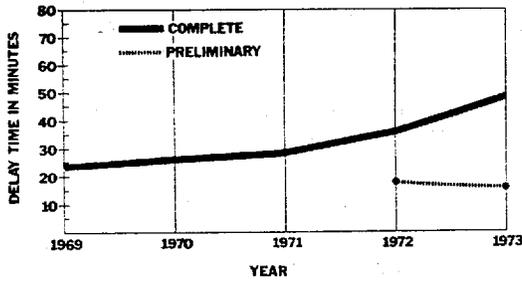


FIGURE 2-3. DELAY TIMES - Receipt of eye data message.

noted in previous years to result in longer delays than a direct phone patch through Andersen aeronautical station.

Table 2-6 depicts the complete center data messages received over one hour after fix time and after warning time. The growth of the percentages in 1973 can be partially attributed to the above mentioned reasons and the increase in the percentage of late fixes (section 4). Nevertheless, only 3% of the messages were delayed more than 80 minutes.

	1967	1968	1969	1970	1971	1972	1973
% COMPLETE FIX MESSAGES DELAYED OVER ONE HOUR	16	4	3	5	6	6	20
% COMPLETE FIX MESSAGES RECEIVED AFTER WARNING TIME	3.1	0.7	0.6	0.9	2.1	5.5	10.1

b. SELECTIVE RECONNAISSANCE PROGRAM

With the advent of the SRP, the importance of radar and satellite fix data has increased from previous years; therefore, a review of the associated communications delays follows. A sampling of radar messages resulted in a considerable variation of receipt delays. Delay times are defined as the differences between the observation time and the time of message entry into the AWN. Several sources were consistently associated with small delay times, while the receipt time of others were highly erratic. AC&W radar site data from the Republic of the Philippines were normally received within 35 minutes. Data from nationally operated radars of the Republic of China, Hong Kong, Japan, and Republic of the Philippines were delayed 20 to 50 minutes depending on country of origin. In the worst cases, the JTWC still received the messages within 90 minutes of observation time. Tropical cyclone radar data is routed to the JTWC over the AWN through the use of a special high precedence collective indicator. Additionally, the AC&W radar messages were phoned to the JTWC from Clark AB, thus providing the information somewhat earlier than indicated.

Over 750 position and intensity estimates were derived from Air Weather Service (AWS) DMSP sites and the aircraft carrier CONSTELLATION during 1973. The data from the AWS DMSP sites were immediately

passed by AUTOVON followed by an AWN message. AUTOVON provided rapid communication of the essentials and a brief two-way discussion of the data (a benefit not possible with message). Average delay times of 51 minutes for telephone and 83 minutes for message resulted from a sampling of the last six storms. These delay times are the difference between satellite equator-crossing time and the time of the telephone call or entry of the message into the AWN. systematic differences in data processing time among the DMSP sites introduces small variations in the above figures which are independent of communications and analysis time. However, it is important to note, that on the average, the data were available to the JTWC within one hour after equator-crossing time.

c. OUTGOING COMMUNICATIONS

Messages originating at the JTWC are handled by the Nimitz Hill Message Center Naval Communications Station, Guam (NHMC). By special agreement, typhoon and tropical storm warnings are placed in the communications system before pending immediate precedence traffic. Manual processing is accomplished as though the warning had flash precedence. Tropical depression warnings are normally handled as immediate messages. Warnings were delivered to the message center an average of 23 minutes before warning time (Figure 2-4). Yearly averages of the parameters described are plotted relative to warning time. The length of the vertical bars represents the average difference between the time typhoon and tropical storm warnings were passed to the NHMC and the time of transmission. Note that the handling time decreased from 31 minutes in 1972 to 15 minutes in 1973. Handling times for tropical depression warning (not shown) were reduced from 51 minutes in 1972 to 25 minutes in 1973.

The dramatic improvement in handling time during 1973 allowed the average message to be placed in the circuits before the established warning time. This was a major improvement over the previous two years when the average message left Guam more than 10 minutes after warning time. The reduced handling time can be attributed primarily to rectification of problems within the NHMC itself. The time of receipt of a warning at a particular station depends on factors beyond the control of both the JTWC and the NHMC.

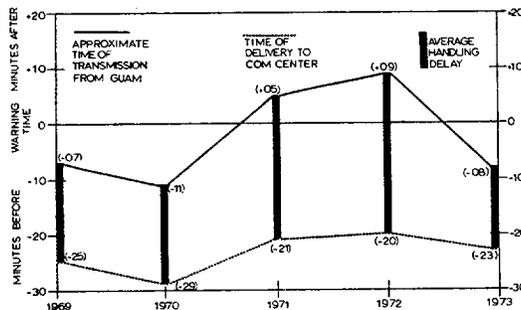


FIGURE 2-4. AUTODIN handling time data for typhoon and tropical storm warnings.