2. RECONNAISSANCE AND FIXES

2.1 GENERAL

The Joint Typhoon Warning Center depends on reconnaissance to provide necessary, accurate, and timely meteorological information in support of advisories, alerts and warnings. JTWC relies primarily on two reconnaissance platforms: satellite and radar. In data rich areas, synoptic data are also used to supplement the above. As in past years, the optimal use of all available reconnaissance resources to support JTWC's products remains a primary concern. Weighing the specific capabilities and limitations of each reconnaissance platform, and the tropical cyclone's threat to life and property both afloat and ashore, continue to be important factors in careful product preparation.

2.2 RECONNAISSANCE AVAILABILITY

2.2.1 SATELLITE — Fixes from Air Force/Navy ground sites and Navy ships provide day and night coverage in JTWC's area of responsibility. Interpretation of this satellite imagery yields tropical cyclone positions and estimates of current and forecast intensities through the Dvorak technique. The Special Sensor Microwave/Imager (SSM/I) data are used to determine the extent of the 30-kt (15 m/sec) winds around the tropical cyclone and to aid in tropical cyclone positioning.

2.2.2 RADAR — Land-based radar remotely senses and maps precipitation within tropical cyclones in the proximity (usually within 175 nm (325 km) of radar sites) of the Philippine Islands, Taiwan, Hong Kong, China, Japan, South Korea, Kwajalein, Guam, Thailand, Australia, and India.

2.2.3 SYNOPTIC — JTWC also determines tropical cyclone positions based on the analysis of surface/gradient-level synoptic data. These positions are an important supplement to fixes provided by remote sensing platforms and become invaluable in situations where neither satellite nor radar fixes are available.

2.3 SATELLITE RECONNAISSANCE SUMMARY

The Air Force provides satellite reconnaissance support to JTWC through the DMSP Tropical Cyclone Reporting Network (DMSP Network), which consists of tactical sites and a centralized facility. The personnel of Det 1, 633 OSS (hereafter referred to as Det 1), collocated with JTWC at Nimitz Hill, Guam, coordinate required tropical cyclone reconnaissance support with the following units:

15 ABW/WE, Hickam AFB, Hawaii
18 OSS/WE, Kadena AB, Okinawa, Japan
603 ACCS/WE, Osan AB, Republic of Korea
Air Force Global Weather Central,
Offutt AFB, Nebraska

Detachment 5, 20 WS, Clark AB, Republic of the Philippines ceased operations in late September following the eruption of Mount Pinatubo and the subsequent closure of Clark AB. These sites provide a combined coverage that includes most of the western North Pacific, from near the international date line westward to the Malay Peninsula. The Naval Oceanography Command Detachment, Diego Garcia, furnishes interpretation of low resolution NOAA polar orbiting coverage in the central Indian Ocean, and Navy ships equipped for direct satellite readout contribute supplementary support. Also, civilian contractors with the U.S. Army at Kwajalein Atoll provide satellite fixes on tropical cyclones in the Marshall Islands to supplement Det 1's satellite coverage. Additionally, DMSP low resolution satellite mosaics are available from the FNOC via the NEDN and NESN lines. These mosaics are used to metwatch the areas not included in the area covered by the DMSP tactical sites, and provide JTWC forecasters with the capability to "see" what AFGWC's satellite image analysts are fixing, albeit, several hours later.

In addition to polar orbiter imagery, Det 1 uses high resolution geostationary imagery to support the reconnaissance mission. Animation of these geostationary images is invaluable for determining the location of cloud system centers and their motion, particularly in the formative stages. Animation is also valuable in assessing environmental, or ambient, changes affecting tropical cyclone behavior. Det 1 is able to receive and process high resolution digital geostationary data through its Meteorological Imagery, Data Display and Analysis System (MIDDAS), and via the NSDS-G or Navy's Geostationary Satellite Receiving System (GSRS). Phase 1 of MIDDAS, installed in December 1990, consists of a minicomputer and large screen work station which provides advanced graphic and enhancement capabilities for geostationary data. Phase 2, installed in September 1991, increased the system to 3 minicomputers and ingests NOAA High Resolution Picture Transmission (HRPT) and TIROS Operational Vertical Sounder (TOVS) data. Software installed in March 1992 gave MIDDAS the capability to process DMSP imagery. Thus, Det 1 can daily process imagery from at least four polar orbiting and one geostationary spacecraft.

AFGWC is the centralized member of the DMSP network. In support of JTWC, AFGWC processes stored imagery from DMSP and NOAA spacecraft. Stored imagery is recorded on board the spacecraft as they orbit the earth, and is later relayed to AFGWC via a network of command readout sites and communication satellites. This enables AFGWC to obtain the coverage necessary to fix all tropical cyclones within JTWC's AOR. AFGWC has the primary responsibility to provide tropical cyclone reconnaissance over the entire Indian Ocean, southwest Pacific, and the area near 180° east longitude in the western North Pacific Ocean. As a backup, AFGWC can be tasked to provide tropical cyclone reconnaissance support in the western North Pacific, when DMSP tactical site coverage is impaired or lost.

The hub of the DMSP network is Det 1. Based on available satellite coverage, Det 1 is responsible for coordinating satellite reconnaissance requirements with JTWC and tasking the individual network sites for the necessary tropical cyclone fixes, current intensity estimates, forecast intensities, and SSM/I surface wind information. When a particular satellite pass is selected to support the development of JTWC's next tropical cyclone warning, two sites are tasked to fix the tropical cyclone from the same pass. This "dual-site" concept provides the necessary redundancy that virtually guarantees JTWC a satellite fix to support each warning. It also supplies independent assessments of the same data to provide JTWC forecasters a measure of confidence in the location and intensity information.

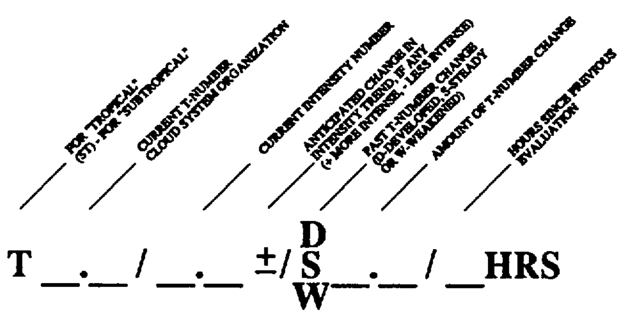
The network provides JTWC with several products and services. The main service is to monitor the AOR for indications of tropical cyclone development. If development is suspected, JTWC is notified. Once JTWC

TABLE 2-1 **POSITION CODE NUMBERS (PCN)**

PCN	METHOD FOR CENTER DETERMINATION/GRIDDING
1	EYE/GEOGRAPHY
2	EYE/EPHEMERIS
3	WELL DEFINED CIRCULATION CENTER/GEOGRAPHY
4	WELL DEFINED CIRCULATION CENTER/EPHEMERIS
5	POORLY DEFINED CIRCULATION CENTER/GEOGRAPHY
6	POORLY DEFINED CIRCULATION CENTER/EPHEMERIS

issues either a Tropical Cyclone Formation Alert or a warning, the network provides three products: tropical cyclone positions, current intensity estimates and forecast intensities. Each satellite-derived tropical cyclone position is assigned a Position Code Number (PCN), which is a measure of positioning confidence. The PCN is determined by a combination of the availability of visible landmarks in the image that can be used as references for precise gridding and the degree of organization of the tropical cyclone's cloud system (Table 2-1). Once the tropical cyclone reaches 50 kt (25 m/sec), information on the distribution of 30-kt (15-m/sec) winds is provided using SSM/I data.

Det 1 provides a minimum of one estimate of the tropical cyclone's current intensity every 6 hours once JTWC is in alert or warning status. Current intensity estimates and 24-hour intensity forecasts are made using the Dvorak (1975, 1984) technique for both visual and enhanced infrared imagery (Figure 2-1). The enhanced infrared technique is preferred due to its increased objectivity and accuracy, however, the visual technique is used to supplement this information during the daylight hours. The standard relationship between tropical cyclone "T-number", maximum sustained surface wind speed and minimum sea-level pressure (Atkinson and Holliday, 1977) for the Pacific is shown in Table 2-2. For subtropical cyclones, intensity estimates are made using the Hebert and Poteat (1975) technique.



Example: T 3.5 / 4.5+ /W1.5 / 24 HRS

Figure 2-1. Dvorak code for communicating estimates of current and forecast intensity derived from satellite data. In the example, the current "T-number" is 3.5, but the current intensity is 4.5. The cloud system has weakened by 1.5 "T-numbers" since the previous evaluation conducted 24-hours earlier. The plus (+) symbol indicates an expected reversal of the weakening trend or very little further weakening of the tropical cyclone during the next 24-hour period.

2.3.1 SATELLITE PLATFORM SUMMARY — Figure 2-2 shows the status of operational polar orbiting spacecraft. Four DMSP spacecraft, 19543 (F8), 20542 (F9), 21544 (F10), and 22546 (F11) were operational during 1991. The F8's SSM/I lost its horizontally polarized 85 gigahertz channel early in the year, however, the channel started providing limited, but useful, data again in October. The spacecraft's Operational Line Scan (OLS) sensor failed on 16 August. The F9 was operational throughout 1991, but lost its OLS on 21 February 1992. The F10, although launched into an elliptical orbit, became operational 15 January 1991. The platform's fluctuating altitudes caused persistent gridding problems, and it continues to precess about 50 seconds a week, thus it is no longer in a sun synchronous orbit. F11 was launched 28 November and became operational on 17 December; one of the shortest periods between launch and operational acceptance in the DMSP history. Two SSM/I sensors, mounted on the F8 and F10 DMSP spacecraft, were operational throughout 1991. A third sensor, recently

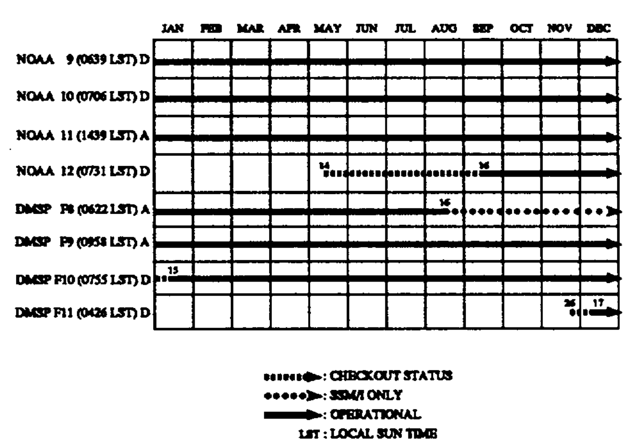


Figure 2-2. Polar orbiters for 1991.

launched on the F11, will expand SSM/I coverage during 1992. Although the horizontally polarized 85 gigahertz channel failed on the F8, the sensor continued to provide valuable surface wind data, and positioning data could be derived using the differential of the 37 gigahertz vertically and horizontally polarized data. With regard to NOAA spacecraft, NOAA 9 remained in standby, and NOAA 10 and NOAA 11 were operational throughout 1991. NOAA 12 was launched 14 May and became operational on 16 September.

2.3.2 STATISTICAL SUMMARY — During 1991, information from the DMSP network was the primary input to JTWC for operational warnings and post analysis best tracks in the entire 53-million square mile area of responsibility for the warning center. Almost all the warnings were based on satellite reconnaissance. JTWC received a total of 4746 satellite fixes during the year. Of these, 3139 were for the western North Pacific, 139 for the North Indian Ocean and 1468 for the Southern Hemisphere. Of this, 38 percent were from polar orbiter, and 62 percent were from geostationary platforms. These totals include 128 fixes in the western North Pacific, 14 in the North Indian Ocean, and 196 in the Southern Hemisphere from non-network sources. The increase in percentage of geostationary fixes (only 49 percent in 1990) is attributed to the deactivation of the DMSP site at Clark AB, significant operational down-time at network sites, and the expanded capability of the MIDDAS. During July through November, significant outage hours for the network sites rose to 51 percent, compared with 12.3 percent for the same period in 1990. A comparison of satellite fixes from all data sources with their corresponding best track positions is shown in Table 2-3.

2.3.3 NEW TECHNIQUES — The MIDDAS system has and will continue to expand Det 1's capabilities to analyze tropical cyclones. In addition to providing analysts with the capability to rapidly make or modify satellite

TABLE 2-2

MAXIMUM SUSTAINED WIND SPEED (KT) AS A FUNCTION OF DVORAK CURRENT AND FORECAST INTENSITY NUMBER AND MINIMUM SEA-LEVEL PRESSURE (MSLP)

TROPICAL CYCLONE INTENSITY NUMBER	WIND SPEED	MSLP (NW PACIFIC)
0.0	<25	- - - -
0.5	25	- - - -
1.0	25	- - - -
1.5	25	- - - -
2.0	30	1000
2.5	35	997
3.0	45	991
3.5	55	984
4.0	65	976
4.5	77	966
5.0	90	954
5.5	102	941
6.0	115	927
6.5	127	914
7.0	140	898
7.5	155	879
8.0	170	858

image enhancements, post analysis techniques are more flexible than previous years. Animated loops and sectorized images archived on 4 mm, 1.2 gigabyte Digital Audio Tapes are rapidly replacing hard copy imagery. When the data files are reloaded on the system from tape, they can again be used for detailed analysis.

The Techniques Development section is working on objective methods to complement current analyses. Constructing satellite derived time series of the area of tropical cyclone deep convection that is colder than a given threshold temperature allows graphical representation of convective trends. Interpretation of the trends are expected to improve genesis analysis, forecasts of rapid intensification, and forecasts of peaking day. (Refer to Chapter 7.)

Tactical sites in the Pacific on the islands of Guam, Oahu, Luzon and Okinawa, as well as AFGWC, received the Mission Sensor Tactical Imaging Computer (MISTIC) during the summer of 1990. Osan AB obtained the former Clark AB MISTIC system in early 1992. The AFGWC Tropical Section continues to provide the majority of the SSM/I support to JTWC. On 1 November 1991, AFGWC began testing 12-bit, high resolution SSM/I data on their Satellite Data Handling System. Initial results have been very encouraging and the final operational acceptance occurred on 1 March 92. AFGWC, Det 1, and 18 OSS/WE provided bulletins to JTWC describing the extent of 30-kt (15 m/sec) winds surrounding the tropical cyclone for all systems with maximum sustained winds of 50 kt (25 m/sec) or greater. In the summer of 1992, expanded MISTIC software should be delivered to the tactical sites. This software will allow processing of full-resolution 12-bit SSM/I data, and will co-register OLS imagery and the SSM/I data.

TABLE 2-3

MEAN DEVIATION (NM) OF ALL SATELLITE DERIVED TROPICAL CYCLONE POSITIONS FROM JTWC BEST TRACK POSITION (NUMBER OF CASES IN PARENTHESES)

NORTHWEST PACIFIC OCEAN

PCN	1981-1990 AVERAGE		1991 AVERAGE	
1&2	13.6	(4442)	13.2	(858)
3&4	20.6	(5112)	22.6	(574)
5&6	35.5	(11040)	40.2	(1707)
Totals:	**27.1**	**(20594)**	**29.6**	**(3139)**

NORTH INDIAN OCEAN

PCN	1981-1990 AVERAGE		1991 AVERAGE	
1&2	13.3	(120)	16.7	(25)
3&4	29.6	(89)	26.6	(6)
5&6	38.4	(905)	47.3	(108)
Totals:	**35.0**	**(1114)**	**40.9**	**(139)**

WESTERN SOUTH PACIFIC AND SOUTH INDIAN OCEAN

PCN	1981-1990 AVERAGE		1991 AVERAGE	
1&2	16.3	(1330)	16.1	(226)
3&4	26.9	(1048)	27.1	(251)
5&6	36.0	(6284)	35.0	(991)
Totals:	**31.9**	**(8662)**	**30.7**	**(1468)**

2.3.4 FUTURE OF SATELLITE RECONNAISSANCE — MIDDAS was formally accepted for operational use by Det 1 on 1 April 1992, and it will provide JTWC with enhanced satellite support for 1992. At Det 1, the goal is to have a fully integrated satellite system, capable of ingesting data from both geostationary and polar satellites and then overlaying graphics from and interfacing with multiple data sources, e.g., Automated Weather Distribution System (AWDS), NEXRAD Doppler radar, and the Mark IVB meteorological data station. The Mark IVB is scheduled to replace the Mark III and Mark IV satellite ingest and display systems during the 1994 time-frame.

Until the installation of AWDS in 1994, the plan is to retrieve the conventional data via the Automated Weather Network (AWN) and overlay it on the satellite imagery. Software developed for the MIDDAS is able to overlay wind, temperature, pressure and height fields on the satellite imagery. Det 1 and JTWC will have the capability to integrate large volumes of data more efficiently and effectively than ever before.

2.4 RADAR RECONNAISSANCE SUMMARY

Twenty-two of the thirty-two significant tropical cyclones in the western North Pacific during 1991 passed within range of land-based radar with sufficient cloud pattern organization to be fixed. A total of 994 land-based radar fixes were obtained and logged at JTWC. There were two airborne radar fixes.

The WMO radar code defines three categories of accuracy: good (within 10 km (5 nm)), fair (within 10-30 km (5-16 nm)), and poor (within 30-50 km (16-27 nm)). Of the 1088 radar fixes encoded in this manner; 313 were good, 331 were fair, and 444 were poor. Excellent support from the radar network through timely and accurate radar fix positioning allowed JTWC to track and forecast tropical cyclone movement during even the most erratic track changes.

Nineteen radar reports were received on southern hemisphere tropical cyclones. None were logged for the North Indian Ocean tropical cyclones.

Looking ahead, the Next Generation Weather (Doppler) Radar (NEXRAD) is expected to be operational on Guam and at JTWC in April 1993.

2.5 TROPICAL CYCLONE FIX DATA

A total of 3139 fixes on thirty-two northwest Pacific tropical cyclones and 139 fixes on four North Indian Ocean tropical cyclones were logged at JTWC. Table 2-4A delineates the number of fixes per platform for each individual tropical cyclone for the western North Pacific and North Indian Oceans. Season totals and percentages are also indicated. Table 2-4B provides similar information for the 1487 fixes in the South Pacific and South Indian Oceans.

TABLE 2-4A

1991 NORTHWEST PACIFIC AND NORTH INDIAN OCEAN FIX PLATFORM SUMMARY

NORTHWEST PACIFIC		SATELLITE	RADAR	SYNOPTIC	TOTAL
TS Sharon	(01W)	122	0	0	122
TY Tim	(02W)	68	0	0	68
TS Vanessa	(03W)	97	0	0	97
STY Walt	(04W)	168	63	1	233*
TY Yunya	(05W)	70	2	0	72
TY Zeke	(06W)	79	0	2	81
TY Amy	(07W)	90	20	0	110
TY Brendan	(08W)	70	18	0	88
TY Caitlin	(09W)	125	164	1	290
TS Enrique	(06E)	19	0	0	19
TS Doug	(10W)	29	0	0	29
TY Ellie	(11W)	128	108	0	236
TY Fred	(12W)	100	6	0	106
TD 13W	(13W)	16	0	0	16
TY Gladys	(14W)	134	98	3	235
TD 15W	(15W)	52	33	0	85
TS Harry	(16W)	35	30	0	65
TY Ivy	(17W)	123	37	0	160
TS Joel	(18W)	53	46	1	100
TY Kinna	(19W)	66	83	2	151
TS Luke	(20W)	77	9	0	86
STY Mireille	(21W)	164	133	0	298*
TY Nat	(22W)	196	144	0	340
TY Orchid	(23W)	143	29	0	172
TY Pat	(24W)	92	0	0	92
STY Ruth	(25W)	172	0	0	172
STY Seth	(26W)	196	19	0	215
TS Thelma	(27W)	89	2	0	91
TS Verne	(28W)	79	0	0	79
TS Wilda	(29W)	72	7	0	79
STY Yuri	(30W)	132	27	0	159
TY Zelda	(31W)	83	10	0	93
Totals NWP:		**3139**	**1088**	**10**	**4239***
Percentage of Total:		**74%**	**26%**	**0%**	**100%**

NORTH INDIAN OCEAN		SATELLITE	RADAR	SYNOPTIC	TOTAL
TC 01A	(01A)	26	0	0	26
TC 02B	(02B)	53	0	0	53
TC 03B	(03B)	39	0	0	39
TC 04B	(04B)	21	0	0	21
Totals NIO:		**139**	**0**	**0**	**139**
Percentage of Total:		**100%**	**0%**	**0%**	**100%**

* Two aircraft fixes were received.

TABLE 2-4B **1991 SOUTH PACIFIC AND SOUTH INDIAN OCEANS FIX PLATFORM SUMMARY**

TROPICAL CYCLONES		SATELLITE	SYNOPTIC	RADAR	TOTAL
TC 01S	- - - -	47	0	0	47
TC 02S	- - - -	29	0	0	29
TC 03P	Sina	60	0	0	60
TC 04S	- - - -	21	0	0	21
TC 05S	Laurence	33	0	2	35
TC 06P	Joy	144	0	13	157
TC 07S	Alison	55	0	0	55
TC 08S	Bella	146	0	0	146
TC 09S	Chris	86	0	0	86
TC 10S	Cynthia	9	0	0	9
TC 11S	Daphne	84	0	6	90
TC 12S	Debra	57	0	0	57
TC 13P	Kelvin	124	0	1	125
TC 14S	Elma	50	0	0	50
TC 15P	- - - -	18	0	0	18
TC 16P	- - - -	53	0	0	53
TC 17S	Fatima	84	0	0	84
TC 18S	Errol	88	0	0	88
TC 19S	Marian	119	0	0	119
TC 20S	Fifi	64	0	0	64
TC 21P	Lisa	67	0	0	67
TC 22S	Gritelle	30	0	0	30
Total Number of Fixes:		**1468**	**0**	**22**	**1490**
Percentage of Total:		**99%**	**0%**	**1%**	**100%**