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 optimum 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 is used to determine the extent of the 30-kt 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 in the Philippine Islands, Taiwan, Hong Kong, China, Japan, South Korea, Kwajalein and Guam. The next DOD radar upgrade will be the arrival of the next generation Doppler radars in the early 1990's.

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, 1WW, collocated with JTWC at Nimitz Hill, Guam, coordinate the satellite acquisitions and tropical cyclone reconnaissance with the following units:

Det 4 , 20 WS, Hickam AFB, Hawaii
Det 5, 20 WS, Clark AB, Republic of the Philippines
Det 8, 20 WS, Kadena AB, Okinawa, Japan
Det 15, 30 WS, Osan AB, Republic of Korea
Air Force Global Weather Central, Offutt AFB, Nebraska

These sites provide a combined coverage that includes most of the western North Pacific, from near the date line westward to the Malay Peninsula. For the remainder of its AOR, JTWC relies on AFGWC to provide coverage using stored satellite data. The Naval Oceanography Command Detachment, Diego Garcia, furnishes interpretation of low resolution NOAA polar orbiting coverage in the central Indian Ocean, and USN ships equipped for direct satellite readout contribute supplementary support. Additionally, civilian contractors with the U.S. Army at Kwajalein Atoll provide satellite fixes on tropical cyclones in the Marshall Islands to supplement Det 1, 1WW's satellite coverage. An additional source of satellite data is DMSP satellite mosaics available from the Fleet Numerical Oceanography Center via the NEDN and NESN lines. These valuable data are used to metwatch the areas not in the DMSP tactical site satellite coverage and provide forecasters the capability to monitor tropical cyclones that AFGWC satellite analysts are fixing.

In addition to polar orbiter imagery, Det 1, 1 WW uses geostationary imagery to support the reconnaissance mission. Low resolution imagery is received, displayed and animated by microcomputers at the DMSP tactical sites. The animation of these images is invaluable in depicting cloud systems in their formative stages and determining coarse motion vectors. Animation is also valuable in assessing environmental changes affecting tropical cyclone behavior. In addition to this capability, Det 1, 1WW receives high resolution digital geostationary data through the Naval Satellite Dissemination System-Geostationary (NSDS-G). The new Det 1 Automation system is being developed and installed by the National Aeronautics and Space Administration (NASA). Phase 1 of Det 1 Automation, 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, scheduled for September 1991, will injest NOAA and DMSP polar orbiter images, SSM/I and satellite sounder data, plus conventional meteorological data already available on site.

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 onboard the spacecraft as they pass over the earth and is later down-linked 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 the dateline in the northwest Pacific Ocean. Additionally, AFGWC can be tasked to provide tropical cyclone support in the northwest Pacific as backup to coverage routinely available in that region.

The hub of the DMSP network is Det 1, 1WW, collocated with JTWC at Nimitz Hill, Guam. Based on available satellite coverage, Det 1, 1WW is responsible for coordinating satellite reconnaissance requirements with JTWC and tasking the individual network sites for the necessary tropical cyclone fixes, current intensity estimates and forecast intensities. 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.

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 detected, JTWC is notified. Once JTWC 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 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, 1 WW provides a minimum of one estimate of the tropical cyclone's current intensity every 12 hours once JTWC is in alert status and every 6 hours when in warning status. Current intensity estimates and 24-hour intensity forecasts are made using the Dvorak technique (NOAA Technical Report NESDIS 11) for both visual and enhanced infrared imagery (Figure 2-1). The enhanced infrared

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

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 (Dvorak, 1984) 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 technique (NOAA Technical Memorandum NWS SR-83, 1975).

2.3.1 SATELLITE PLATFORM SUMMARY --- Figure 2-2 shows the status of operational polar orbiting spacecraft. Two DMSP spacecraft, 19543 (F8) and 20542 (F9), were operational during 1990. The SSM/I on spacecraft F8 experienced increasing noise problems on its horizontally polarized 85 gigahertz channel during the year. A new DMSP spacecraft 21544 (F10), which was launched on 1 December 1990, became operational on 15 January 1991 and will be ready for 1991 tropical cyclones. With regard to the NOAA spacecraft, NOAA 9 remained in standby and NOAA 10 and NOAA 11 spacecraft were operational throughout 1990.

2.3.2 STATISTICAL SUMMARY — During 1990, 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 2834 satellite fixes from the DMSP network on 31 tropical cyclones in the western North Pacific Ocean. Of this, 51 percent were from polar orbiters, while 49 percent were from geostationary. Another 306 fixes were received from non-network sites. In addition, 64 network and 16 non-network fixes were made on tropical cyclones in the North Indian Ocean and 1342 network and 360 non-network fixes on cyclones in the Southern Hemisphere. A comparison of satellite fixes from all data sources with their corresponding best track positions is shown in Tables 2-3A and 2-3B. For the western North Pacific, the total mean error was comparable to the multi-year average and has essentially remained constant.

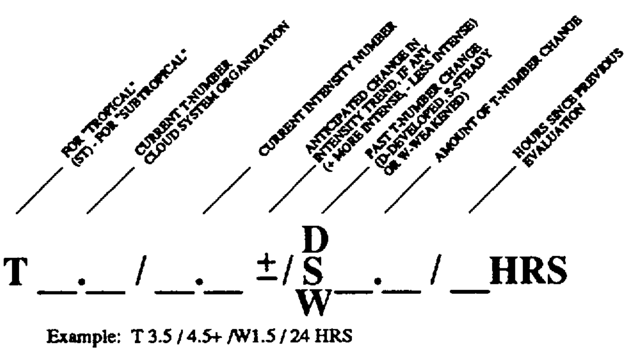

Figure 2-1. Dvorak code for communicating estimates of current and forecast intensity derived from satellite data. In the example, the current "T-number" is 3.5, but the current intensity is 4.5. The cloud system has weakened by 1.5 "T-numbers" since the previous evaluation conducted 24-hours earlier. 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.

2.3.3 NEW TECHNIQUES — The Det 1 Automation system was installed just two weeks prior to year's end and provided Det 1, 1 WW satellite analysts with the capability to rapidly make or modify satellite image enhancements.

The SSM/I, mounted on the F8 DMSP spacecraft, was operational throughout 1990. Four tactical sites in the Pacific: Nimitz Hill, Hickam AFB, Kadena AB, and Clark AB; as well as AFGWC received the Mission Sensor Tactical Imaging Computer (MISTIC) during the summer of 1990. As in 1989, extensive SSM/I support was provided by analysts in the AFGWC Tropical Section. Both AFGWC and Det 1, 1 WW provided bulletins to JTWC

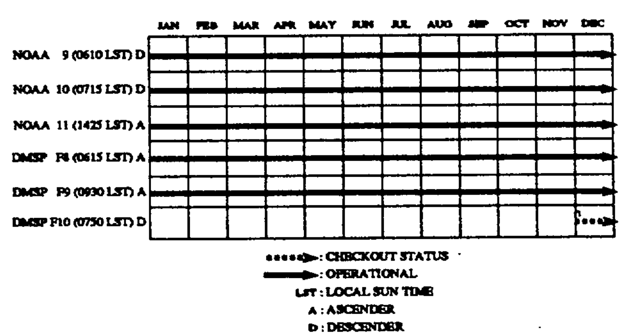

Figure 2-2. Polar orbiters for 1990.

describing the extent of 30-kt winds surrounding the tropical cyclone for all systems with maximum sustained winds of 50 kt or greater. Because Det 1 can only receive realtime DMSP data directly down linked to its tracking antenna, SSM/I coverage is limited to within approximately 20 degrees longitude of Guam. While Operating Line Scan (OLS) imagery can be obtained at a distance of 28 degrees longitude, such low elevation angles prevent retrieval of sufficient quantities of SSM/I data to produce an image. Winds can only be obtained in rain-free areas and areas free of deep moisture. If the cloud system center was rain free, analysts provided center/eye positions based on the 85 GHz microwave channel display. These positions provided a comparison with those made using visual and infrared spectral windows. However, limitations of the computer's ephemeris program caused geolocation errors varying up to 1.4 degrees. The tactical sites compensated by comparing the locations of conservative convective features on the microwave image with those on the OPS imagery.

2.3.4 FUTURE OF SATELLITE RECONNAISSANCE

— Det 1 Automation will be 100 percent operational by the summer of 1991 and it will provide JTWC with the enhanced satellite support. At Det 1, 1 WW, 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 advanced tactical terminal(Mark IVB). The Mark IVB is scheduled to replace the Mark III and Mark IV satellite ingest and display systems during the 1992-1993 time frame.

Until the installation of AWDS in 1993, data will be retrieved via the Automated Weather Network (AWN) and then overlaid on Satellite Imagery. With GEMPAC software developed by NASA, analysts will be able to overlay SSM/I, doppler, wind, temperature, pressure and height fields on visual or infrared imagery. Det 1, 1 WW/JTWC will have the capability to integrate large volumes of data more efficiently and effectively than ever before. Additionally,

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

TABLE 2-3A **MEAN DEVIATION (NM) OF ALL SATELLITE DERIVED TROPICAL CYCLONE POSITIONS FROM JTWC BEST TRACK POSITIONS IN THE NORTHWEST PACIFIC AND NORTH INDIAN OCEANS (NUMBER OF CASES IN PARENTHESES)**

	NORTHWEST PACIFIC OCEAN				NORTH INDIAN OCEAN			
PCN	1979-1989 AVERAGE		1990 AVERAGE		1980-1989 AVERAGE		1990 AVERAGE	
1	13.8	(1848)	13.6	(232)	14.7	(64)	8.6	(16)
2	14.4	(3653)	12.9	(519)	13.3	(33)	12.9	(7)
3	20.9	(2415)	21.0	(275)	23.9	(47)	47.4	(2)
4	21.3	(2991)	18.1	(654)	33.7	(39)	78.5	(1)
5	36.3	(4141)	37.0	(317)	37.4	(375)	24.9	(41)
6	35.2	(7587)	40.2	(1143)	40.0	(496)	58.6	(13)
1&2	13.8	(5501)	13.1	(751)	14.2	(97)	9.9	(23)
3&4	21.2	(5406)	19.0	(929)	28.4	(86)	57.8	(3)
5&6	35.6	(11728)	39.5	(1460)	38.9	(871)	33.0	(54)
1,3&5	27.0	(8404)	25.1	(824)	33.2	(486)	21.2	(59)
2,4&6	26.9	(14231)	27.8	(2316)	38.0	(568)	44.3	(21)
Totals:	**26.9**	**(22635)**	**27.1**	**(3140)**	**35.7**	**(1054)**	**27.3**	**(80)**

TABLE 2-3B **MEAN DEVIATION (NM) OF ALL SATELLITE DERIVED TROPICAL CYCLONE POSITIONS FROM JTWC BEST TRACK POSITIONS IN THE WESTERN SOUTH PACIFIC AND SOUTH INDIAN OCEANS (NUMBER OF CASES IN PARENTHESES)**

PCN	1985 - 1989 AVERAGE		1990 AVERAGE	
1	15.8	(211)	15.5	(153)
2	16.1	(804)	19.0	(162)
3	31.0	(170)	26.2	(79)
4	26.5	(631)	24.6	(168)
5	37.9	(758)	30.3	(362)
6	36.5	(4386)	33.9	(778)
1&2	16.1	(1015)	17.3	(315)
3&4	27.5	(801)	25.1	(247)
5&6	36.8	(5144)	32.8	(1140)
1,3&5	32.7	(1139)	25.9	(594)
2,4&6	32.6	(5821)	30.3	(1108)
Totals:	**32.6**	**(6960)**	**28.8**	**(1702)**

procedures for post storm reviews will be simplified. Archived hard copy imagery will be replace by loops and sectorized images archived on 4 mm, 1.2 gigabyte tapes. When unarchived, the data can again be enhanced for further detailed analysis. Det 1 and NASA are working together to explore the possible use of optical disks and other large storage devices for instantaneous access of short term archived data. The Mark IVB will also have powerful graphic and enhancement capabilities. Therefore, it is essential that the two systems are integrated in order to exploit their full potential.

2.4 RADAR RECONNAISSANCE

Twenty-one of the thirty-two significant tropical cyclones in the western North Pacific during 1990 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. Four airborne radar fixes were obtained by a research aircraft associated with the 1990 Office of Naval Research Tropical Cyclone Motion Experiment (TCM-90).

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 1073 radar fixes encoded in this manner; 314 were good, 341 were fair, and 418 were poor. Compared to JTWC's best track, the mean vector deviation for land-based radar sites was 20 nm (37 km). 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.

No radar reports were received on Southern Hemisphere or North Indian Ocean tropical cyclones. However, a projected GTS circuit between Melbourne, Australia and Hickam AFB, Hawaii should provide access to radar reports from the South Pacific and Indian Oceans.

2.5 TROPICAL CYCLONE FIX DATA

A total of 4139 fixes on thirty-two northwest Pacific tropical cyclones and 80 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 1702 fixes in the South Pacific and South Indian Oceans.

TABLE 2-4A

1990 NORTHWEST PACIFIC AND NORTH INDIAN OCEAN
FIX PLATFORM SUMMARY

NORTHWEST PACIFIC		SATELLITE	RADAR	SYNOPTIC	TOTAL
TY Koryn	(01W)	97	26	0	123
TS Lewis	(02W)	75	0	0	75
TY Marian	(03W)	60	0	0	60
TD 04W	(04W)	19	0	0	19
TS Nathan	(05W)	75	0	0	75
TY Ofelia	(06W)	136	59	0	195
TY Percy	(07W)	126	0	0	126
TS Robyn	(08W)	108	13	0	121
TY Steve	(09W)	107	1	0	108
TY Tasha	(10W)	60	5	0	65
TY Vernon	(11W)	159	35	0	194
TY Winona	(12W)	87	70	0	157
TS Aka	(01C)	30	0	0	30
TY Yancy	(13W)	131	84	0	215
TY Zola	(14W)	96	66	0	162
TY Abe	(15W)	123	98	0	221
TY Becky	(16W)	92	11	0	103
TY Dot	(17W)	82	32	0	114
TY Cecil	(18W)	22	13	0	35
TY Ed	(19W)	175	30	0	205
STY Flo	(20W)	102	76	0	182 *
TY Gene	(21W)	145	250	0	395
TY Hattie	(22W)	125	80	0	205
TS Ira	(23W)	23	0	0	23
TS Jeana	(24W)	19	0	0	19
TY Kyle	(25W)	102	2	0	104
TS Lola	(26W)	34	0	0	34
STY Mike	(27W)	177	0	0	177
TS Nell	(28W)	22	0	0	22
STY Page	(29W)	180	15	0	195
STY Owen	(30W)	174	2	0	176
TY Russ	(31W)	177	26	0	203
Totals NWP:		**3140**	**994**	**0**	**4138***
Percentage of Total:		**76 %**	**24 %**	**0 %**	**100 %**

NORTH INDIAN OCEAN		SATELLITE	RADAR	SYNOPTIC	TOTAL
TC 01B	(01B)	5	0	0	5
TC 02B	(02B)	48	0	0	118
TC 03B	(03B)	13	0	0	13
TC 04B	(04B)	14	0	0	14
Totals NIO:		**80**	**0**	**0**	**80**
Percentage of Total:		**100 %**	**0 %**	**0 %**	**100 %**

* Four airborne radar fixes were received.

TABLE 2-4B

1990 SOUTH PACIFIC AND SOUTH INDIAN OCEANS
FIX PLATFORM SUMMARY

TROPICAL CYCLONES		SATELLITE	SYNOPTIC	RADAR	TOTAL
TC 01S	- - - -	18	0	0	18
TC 02S	- - - -	38	0	0	38
TC 03S	- - - -	16	0	0	16
TC 04S	- - - -	26	0	0	26
TC 05S	- - - -	26	0	0	26
TC 06S	Pedro	71	0	0	71
TC 07P	Felicity	67	0	0	67
TC 08S	Alibera	178	0	0	178
TC 09S	Baomavo	61	0	0	61
TC 10S	Sam	80	0	0	80
TC 11S	Tina	40	0	0	40
TC 12P	Nancy	61	0	0	61
TC 13P	Ofa	61	0	0	61
TC 14S	Cezera	85	0	0	85
TC 15S	Dety	68	0	0	68
TC 16P	Peni	20	0	0	20
TC 17S	Vincent	64	0	0	64
TC 18S	Edisaona	63	0	0	63
TC 19P	Greg	41	0	0	41
TC 20S	Walter	39	0	0	39
TC 21P	Hilda	55	0	0	55
TC 22S	Felana	60	0	0	60
TC 23S	Gregoara	98	0	0	98
TC 24S	Alex	108	0	0	108
TC 25P	Ivor	94	0	0	94
TC 26P	Rae	42	0	0	42
TC 27S	- - - -	19	0	0	19
TC 28S	Bessi	26	0	0	26
TC 29S	Ikonjo	77	0	0	77
Total Number of Fixes:		1702	0	0	1702