

DOCKET NO. **SA- 516**

EXHIBIT NO. **13A**

**NATIONAL TRANSPORTATION SAFETY BOARD  
WASHINGTON, D.C**

**AIRPLANE PERFORMANCE STUDY**

**National Transportation Safety Board  
Office of Research and Engineering  
Washington, D.C.**

September 30, 1997

**AIRPLANE PERFORMANCE STUDY** *ETH*

**DCA-96-MA-070**

**I. ACCIDENT**

Location: East Moriches, New York  
Date: July 17, 1996  
Time: 2031 Eastern Daylight Time (EDT)  
Aircraft: Boeing 747-131, N93119  
Carrier: Trans World Airlines (TWA), Flight 800

**II. GROUP IDENTIFICATION**

Chairman: Charles Pereira  
NTSB, RE-60

Member: Joe Bracken  
Airline Pilots Association

Member: Dave F. Warne  
TWA

Member: Mark Sweepe  
Boeing Commercial Airplane Group

Member: Don Wilson  
FAA Seattle ACO

Member: Erik Mogelgaard  
FBI

**III. SUMMARY**

On July 17, 1996, at 2031:12.5 Eastern Daylight Time (EDT<sup>1</sup>), a Boeing 747-131, N93119, crashed into the Atlantic Ocean about 8 miles south of East Moriches, New York, after taking off from John F. Kennedy International Airport (JFK). The airplane was operating on an instrument flight rules (IFR) flight plan under the provisions of Title 14, Code of Federal

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<sup>1</sup> All times are given in EDT unless otherwise noted.

Regulations (CFR), Part 121, on a regularly scheduled flight to Charles De Gaulle International Airport (CDG), Paris, France, as Trans World Airlines (TWA) Flight 800. The airplane was destroyed by explosion, fire, and impact forces with the ocean. All 230 people aboard were killed

#### IV. DETAILS OF THE INVESTIGATION

Review of the accident airplane's Flight Data Recorder (FDR) data<sup>2</sup> and Cockpit Voice Recorder (CVR) transcript<sup>3</sup> indicate that performance was normal throughout the takeoff and flight, including the last second of FDR data. Predicted rate-of-climb values for 3 sample areas were in excess of the actual TWA 800 rate-of-climb; however, Boeing has attributed these differences to the unsteadiness of the climb (Air Traffic Control altitude/climb instructions resulted in several rate-of-climb changes. The CVR indicates that the flying pilot, who apparently was new to the 747, was having minor difficulty trimming the airplane properly in the pitch axis on at least one occasion). For further details concerning the performance of Flight 800, see Attachment I, Boeing's TWA Flight 800 FDR Data Summary.

Radar data for the accident airplane and the surrounding area were obtained from the Federal Aviation Administration (FAA), Department of Defense (NAVY and NORAD), and Sikorsky. These are all of the known sources of radar data for the area where TWA flight 800 crashed, with a total of 9 radars located in 5 states (Pennsylvania, New Jersey, New York, Connecticut, Massachusetts).

The FAA radar data are from New York Approach Control (NYTRACON) and the New York and Boston Air Route Traffic Control Centers (ARTCCs, commonly referred to as Centers). NYTRACON has 5 radars, each with a range of approximately 60 nautical miles. The 5 NYTRACON radars are located at JFK airport, Newark, NJ airport (EWR), Islip, NY airport (ISP), White Plains, NY airport (HPN), and Stewart Field airport in Newburg, NY (SWF). The NYTRACON radar data were provided to the NTSB in range/magnetic azimuth format relative to each radar site. Three Center radars, each with a range of approximately 250 nautical miles, were within range of the accident area. The 3 Center radars are located at Trevose, PA, Riverhead, NY, and North Truro, MA. The Center radar data were provided to the NTSB in latitude/longitude format.

The NAVY and NORAD radar data for the accident area also come from the FAA Center radars at Trevose, PA, North Truro, MA, and Riverhead, NY via modem. Because the NAVY and NORAD radar data for the accident area come from the same radars as the FAA Center radar data, the NAVY and NORAD radar data are essentially identical to the FAA Center radar data. However, data transmission, processing, and recording differences between NAVY, NORAD, and the FAA Centers resulted in some minor differences in the respective data sets (such as computer clock times, missing data points likely due to modem transmission errors, etc.). The NAVY and NORAD data were provided to the NTSB in range/true azimuth format relative to each radar site.

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<sup>2</sup> See Flight Data Recorder Factual Report.

<sup>3</sup> See Cockpit Voice Recorder Factual Report.

The Sikorsky radar data were recorded at the Sikorsky aircraft plant in Stratford, CT. The radar data come from the FAA Center radar in Riverhead, NY and from Sikorsky's own radar in Shelton, CT (approximately 3 miles from their plant). The radar data from the FAA's Riverhead, NY Center radar are sent to Sikorsky via modem by the NAVY immediately after the NAVY receives them from the FAA. Because Sikorsky, FAA, NAVY, and NORAD all get essentially identical radar data from the Riverhead, NY radar, the Riverhead, NY portion of the Sikorsky, FAA, NAVY, and NORAD radar data are essentially identical. Note that the Sikorsky radar in Shelton, CT is a secondary radar system<sup>4</sup> only - no primary radar<sup>5</sup> data are available from this radar. The Sikorsky radar data were provided to the NTSB in range/true azimuth format relative to each radar site.

The radar data for TWA 800 (transponder code 2633) were converted from either range/azimuth or latitude/longitude data (depending on data source) to x/y position data relative to the FAA's Islip, New York Airport Surveillance Radar (ASR) radar site. The coordinate conversion was accomplished using NTSB software and FAA/Sikorsky-provided facility position and magnetic variation data. All radar data sets were aligned in x/y position assuming that the FAA Center radar data positions were the most accurate. Attachment II contains tabular listings of the facility position and magnetic variation data. Tabular listings of each radar data set will be presented in a separate addendum to this report.

The CVR group established time correlation between the FAA's Boston Center ATC voice recording and the CVR by aligning microphone keying signatures in the audio data. The FDR group then established time correlation between the FDR and the CVR by aligning CVR microphone keying signatures in the audio data with FDR microphone keying discrete data. This study establishes an additional time correlation between the FDR time base and all radar data sources. The time correlation was established by graphing and aligning TWA 800's radar altitude as a function of time with its FDR altitude as a function of time (see Attachment III). The following time correlation was established:

Data Source	Time Offset Required to Align Data Source Time Base with Boston Center Voice Time Base
Boston Center Radar Data	-1.25 seconds
New York Center Radar Data	-2.25 seconds
All New York TRACON ASR Radar Data	-0.25 seconds
NAVY Radar Data	-2.80 seconds
NORAD Radar Data	+75.715 seconds
Sikorsky Radar Data	N/A (anomalous times)

<sup>4</sup> Air traffic control secondary radar systems transmit coded electromagnetic signals (interrogation) that can be received by transponder-equipped aircraft. The aircraft receives the signal, decodes it, and then transmits a coded electromagnetic signal in response to the interrogation. Secondary returns can provide information on the aircraft's identity, altitude, and position.

<sup>5</sup> Air traffic control primary radar systems transmit electromagnetic signals that can be reflected by an object such as an aircraft. The position of the object can be determined by timing of the transmission and return of the electromagnetic signals, and by measurement of the direction in which the radar antenna is pointed when the signals are transmitted and returned.

The FDR pressure altitude data and Navy/NORAD/Sikorsky radar data altitudes are based on 29.92 inches of mercury, and the New York TRACON radar data altitudes are based on 30.03 inches of mercury. Therefore, in order to align the altitudes during the time correlation, 100 feet was added to the FDR pressure altitude data and Navy/NORAD/Sikorsky radar altitudes. Also note that the times for the Sikorsky radar data were found to be anomalous; therefore, a time correlation was not established for the Sikorsky radar data.

The time correlation was further verified by graphing x/y position for all radar data sets and observing proper time/position sequencing of the radar returns (see Attachment IV). As an example, a radar return from the White Plains, New York ASR shows up at the expected approximate time and position relative to the previous radar return from New York Center.

Selected CVR excerpts, which were also overlaid on the altitude versus time and x/y graphs, support the time correlation as well due to agreement between pilot/ATC dialogue and the flight path. As an example, the airplane levels off at approximately 13,000 feet altitude after the CVR transcript shows ATC instructing TWA 800 to amend its altitude clearance to 13,000 feet. Further, the FDR and radar altitudes oscillate in the area where the CVR shows the flying pilot commenting about having difficulty trimming the airplane.

The time correlation indicates that the last secondary radar return from TWA 800 (recorded by the FAA's Trevoze, PA radar site) occurred at approximately 20:31:12.0, the FDR recording ended at 20:31:12.26, the CVR recording ended at 20:31:12.50, and the first of several hundred primary radar returns consistent with TWA 800's flight path and in-flight break-up was recorded at 20:31:14.39. This sequence of events is consistent with a normal climb through 13,750 feet msl (altitude based on FDR, radar, and altimeter setting data) terminating in nearly simultaneous loss of electrical power to the accident airplane's altitude encoding transponder, FDR, and CVR.

The radar data were subsequently reviewed for evidence of airplanes or unidentified radar returns in the vicinity of TWA 800. Primary and secondary radar data returns throughout the accident area were reviewed, eventually focusing on a square area 20 nautical miles per side centered around the accident area (see graphs in Attachment IV and V). The radar data review showed the following vehicle and/or object tracks within 10 nautical miles of TWA 800 just prior to the time of the accident (local time 20:30:30-20:31:13):

1. a Navy P-3 anti-submarine airplane less than 3 nautical miles south-southwest and approximately 6,300 feet above TWA 800 (P-3 altitude data is based on P-3 flight crew interview), moving southwest at over 250 knots groundspeed (labeled "1" on graph in Attachment V)
2. USAIR flight 217 approximately 3 nautical miles south-southwest and approximately 8,000 feet above TWA 800, moving north (labeled "2" on graph in Attachment V)
3. TWA flight 900 approximately 9 nautical miles west and approximately 5,300 feet above TWA 800, moving east-northeast (labeled "3" on graph in Attachment V)

4. an unidentified track less than 3 nautical miles south-southeast moving south-southwest at just over 30 knots groundspeed, consistent with the speed of a boat (labeled "4" on graph in Attachment V)
5. an unidentified track approximately 5 nautical miles west moving east-southeast at approximately 15 knots groundspeed, consistent with the speed of a boat (labeled "5" on graph in Attachment V)
6. an unidentified track approximately 5 nautical miles west-northwest moving south-southwest at approximately 12 knots groundspeed, consistent with the speed of a boat (labeled "6" on graph in Attachment V)
7. an unidentified track approximately 6 nautical miles northwest moving southeast at approximately 20 knots groundspeed, consistent with the speed of a boat (labeled "7" on graph in Attachment V)

The radar data in this area and time period also show several primary returns not associated with any track. The presence of such unassociated primary returns is common and can be caused by ground/sea clutter, temperature inversions (see text portion of Attachment VI), ships, birds, radar signals reflecting off structures around the radar, and other factors.

No sequence of radar returns intersected TWA 800's position at any point in time, nor were there any radar returns consistent with a missile or other projectile traveling towards TWA 800. There was one sequence of 8 primary radar returns<sup>6</sup> from the NYTRACON ISP radar which were studied further (see Attachment VI). These 8 radar returns, which started at 2030:15 and ended at 2031:30 (18 seconds after TWA 800's last secondary return), appeared to show a target moving at over 400 knots groundspeed on a southeasterly heading (156-157 degrees magnetic) away from TWA 800's position. This target track never came closer than 6 nautical miles to TWA 800 and remained on a straight track away from TWA 800 without turning towards TWA 800.

ISP was the only primary radar system out of 8 to show these primary radar returns and no associated secondary radar returns were found in any of the 9 secondary radar data sets. The ISP radar data from time 20:30:00 to 20:40:00 in the azimuth range 150 to 160 degrees show 3 examples of primary-only target tracks with groundspeeds over 300 knots (see graph in Attachment VI). In each case a primary radar track appears with no prior track leading to it and then disappears after 4-8 returns, with occasional intermittent single returns at either end of the track or in the middle. For each of these primary target tracks, the signal strength varies randomly between low and high values between the first and last return. Additionally, none of these ISP primary tracks are shown on the other 7 primary radar systems and none has any associated secondary target track. However, secondary target tracks with similar groundspeeds were found in other geographic areas.

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<sup>6</sup> Initially only 4 primary radar returns from this track were identified. Further review showed 4 more primary radar returns after the first 4, each consistent with the speed and heading of the first 4.

These findings, as well as prior case history and consultation with air traffic control and radar specialists indicate that the 8 primary radar returns and other 300+ knot Islip ASR primary target tracks shown in Attachment VI are consistent with false primary targets resulting from ground or building reflections of actual aircraft primary returns from another geographic area. Several instances of this have reportedly occurred at FAA approach control radar sites because of their location at or near city airports where buildings and other reflective structure is near the radar.



Charles Pereira  
Aerospace Engineer/DFDR

Attachments

**Attachment I**

Boeing's TWA Flight 800 FDR Data Summary

## TWA Flight 800 FDR Data Summary

The FDR data was processed and validated at the NTSB FDR lab on July 26 and 27, 1996. Aircraft motion, control deflection, engine EPR, thrust reverser, and leading edge flap parameters are described.

### 1) Aircraft motion

- No unusual aircraft motion throughout the entire flight
- Vertical and longitudinal accelerations are normal
- Lateral acceleration is not recorded
- Pitch, roll, and heading are all normal

### 2) Control input

- No unusual control inputs
- Control wheel deflection is very noisy for both flight 800 and the previous flight. The noise appears to diminish when the control wheel is deflected during roll commands.
- Upper and lower rudder deflections are normal. No change in rudder deflection was recorded during the last 3 minutes of recorded data (above 12500 ft pressure altitude). A constant deflection of .8 degrees T.E. right was recorded for this time period. During the takeoff roll, varying rudder deflection occurred with a maximum recorded deflection of 9.5 degrees. The average rudder deflection during the takeoff roll is T.E. left which suggests a small crosswind from the right. Correct processing of the rudder deflection data were verified by confirming that the yaw damper saturation which occurred during taxi was near the expected deflection of 4.2 degrees. A rudder control sweep occurred prior to takeoff and was also confirmed to be near the expected maximum rudder deflection of 26 degrees.
- Right and left elevator deflections were less than 1 degree during the last 3 minutes. Correct processing of the elevator deflection data was verified by confirming that the deflection which occurred during takeoff rotation was near the expected deflection of 7 degrees T.E. up. An elevator control sweep was not recorded by the FDR.

### 3) Engine EPR

- No unexplained power changes. The power is retarded to near idle (EPR approximately 1.00 to 1.12) for 2 minutes, ending 44 seconds before the end of the recording. Within this period of time, the power is at idle (EPR of 1.00 to 1.01) for 37 seconds, ending 1 minute and 44 seconds before the end of the recording. This power reduction is consistent with the ATC direction to hold at 13,000 ft.

### 4) Flight path and control changes in last minute

Time from end  
of recording  
(min:sec)

Event

2:45 EPRs reduce to 1.1 average (Split EPRs 1.08 to 1.12)

A roll to 16 degrees is initiated (roll maneuver lasts approximately 30 seconds)  
Variation in pitch attitude of 3 degrees starts

2:22 EPRs reduce to 1.0

2:15 Return to wings level (Bank angle within +/- 3 degrees for remainder of flight  
Altitude of 13,000 ft achieved momentarily  
Slow descent begins and deceleration continues until power is advanced

1:44 EPRs begin to advance toward 1.05 to 1.12 EPR (Split EPRs)

0:37 EPRs advanced toward climb power (Split EPRs 1.25 to 1.31)  
EPR differences continue to diminish until end of recording when all are 1.30

0:00 At end of recorded data:

Vertical accel = .90 (-.03 offset indicated by .97 during taxi)  
Longitudinal accel = .10 (No offset indicated)  
Pitch attitude = 3.6 deg  
Roll attitude = 0.0 deg (No offset indicated)  
Heading = 82.4 deg  
Indicated Airspeed = 298 kt  
Pressure Altitude = 13600 ft

5) Last several seconds of recorded data

There are no sudden changes in any parameter in the last several seconds of the recording.

6) Thrust reversers

For all four thrust reversers (T/R), "not-in-transit" and "not-deployed" are recorded for the entire flight. No rapid yaw or roll nor aircraft buffet is recorded that would be indicative of a sudden T/R deployment in flight. Prior to flight 800, the #3 T/R was locked-out by maintenance and was being treated as an MEL item.

During the landing at JFK, #3 T/R "in-transit" was recorded during the entire time that the T/R deployed condition was recorded. This is unlike #1, 2, and 4 which are "in-transit" for 3 to 4 seconds, then are "not-in-transit" until the 3 to 4 second period prior to the T/R becoming "not-deployed" toward the end of the landing roll-out.

The deployed signals for all four T/Rs occur simultaneously with the "in-transit" recording. This suggests that the deploy signals are actually "not-stowed" signals, since full T/R deployment occurs in 3 to 4 seconds. The 3 to 4 second transit time is confirmed by the duration of the "in-transit" condition recorded for T/Rs 1, 2 and 4. The T/R discrettes are recorded every second by the FDR.

The #3 T/R had been locked-out and was being treated as an MEL item. Consistent with a locked-out reverser, the #3 EPR did not increase

throughout the landing rollout at JFK. Severed #3 T/R control cables were replaced in New York.

7) Leading edge flaps

The FDR recorded an "in-transit" condition for the #3 left leading edge flap drive during the entire time that the flaps were retracted for both flight 800 and the previous flight. After flap extension, "not-in-transit" is recorded. For all other leading edge drives, "not-in-transit" is recorded after retraction and extension.

For all of the leading edge extend discrettes, the extended condition is recorded simultaneously with the first recording of "in-transit". This also suggests, like the T/R discrettes, that the extended discrettes are actually "not-retracted" discrettes.

The maintenance log contains the entry: "July 15<sup>th</sup>, 3L LE flap Amber Lt. Stays on with LE Flaps Up and Retracted electrically. FWD panel lights ops check O.K. Because the in-transit condition occurred with alternate flap operation, the "in-transit" flight deck indication and FDR recording are believed to be false signals, probably due to an out-of-rig condition of the sensor.

The left #3 leading edge drive powers the two flap segments outboard of the inboard engine.

7) Aircraft Performance

The aircraft performance appears normal throughout flight 800. Quantitative comparisons between estimated and FDR recorded performance were made for segments of flight 800 that were least unsteady. However, varying differences in the rates-of-climb are calculated and are believed to be due to unsteadiness of the flight profile:

Time segment min:sec	Rate-of-Climb (feet/minute)	
	FDR	Estimated
10:12 to 10:32	750	840
15:52 to 16:02	1500	2200
20:40 to End	1650	1900

Takeoff:

- Derated EPRs of approximately 1.34 were achieved
- Stabilizer position of 6 units was set and resulted in the aircraft nearly trimmed at the all engine climb speed
- Liftoff occurs at approximately 10 degrees of pitch attitude
- Normal initial climb pitch attitude of 17 degrees was achieved



206-965-5401

**Attachment II**

Tabular Listings of the FAA/Sikorsky-Provided Facility Data

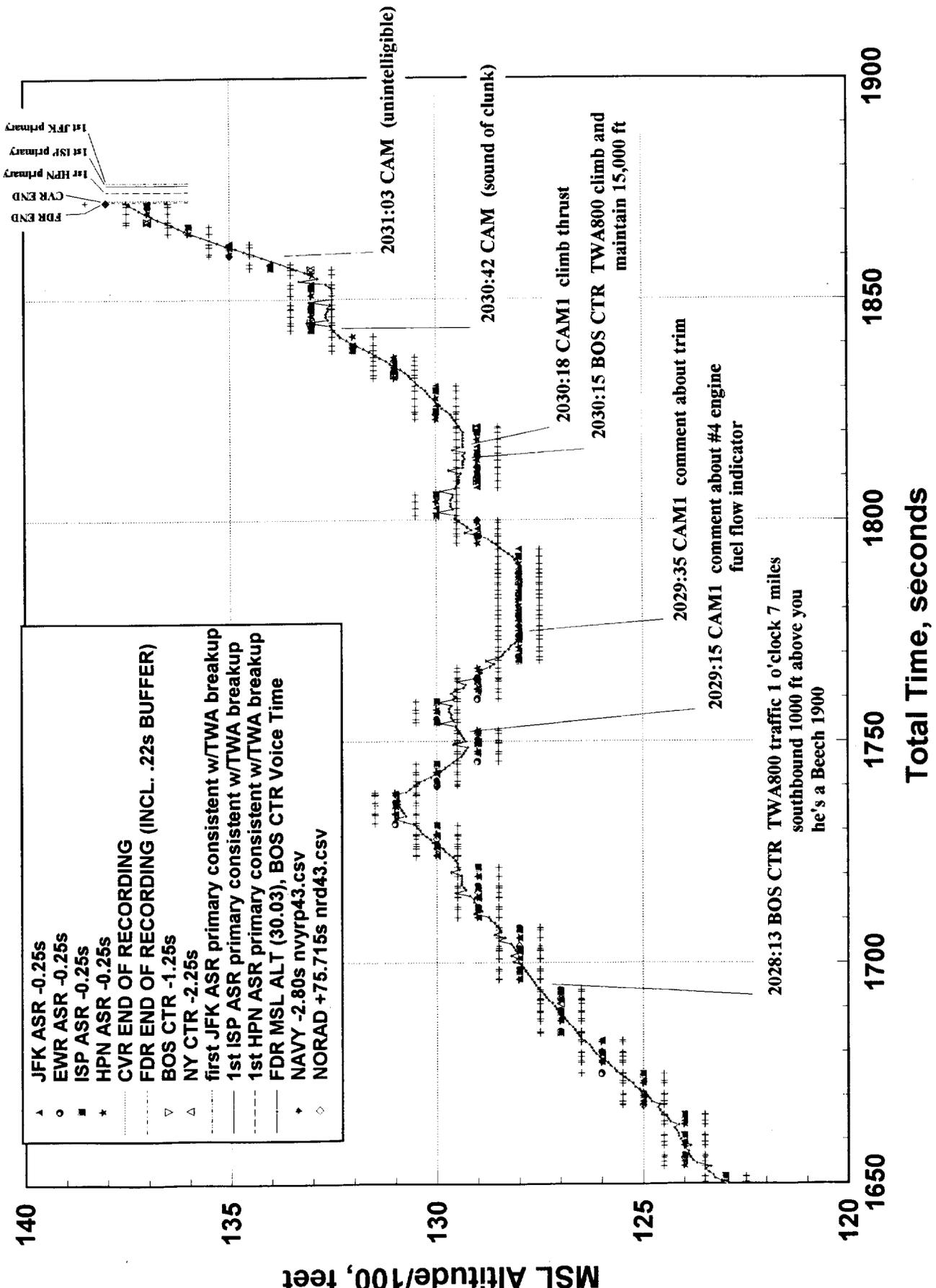
Radar Sites

40	38	22.4	73	45	59.2	JFK ASR radar site, lat/lon coordinates x/y coordinates relative to ISP ASR FAA-provided magnetic variation
-30.455	-9.14					
W 13.0						
40	41	25.1	74	9	46	EWR ASR radar site, lat/lon coordinates x/y coordinates relative to ISP ASR FAA-provided magnetic variation
-48.53	-5.906					
W 13.0						
40	47	38.2	73	6	0.5	ISP ASR radar site, lat/lon coordinates x/y coordinates relative to ISP ASR FAA-provided magnetic variation
0	0					
W 13.0						
41	3	40.35	73	42	50.87	HPN ASR radar site, lat/lon coordinates x/y coordinates relative to ISP ASR FAA-provided magnetic variation
-27.875	16.136					
W 12.0						
41	29	26.14	74	6	20.52	SWF ASR radar site, lat/lon coordinates x/y coordinates relative to ISP ASR FAA-provided magnetic variation
-45.339	42.059					
W 12.0						
40	8	3.4	74	59	11.91	Trevoze PA radar site, lat/lon coordinates x/y coordinates relative to ISP ASR
-86.911	-38.592					
40	52	42.66	72	41	15.95	Riverhead NY radar site, lat/lon coordinates x/y coordinates relative to ISP ASR
18.775	5.12					
42	2	2.4	70	3	11.1	North Truro MA radar site, lat/lon coordinates x/y coordinates relative to ISP ASR
136.148	76.879					
41	17	42	73	4	59	Sikorsky secondary radar site, lat/lon coordinates x/y coordinates relative to ISP ASR Sikorsky-provided magnetic variation
0.771	30.054					
W 14.0						

### **Attachment III**

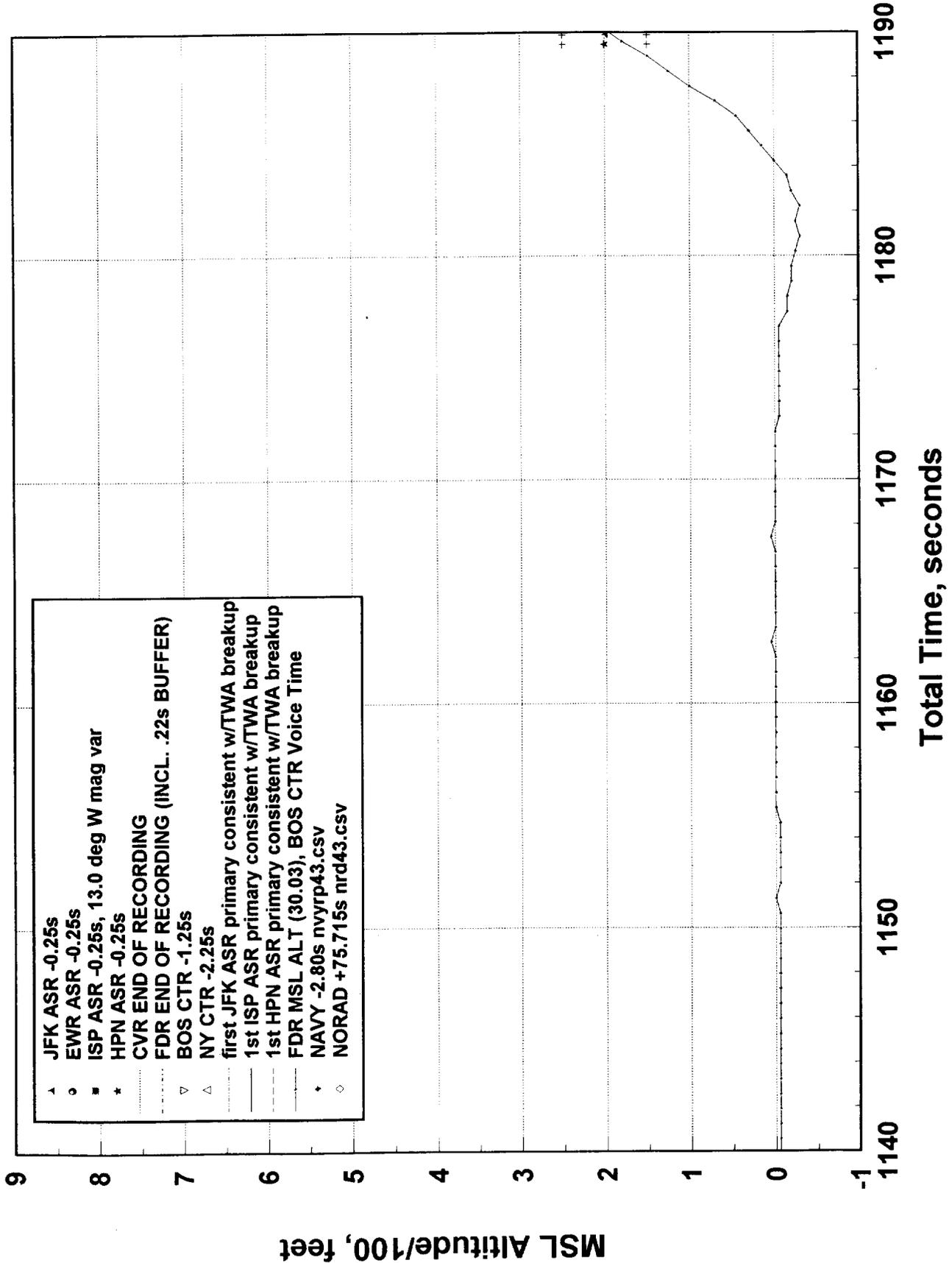
**Altitude, X, and Y versus Time Graphs**

# TWA 747 out of JFK, 7/17/96



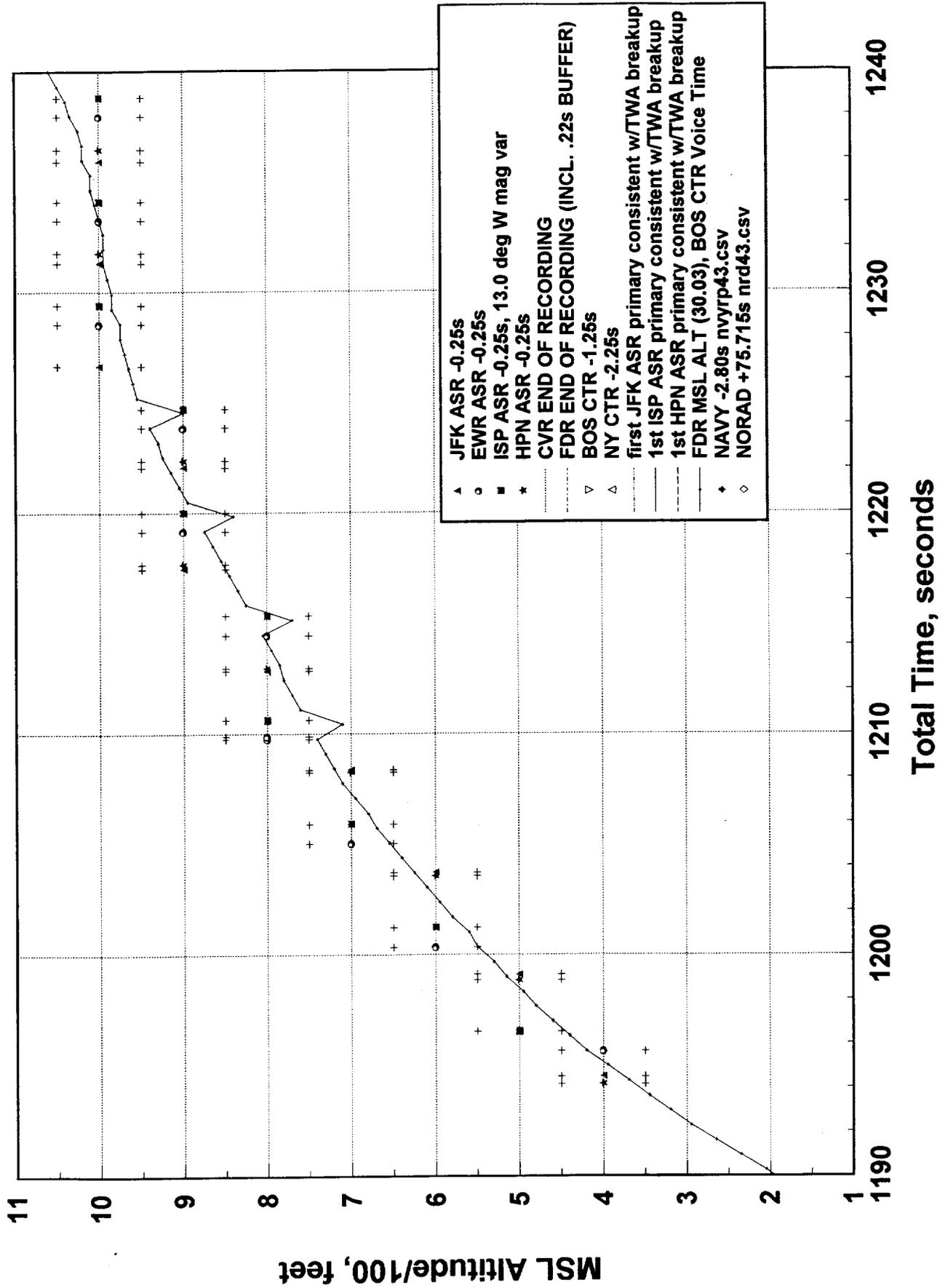
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# TWA 747 out of JFK, 7/17/96



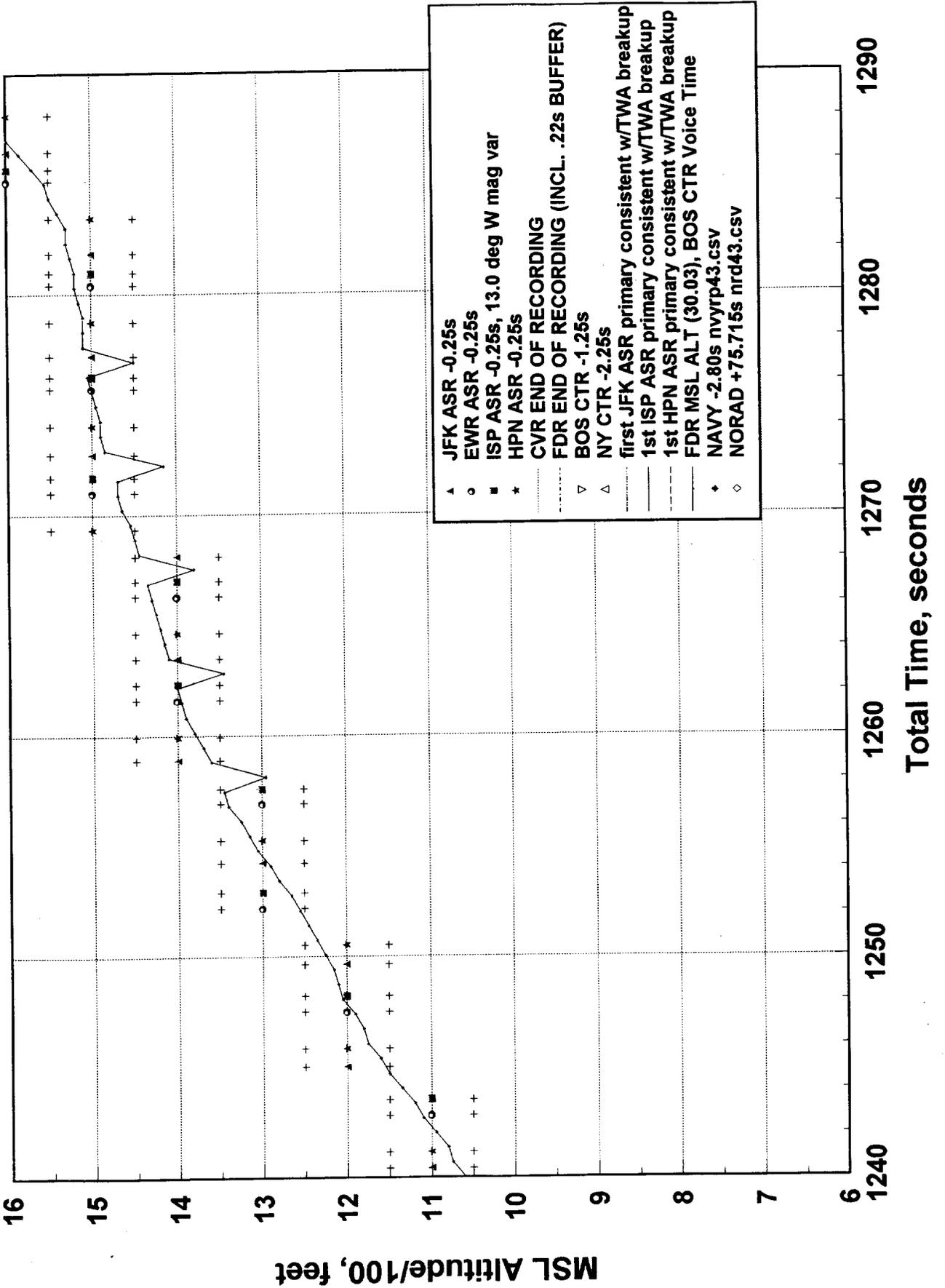
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SCAP. 7c

# TWA 747 out of JFK, 7/17/96



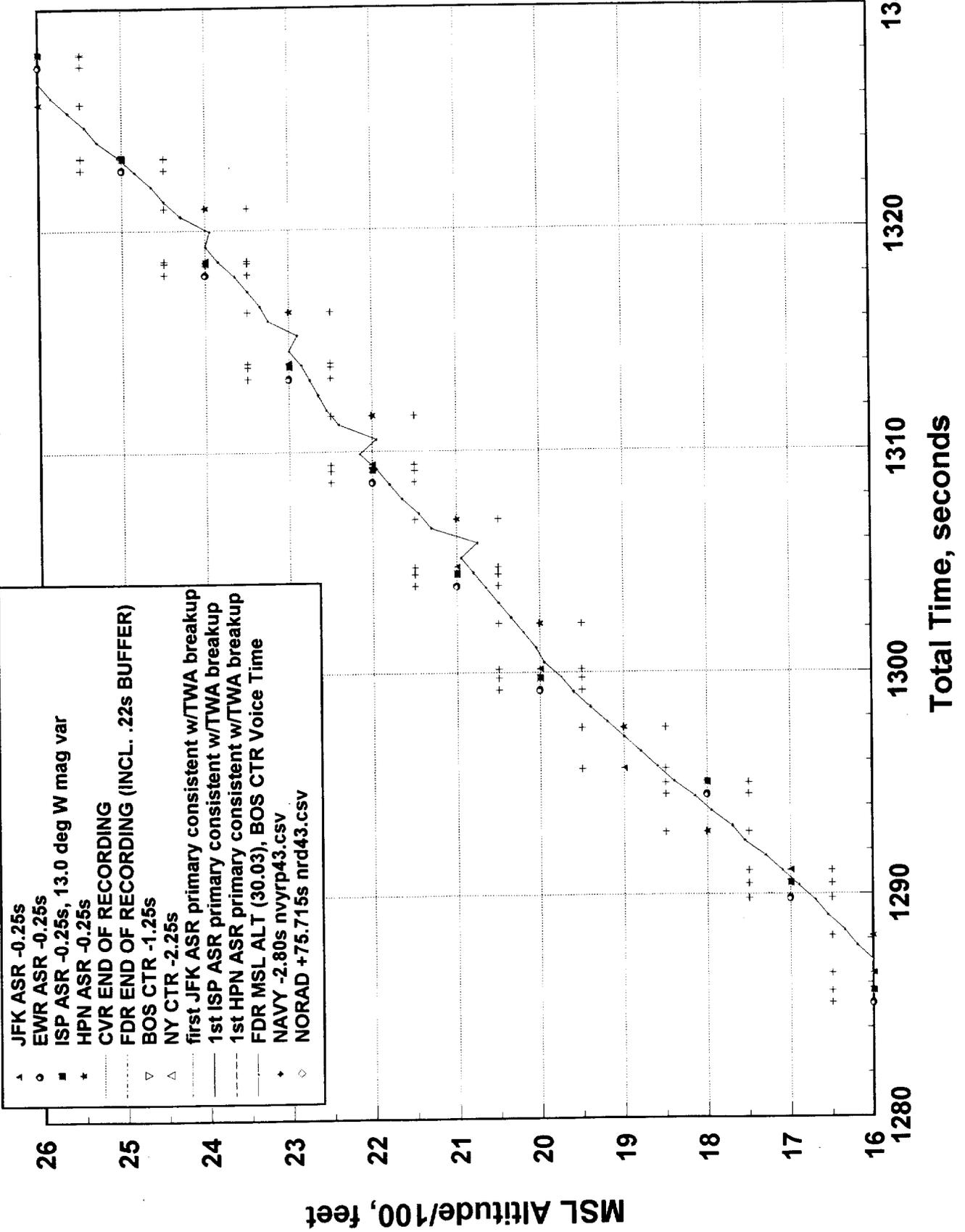
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# TWA 747 out of JFK, 7/17/96



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S-LDF 18

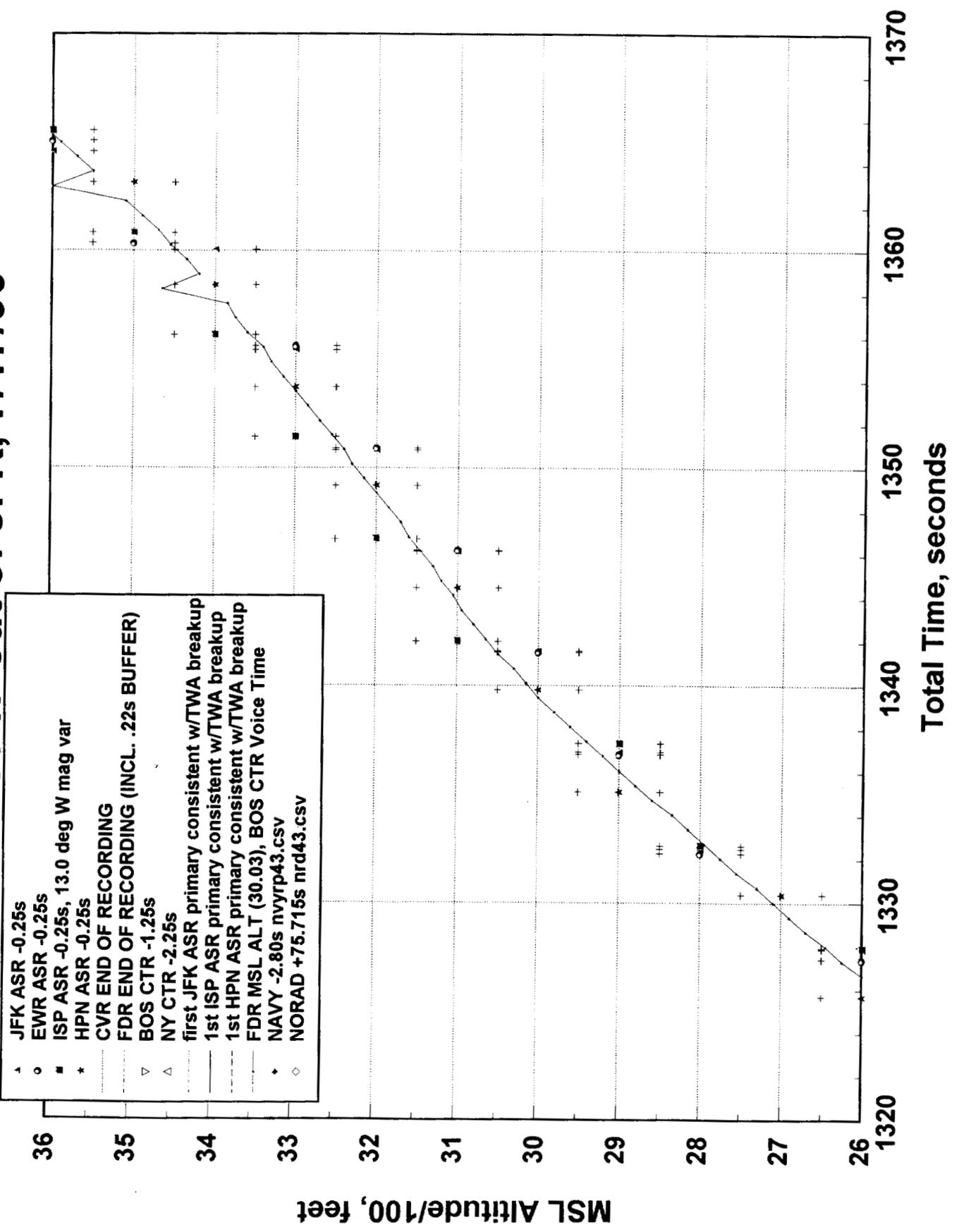
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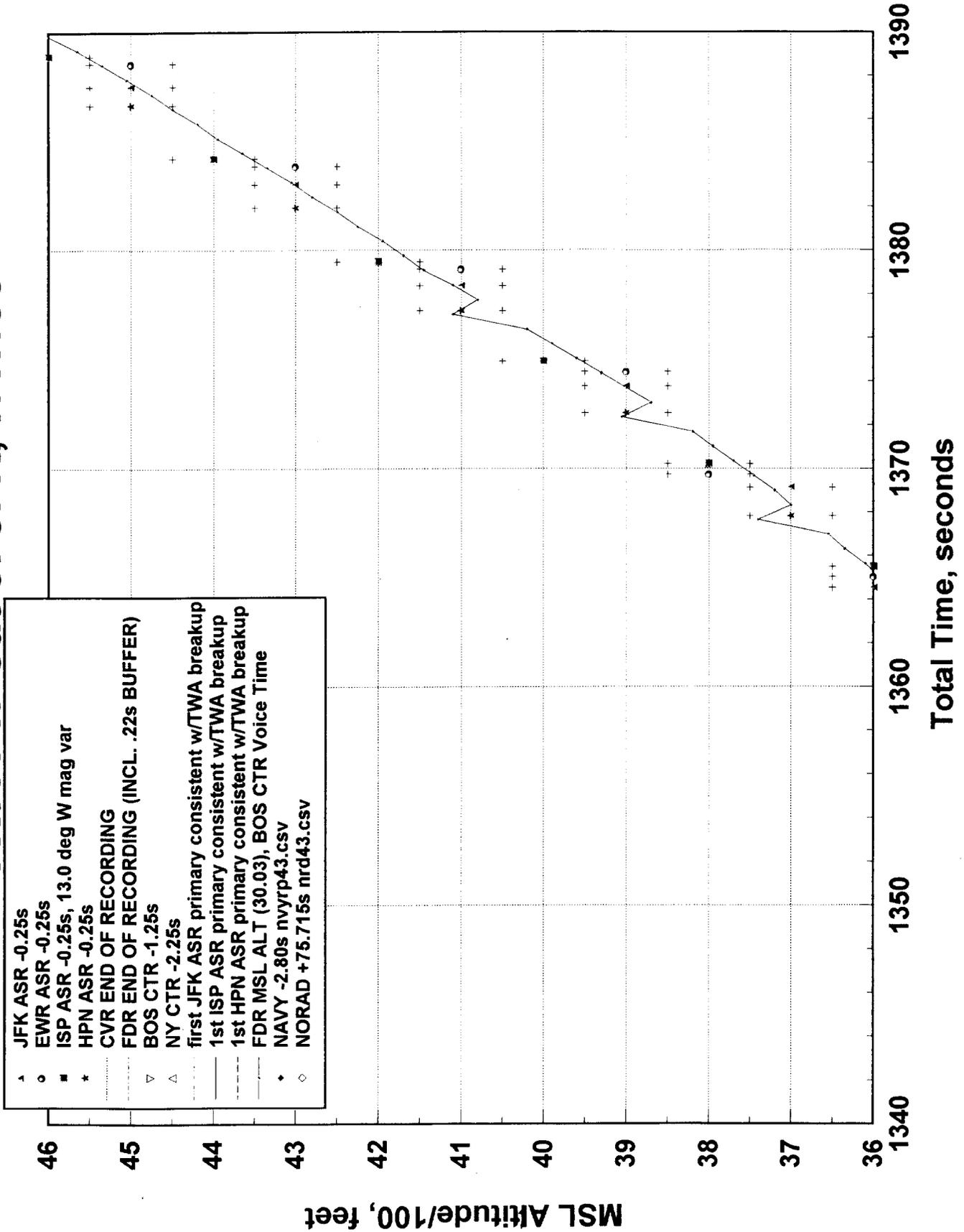
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# TWA 747 out of JFK, 7/17/96

ALTT-97.SGX  
 6/10/96



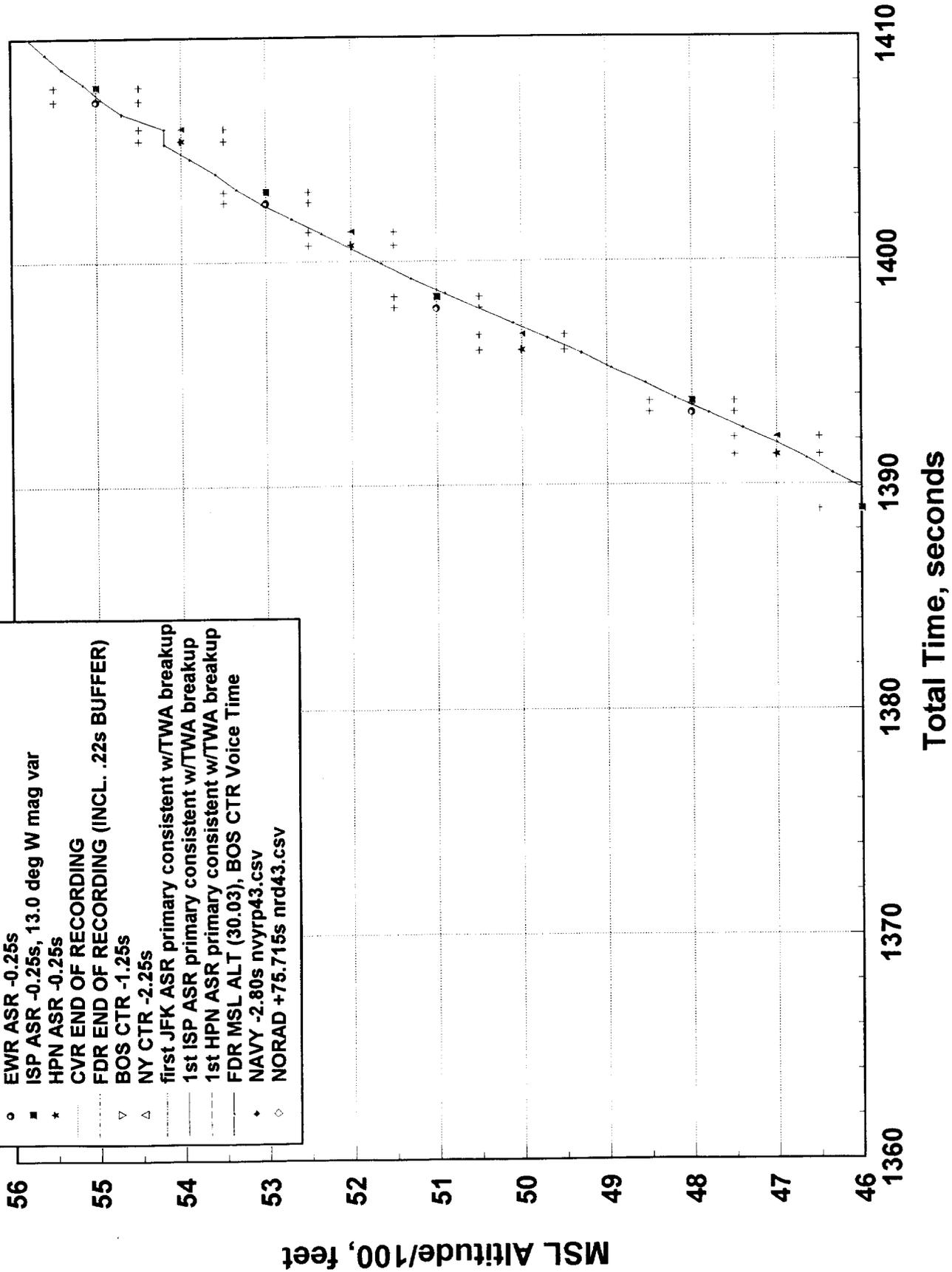
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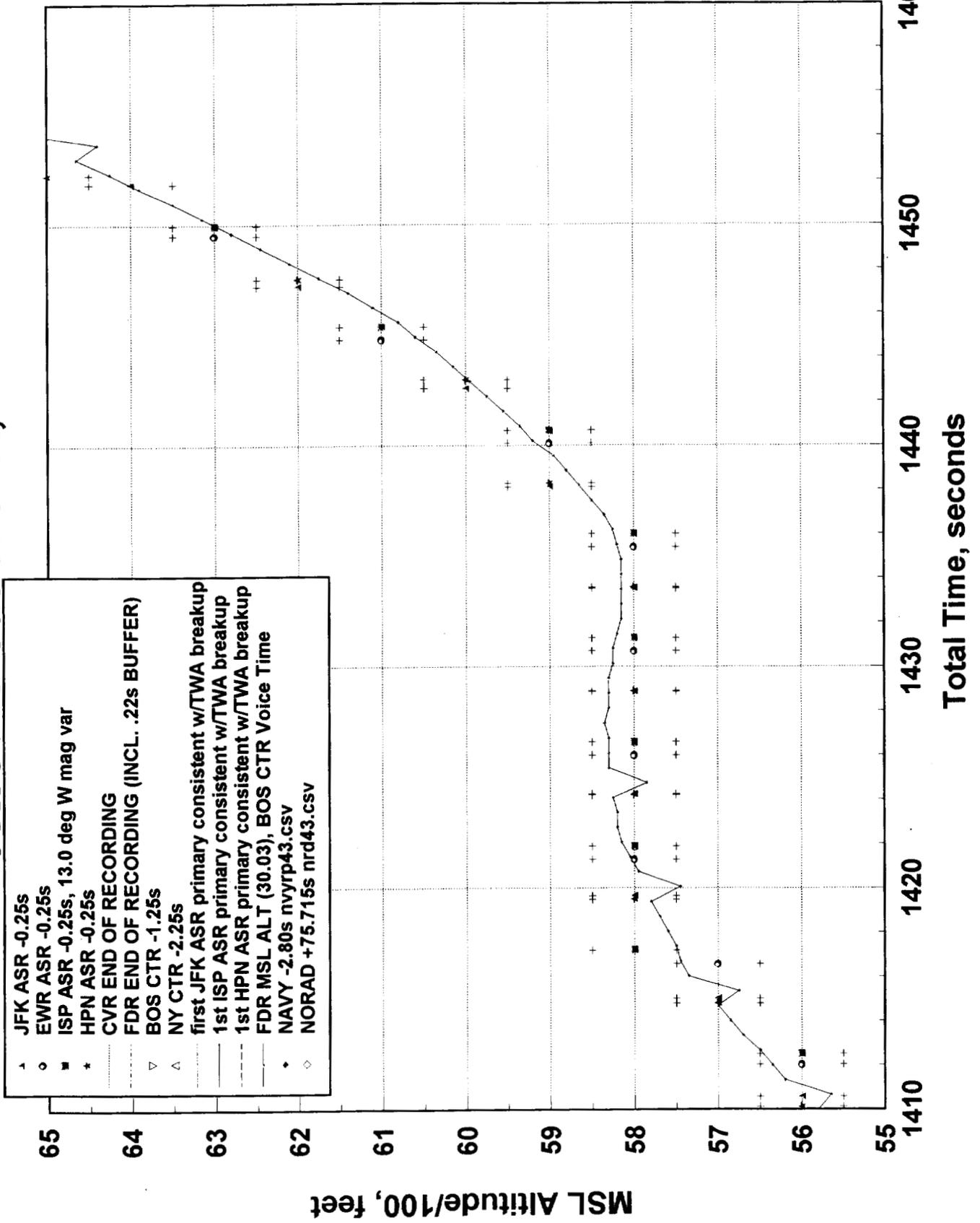
# TWA 747 out of JFK, 7/17/96

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- EWR ASR -0.25s
- ISP ASR -0.25s, 13.0 deg W mag var
- \* HPN ASR -0.25s
- ..... CVR END OF RECORDING
- FDR END OF RECORDING (INCL. .22s BUFFER)
- ▽ BOS CTR -1.25s
- △ NY CTR -2.25s
- ..... first JFK ASR primary consistent w/TWA breakup
- 1st ISP ASR primary consistent w/TWA breakup
- 1st HPN ASR primary consistent w/TWA breakup
- FDR MSL ALT (30.03), BOS CTR Voice Time
- ◆ NAVY -2.80s nvyrp43.csv
- ◇ NORAD +75.715s nrd43.csv



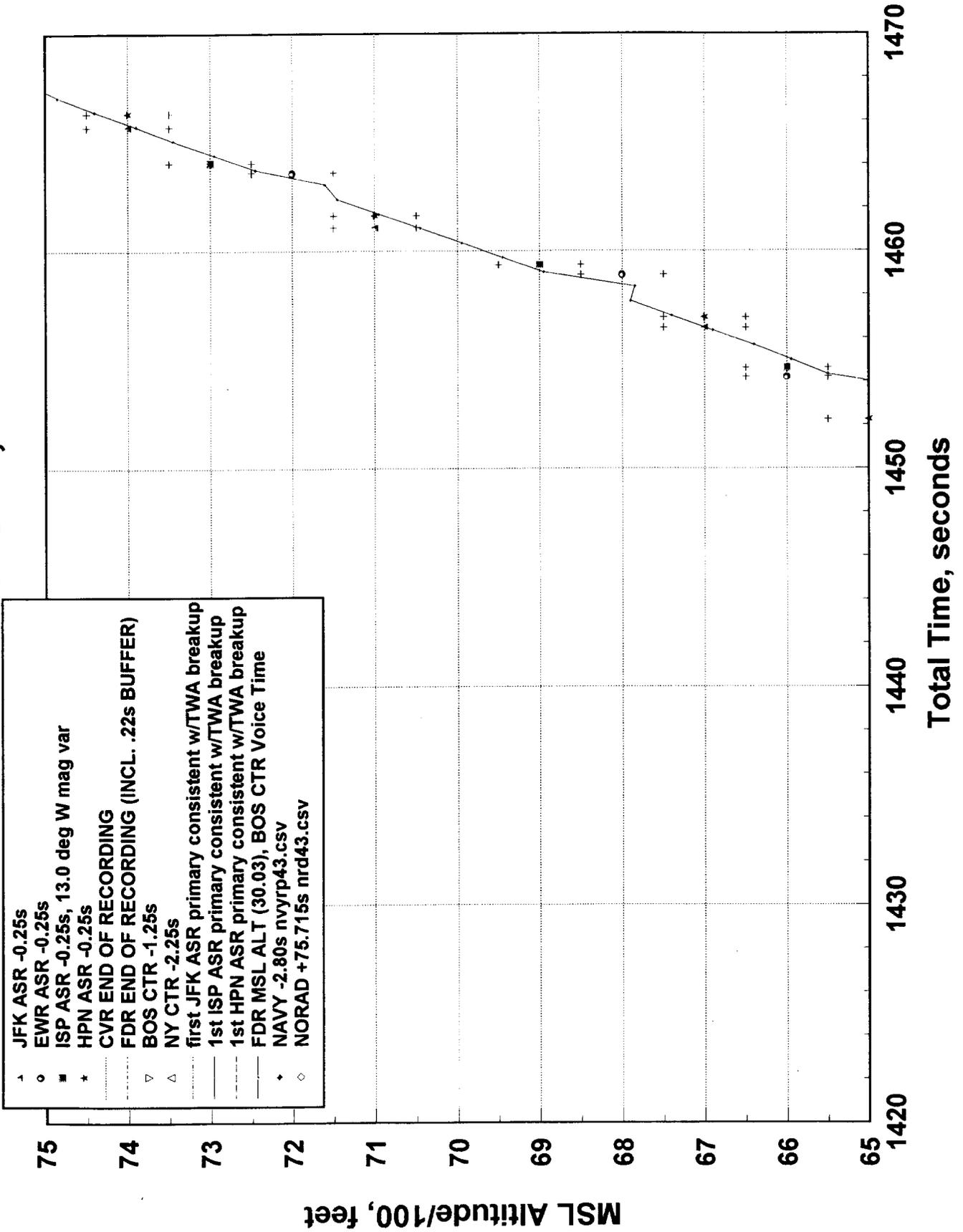
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# TWA 747 out of JFK, 7/17/96



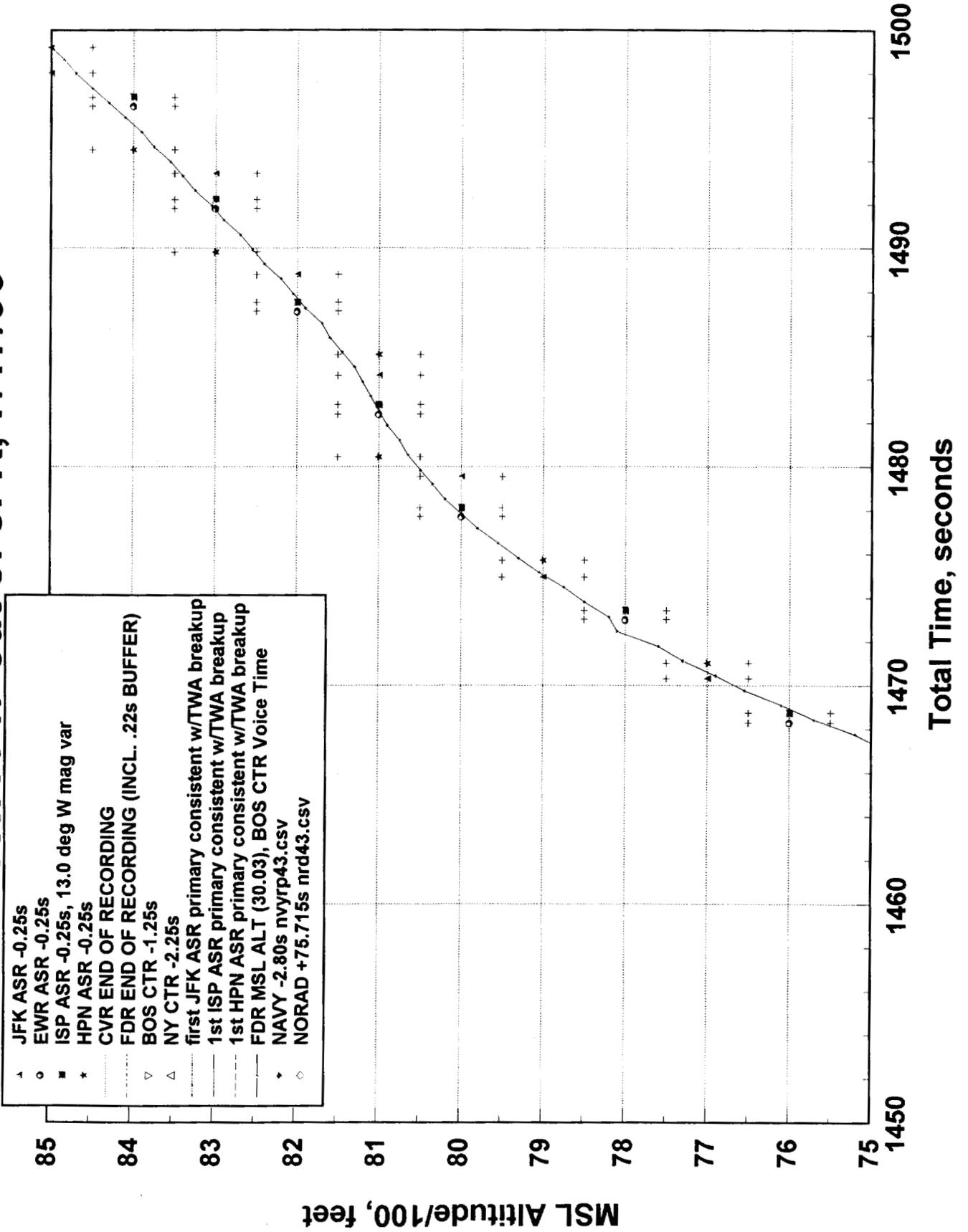
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# TWA 747 out of JFK, 7/17/96



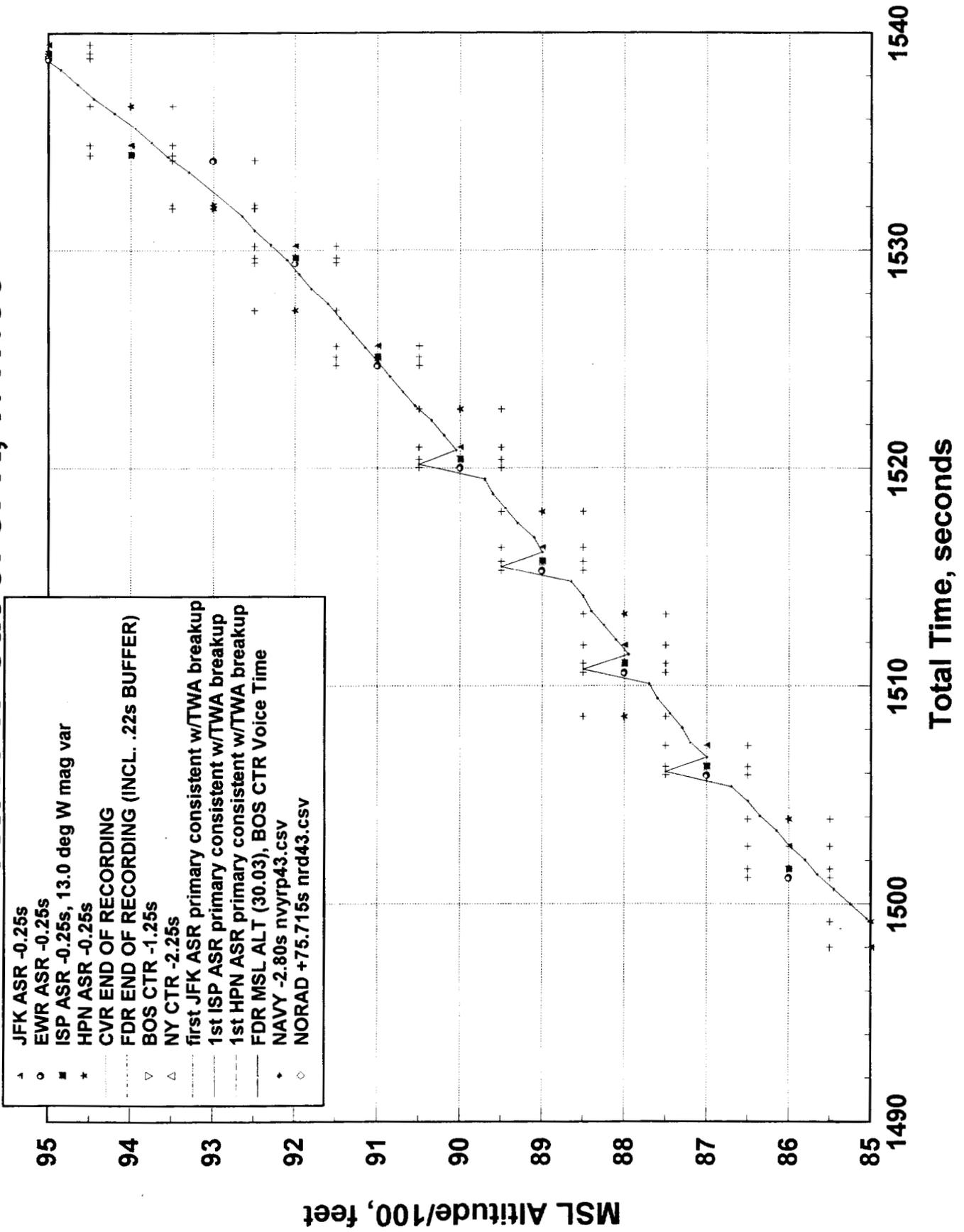
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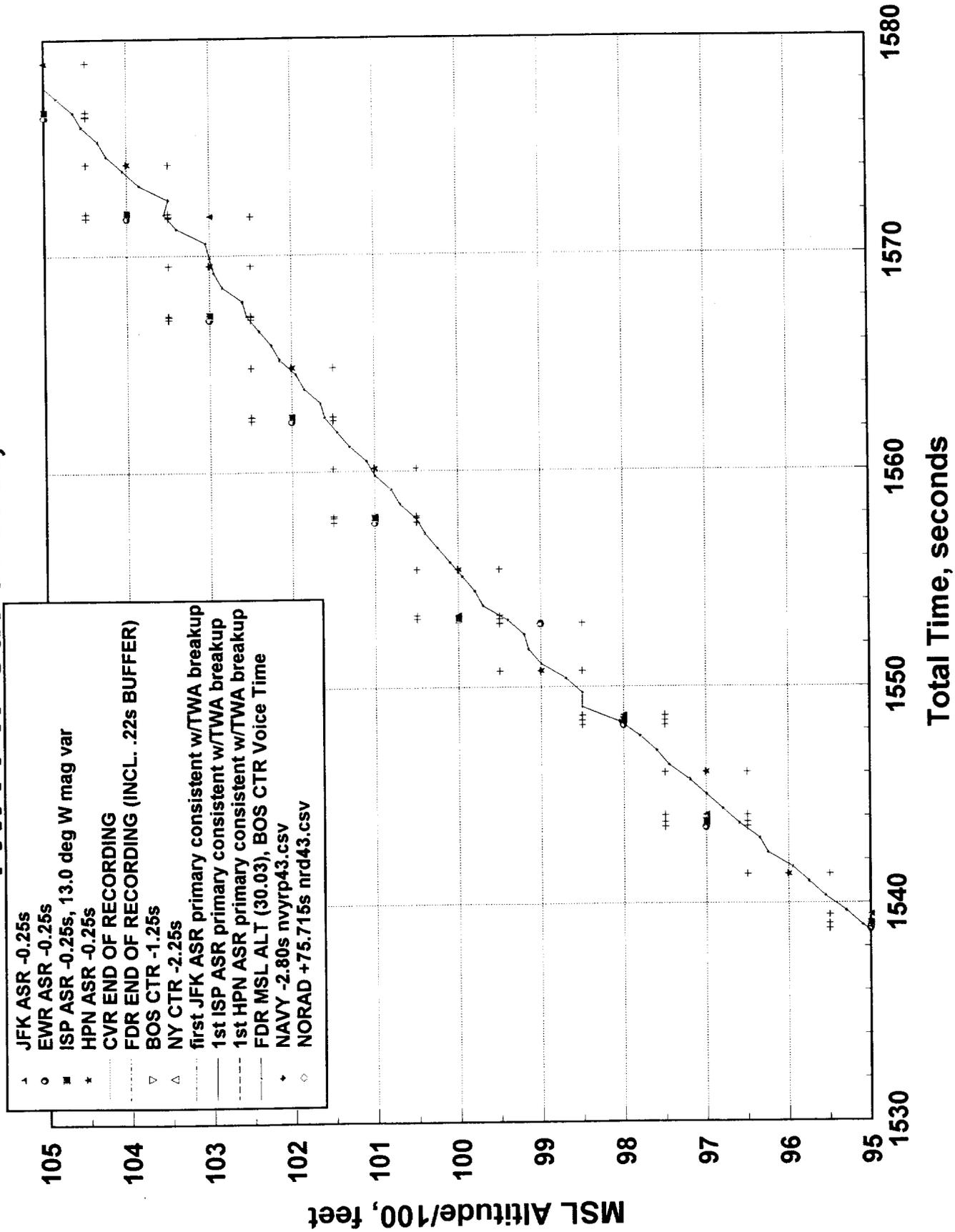
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# TWA 747 out of JFK, 7/17/96



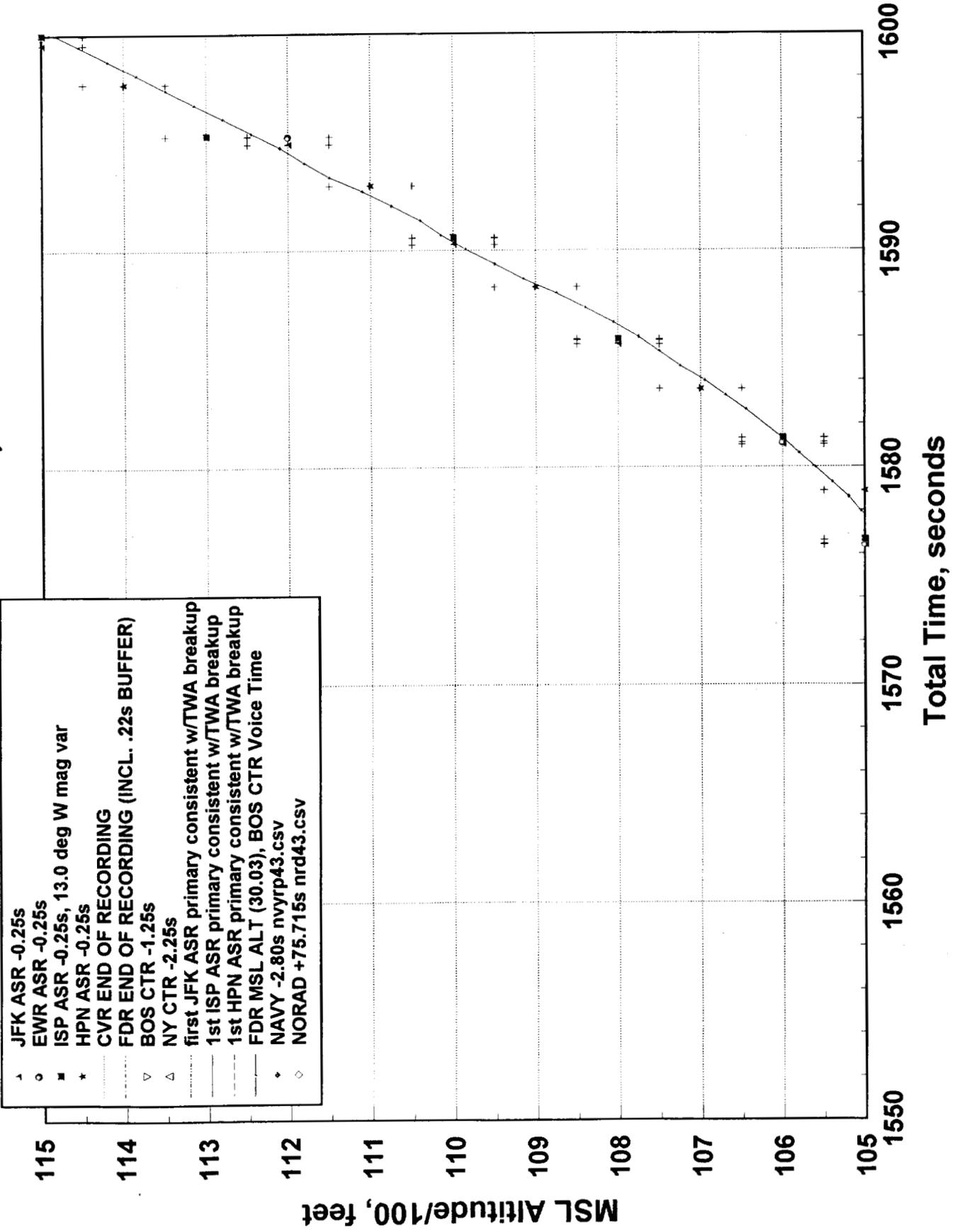
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# TWA 747 out of JFK, 7/17/96



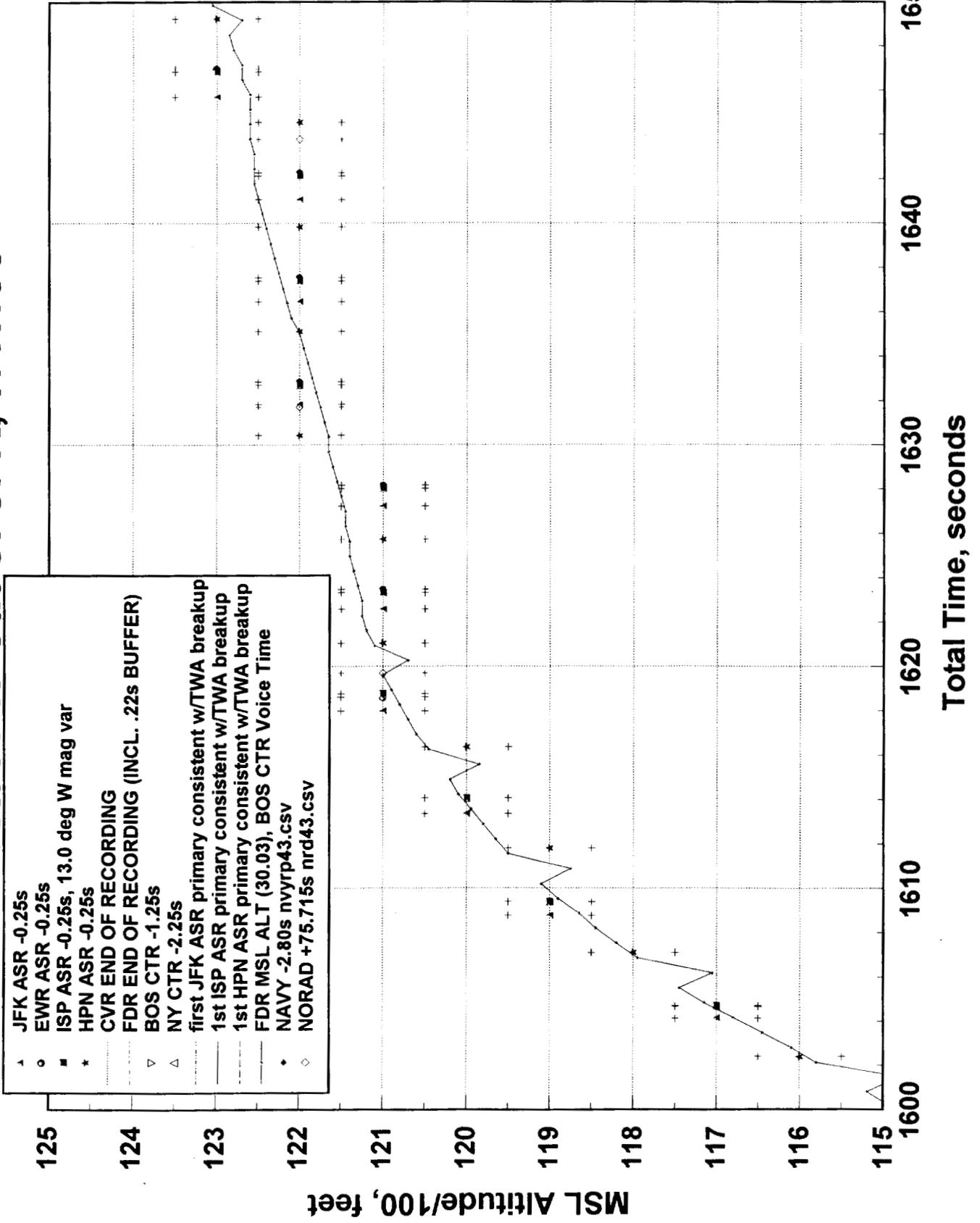
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# TWA 747 out of JFK, 7/17/96



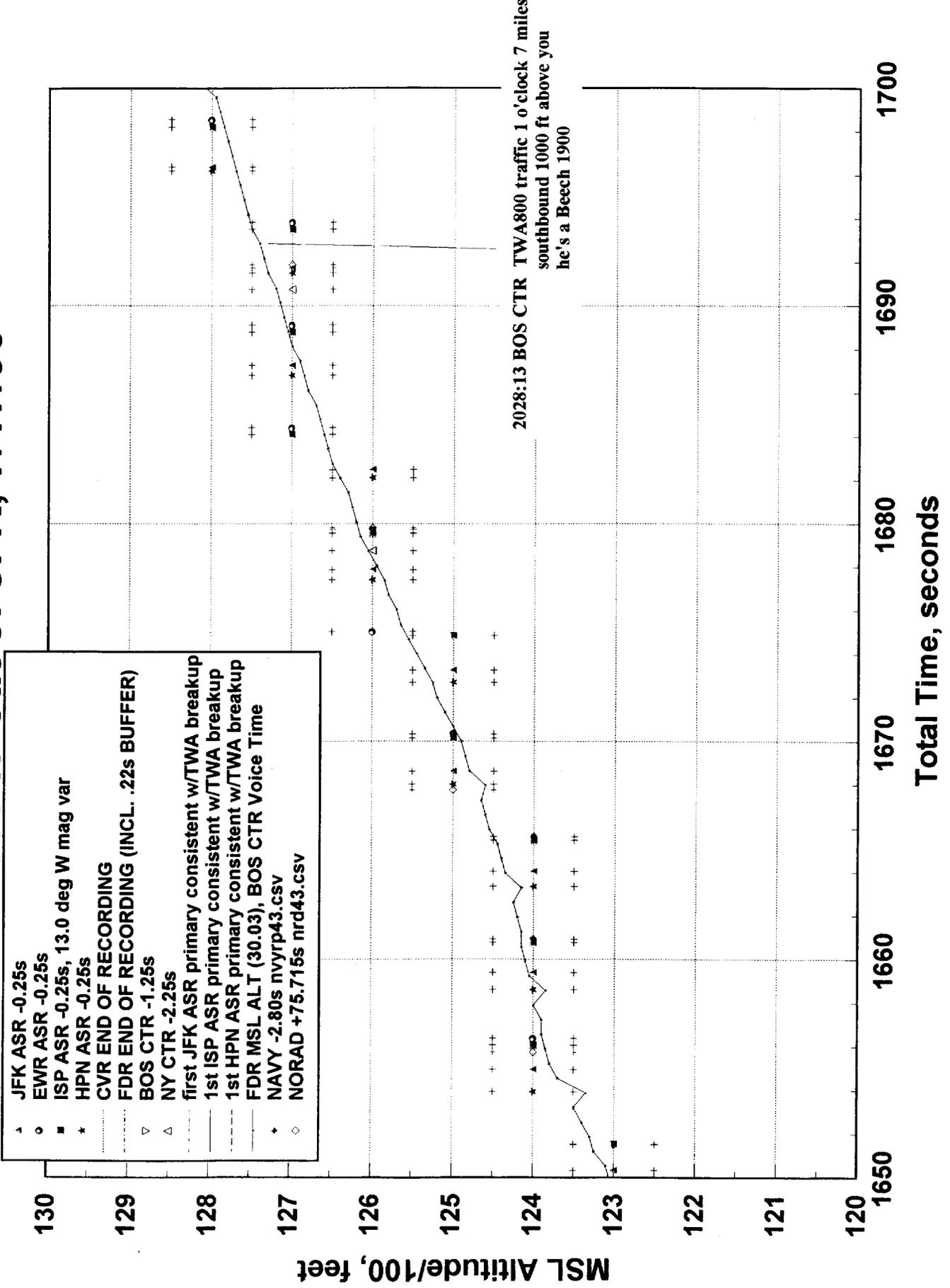
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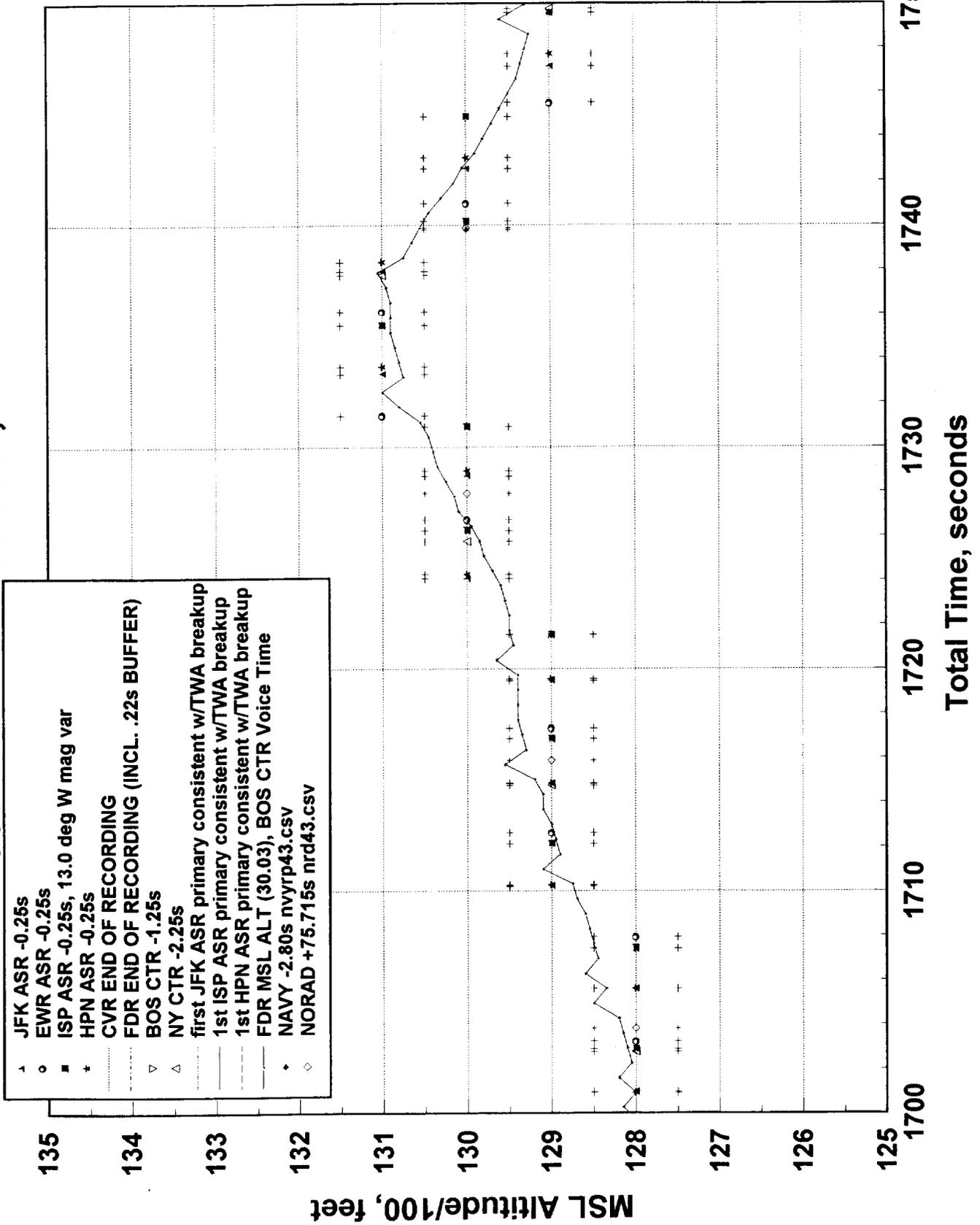
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SLIDE 7

# TWA 747 out of JFK, 7/17/96



ATT-97.SGX  
SLIDE-6

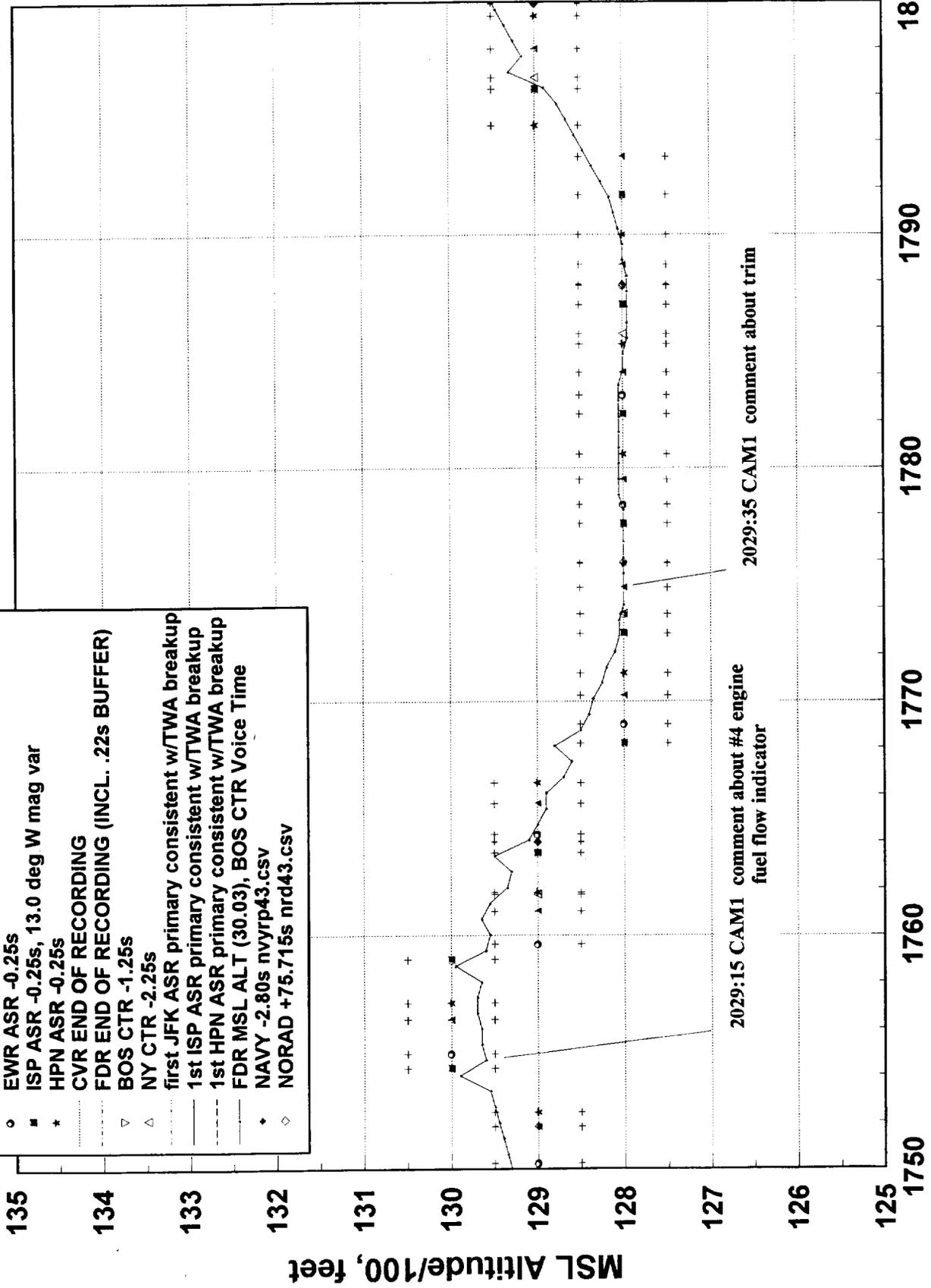
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AZTE 97-SGX  
SLIDE 5

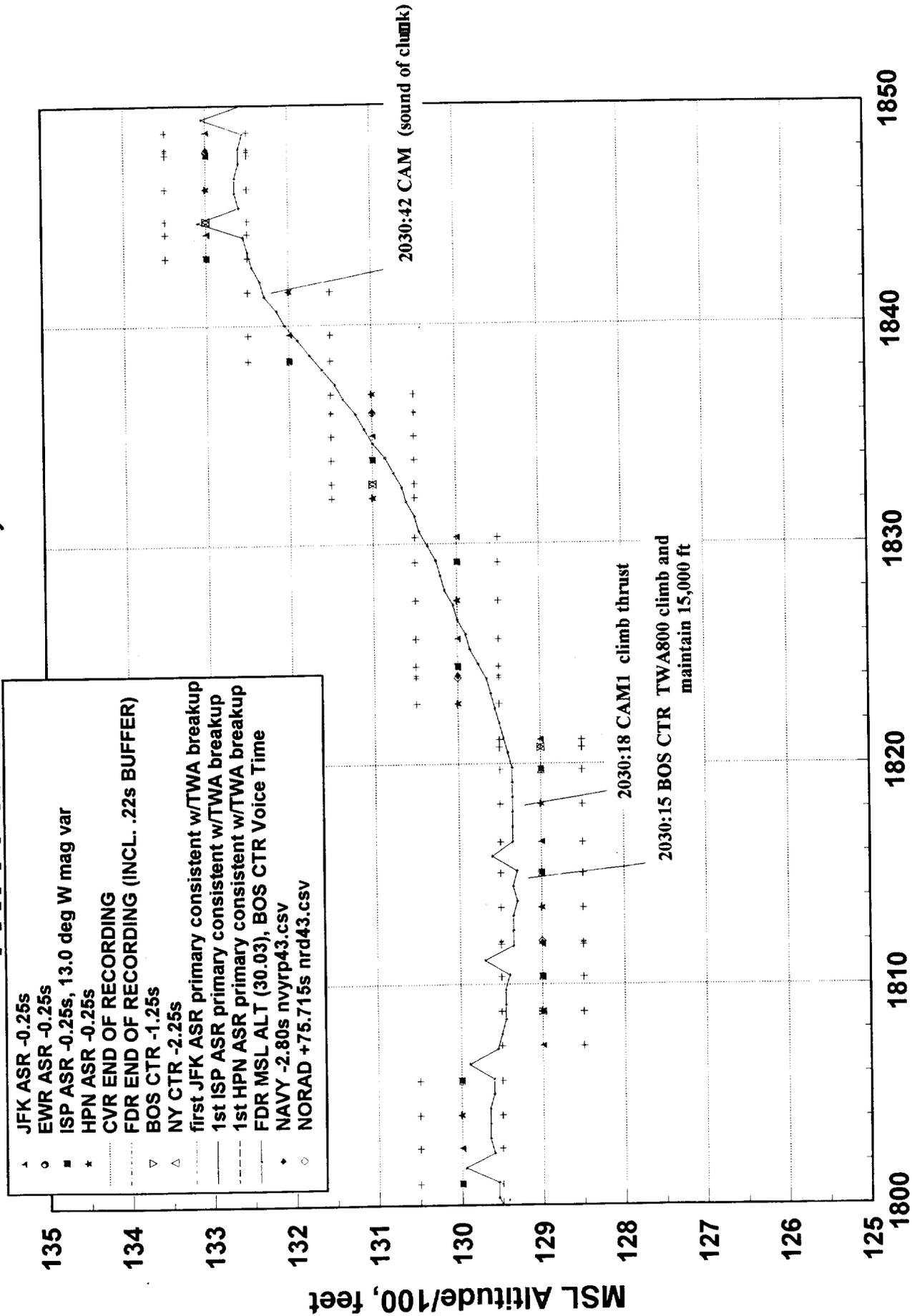
# TWA 747 out of JFK, 7/17/96

- ▲ JFK ASR -0.25s
- EWR ASR -0.25s
- ISP ASR -0.25s, 13.0 deg W mag var
- \* HPN ASR -0.25s
- ⋯ CVR END OF RECORDING
- ⋯ FDR END OF RECORDING (INCL. .22s BUFFER)
- ▽ BOS CTR -1.25s
- △ NY CTR -2.25s
- ⋯ first JFK ASR primary consistent w/TWA breakup
- ⋯ 1st ISP ASR primary consistent w/TWA breakup
- ⋯ 1st HPN ASR primary consistent w/TWA breakup
- ⋯ FDR MSL ALT (30.03), BOS CTR Voice Time
- ♦ NAVY -2.80s nvyrp43.csv
- ◇ NORAD +75.715s nrd43.csv



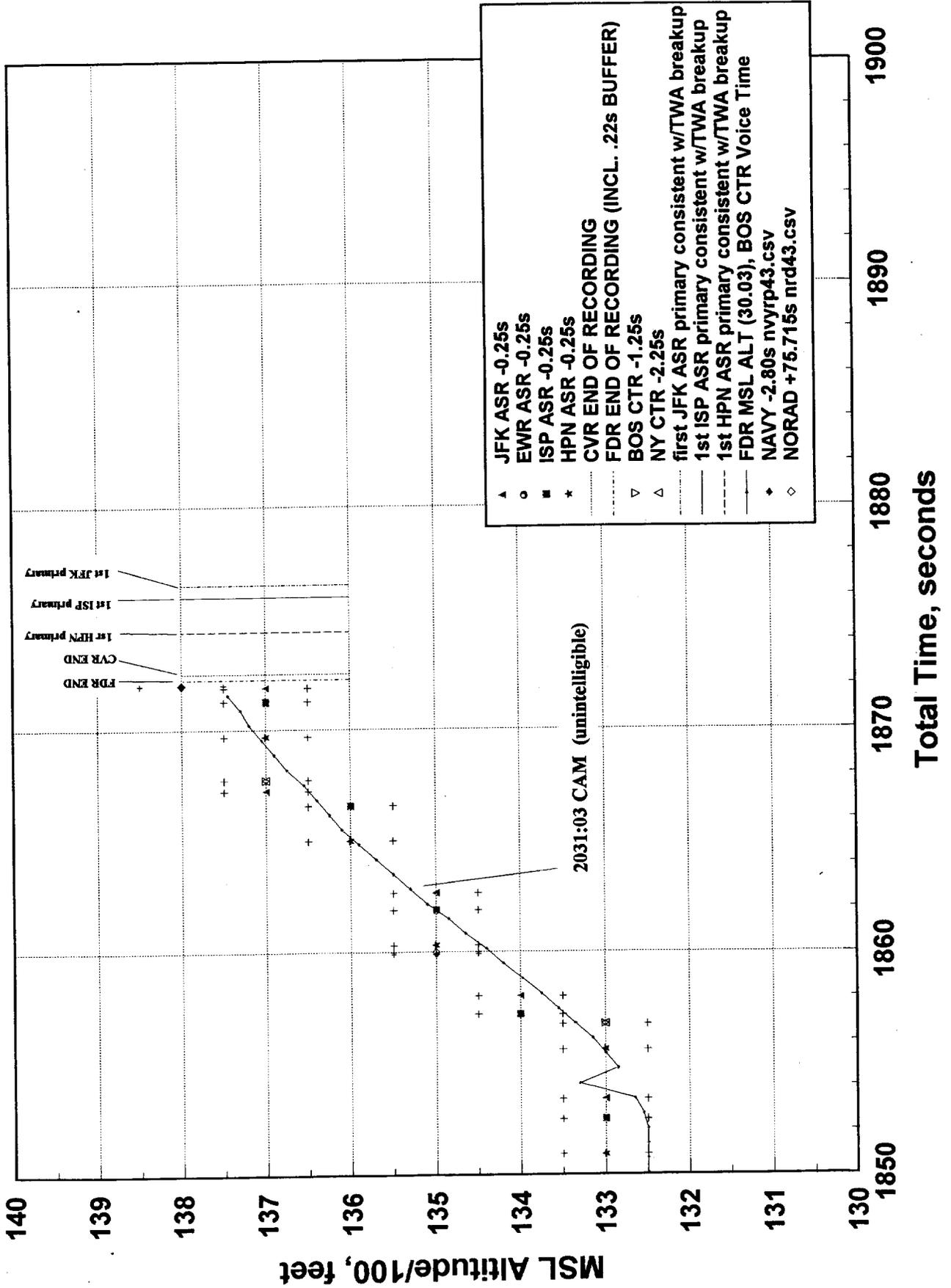
Total Time, seconds

# TWA 747 out of JFK, 7/17/96

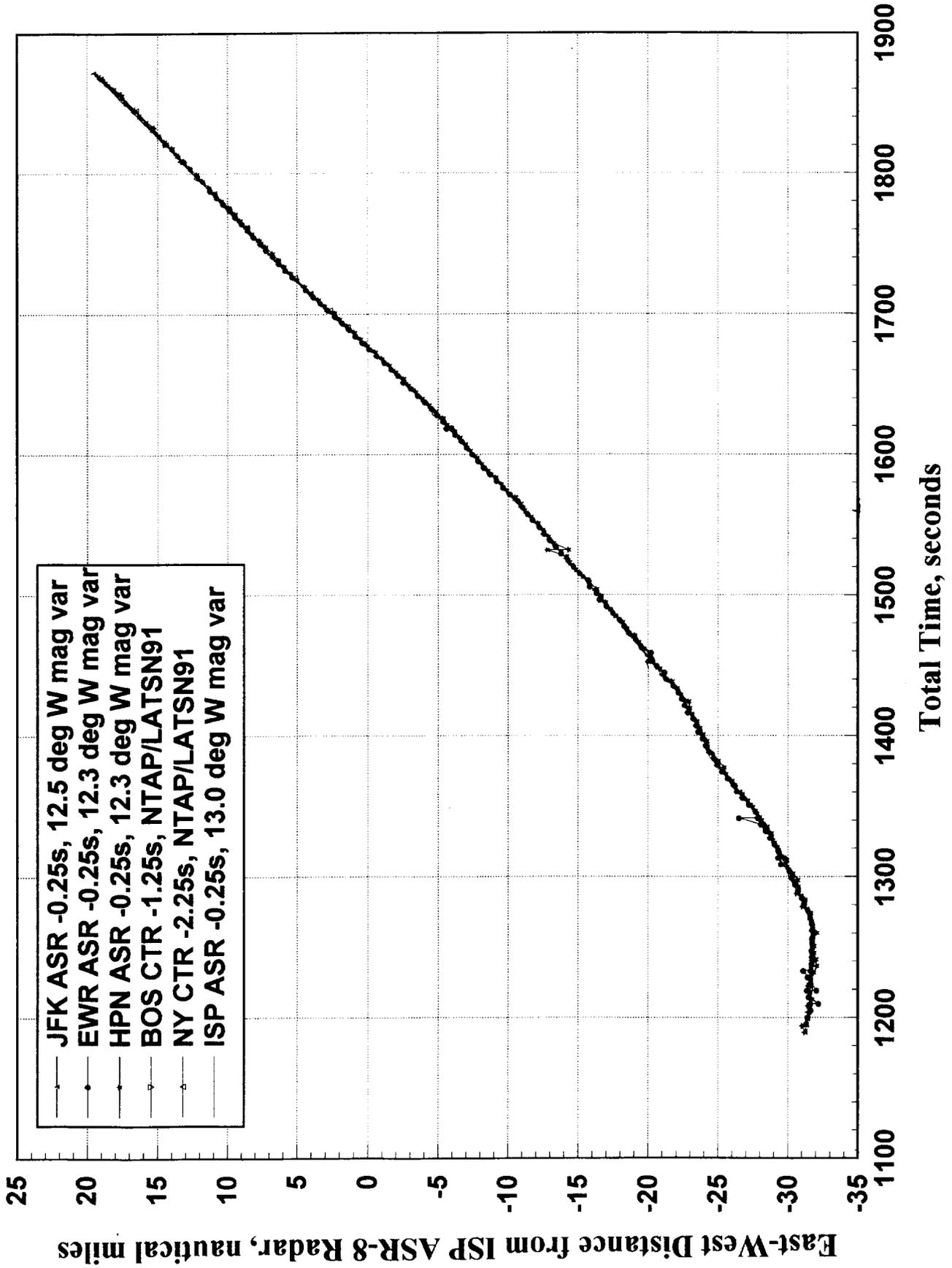


ATT-97.56X  
SIDE 3

# TWA 747 out of JFK, 7/17/96

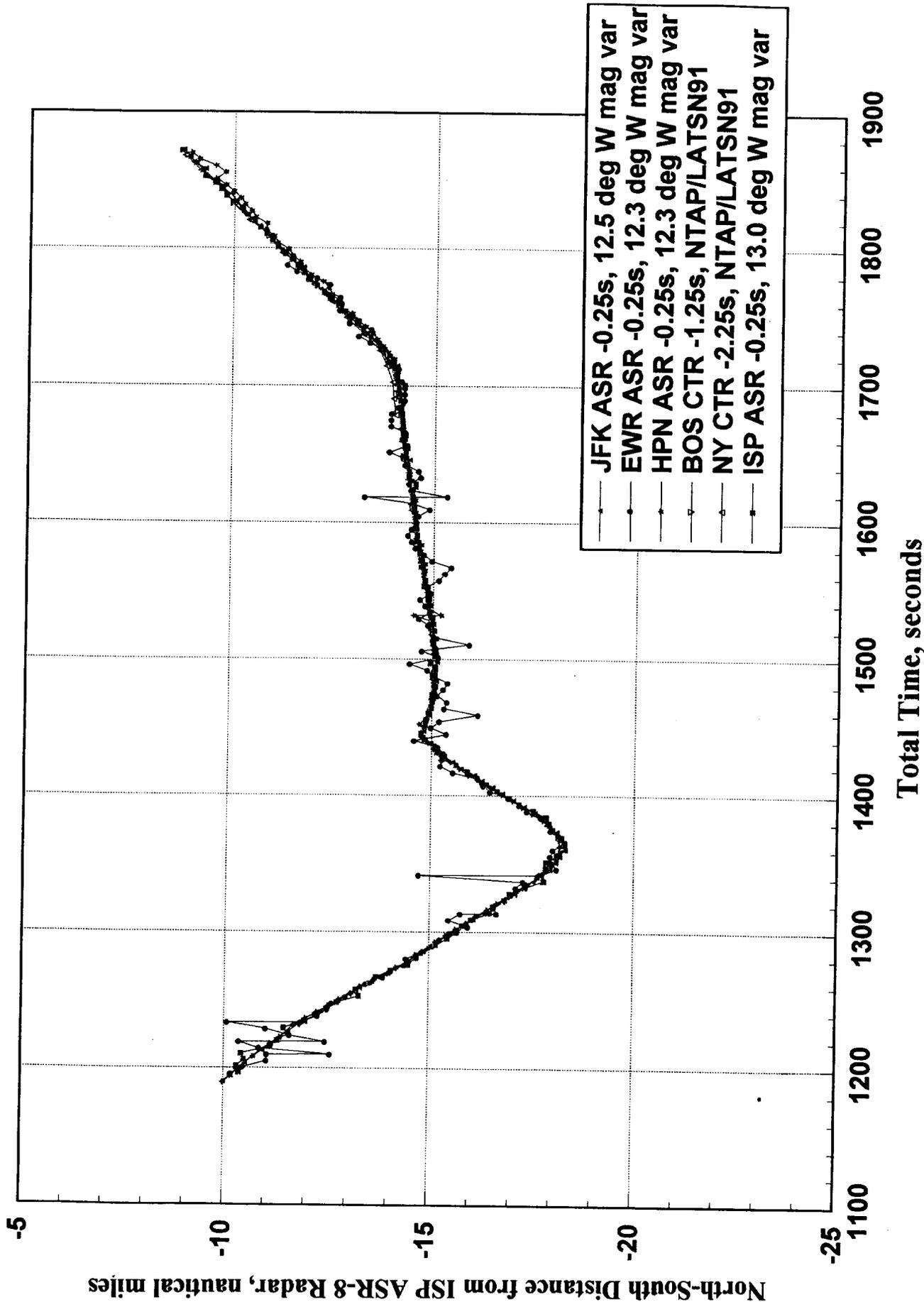


# TWA 747 Out Of JFK, 7/17/96



AZTT=97.56X  
 S.110E 7.1

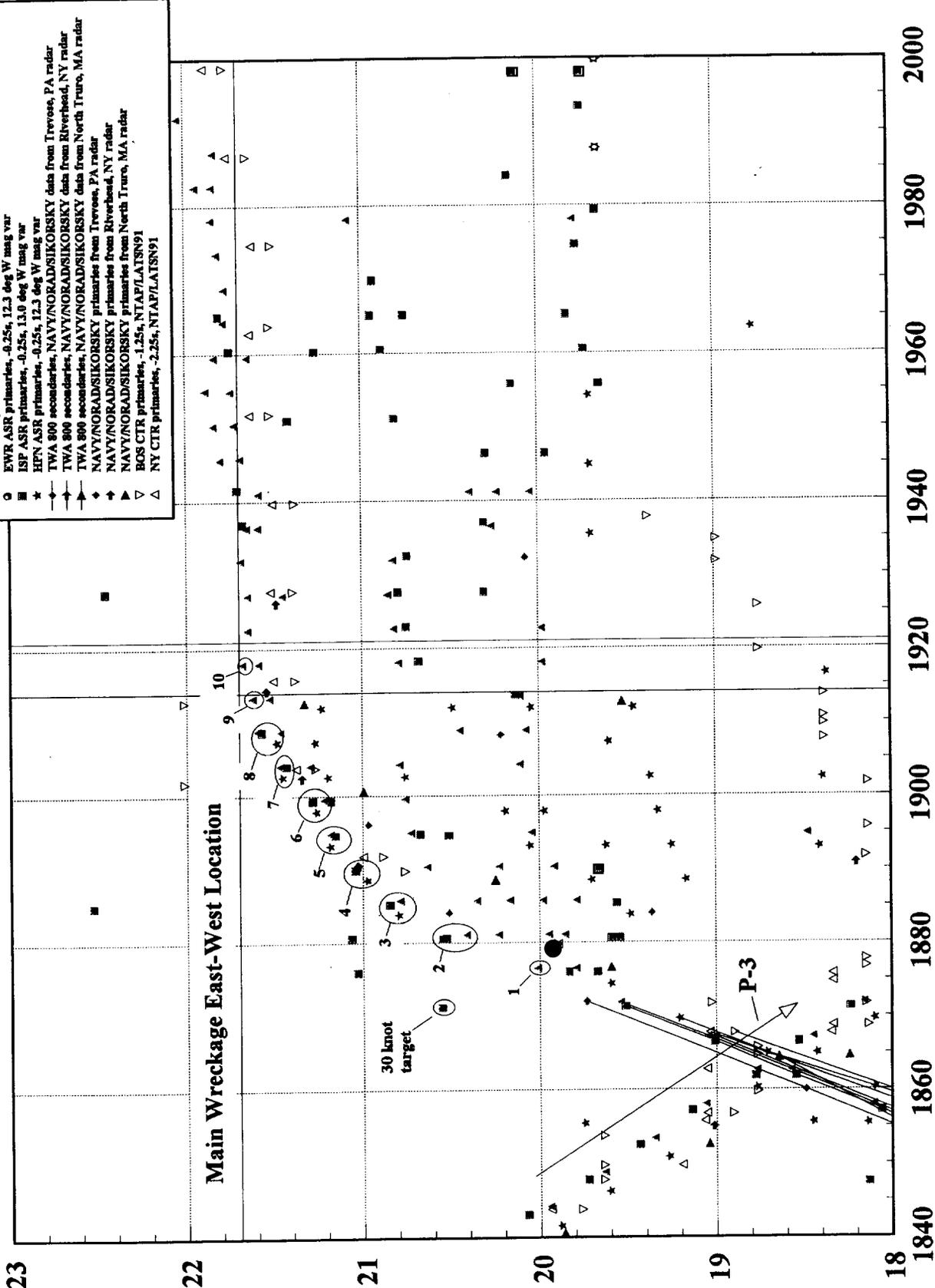
# TWA 747 Out Of JFK, 7/17/96



22

AZTT-97, 5G-X  
SL10E22

**TWA 747 Out of JFK, July 17, 1996  
 FAA Radar Data From NYTRACON, NYCTR, and BOSCTR**



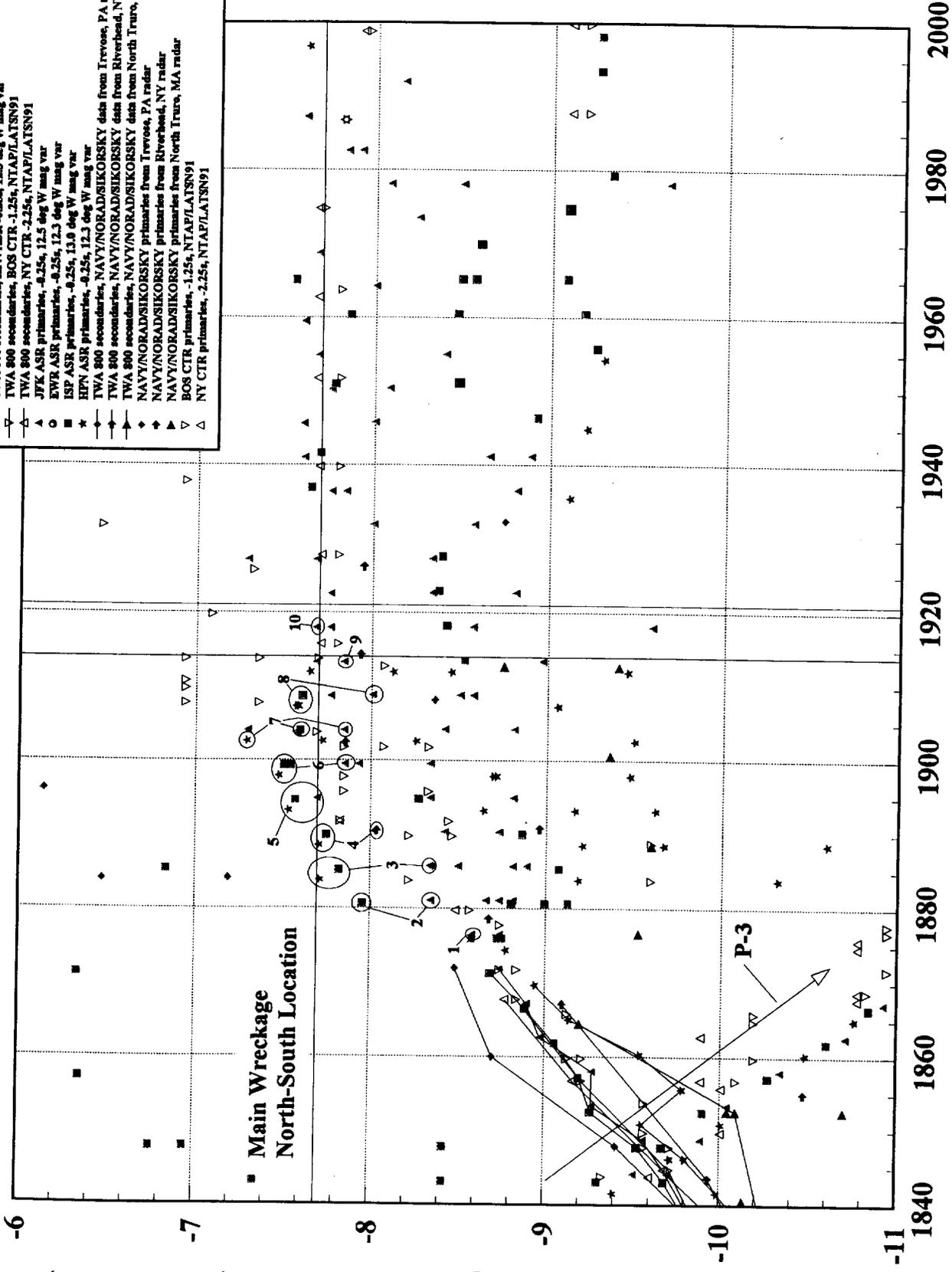
- ▲ TWA 800 secondaries, JFK ASR -0.25s, 12.5 deg W mag var
- TWA 800 secondaries, EWR ASR -0.25s, 12.3 deg W mag var
- △ TWA 800 secondaries, ISP ASR -0.25s, 13.0 deg W mag var
- ★ TWA 800 secondaries, HFN ASR -0.25s, 12.3 deg W mag var
- ▽ TWA 800 secondaries, BOS CTR -1.25s, NTAP/LATS/N91
- △ TWA 800 secondaries, NY CTR -2.25s, NTAP/LATS/N91
- ▲ JFK ASR primaries, -0.25s, 12.5 deg W mag var
- EWR ASR primaries, -0.25s, 12.3 deg W mag var
- △ ISP ASR primaries, -0.25s, 13.0 deg W mag var
- ★ HFN ASR primaries, -0.25s, 12.3 deg W mag var
- ▽ TWA 800 secondaries, NAVY/NORAD/SIKORSKY data from Riverhead, NY radar
- ▲ TWA 800 secondaries, NAVY/NORAD/SIKORSKY data from North Truro, MA radar
- NAVY/NORAD/SIKORSKY primaries from Riverhead, NY radar
- ★ NAVY/NORAD/SIKORSKY primaries from North Truro, MA radar
- ▽ BOS CTR primaries, -1.25s, NTAP/LATS/N91
- △ NY CTR primaries, -2.25s, NTAP/LATS/N91

Total Time, seconds

TWAXT-97.56-X  
 SLIDE 1

**TWA 747 Out of JFK, July 17, 1996  
 FAA Radar Data From NYTRACON, NYCTR, and BOSCTR**

North-South Distance From Islip, NY ASR-8 Radar (nautical miles)



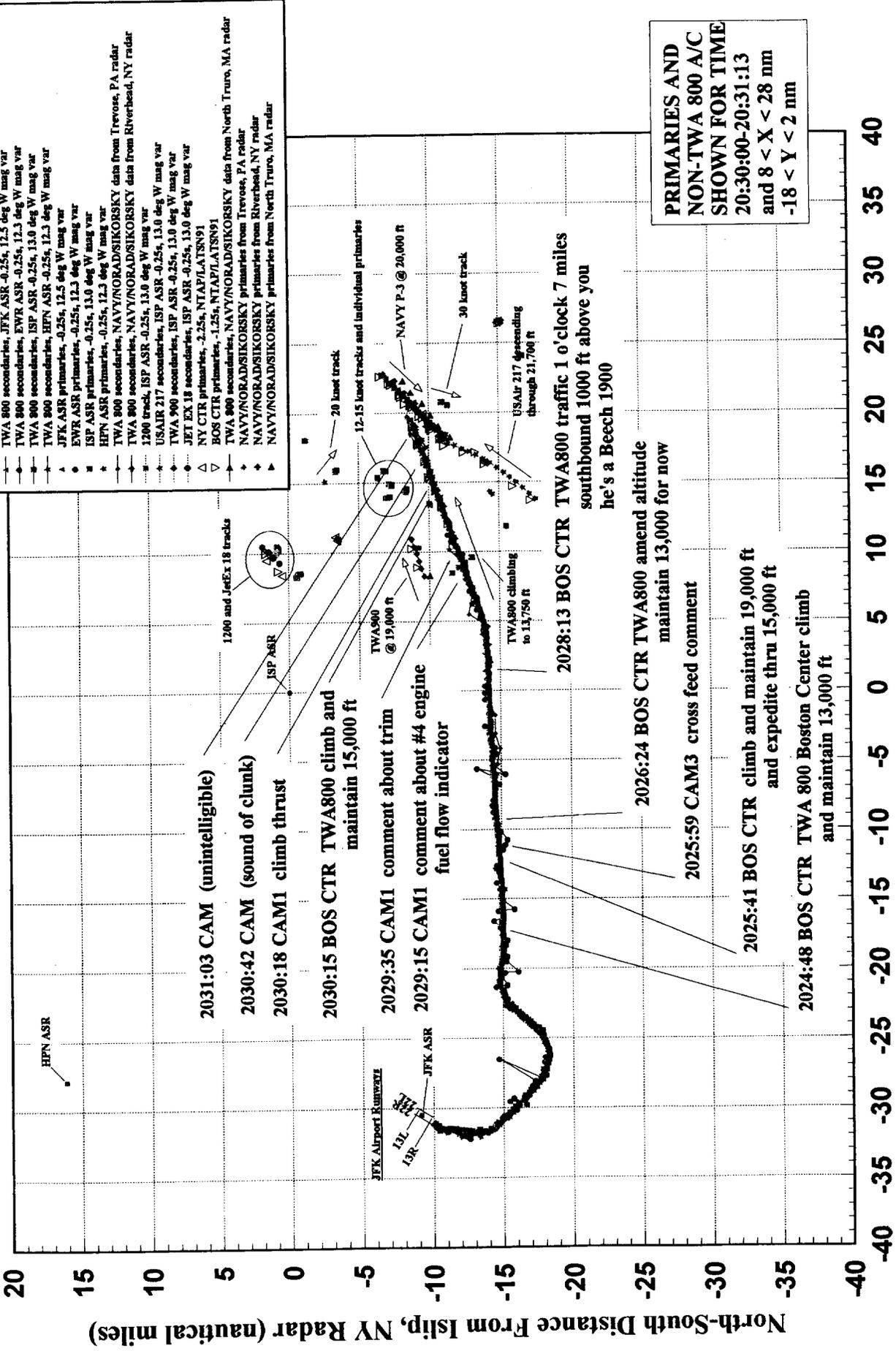
- ★ TWA 800 secondaries, JFK ASR -0.25, 12.5 deg W mag var
- TWA 800 secondaries, EWR ASR -0.25, 12.3 deg W mag var
- TWA 800 secondaries, ISP ASR -0.25, 13.0 deg W mag var
- ▲ TWA 800 secondaries, HPN ASR -0.25, 12.3 deg W mag var
- ▽ TWA 800 secondaries, BOS CTR -1.25, NTAP/LATS91
- △ TWA 800 secondaries, NY CTR -2.25, NTAP/LATS91
- ▲ JFK ASR primaries, -0.25, 12.5 deg W mag var
- EWR ASR primaries, -0.25, 12.3 deg W mag var
- ISP ASR primaries, -0.25, 13.0 deg W mag var
- ▲ HPN ASR primaries, -0.25, 12.3 deg W mag var
- ▽ TWA 800 secondaries, NAVY/NORAD/SIKORSKY data from Riverhead, NY radar
- △ TWA 800 secondaries, NAVY/NORAD/SIKORSKY data from North Truro, MA radar
- ★ NAVY/NORAD/SIKORSKY primaries from Riverhead, NY radar
- NAVY/NORAD/SIKORSKY primaries from North Truro, MA radar
- BOS CTR primaries, -1.25, NTAP/LATS91
- △ NY CTR primaries, -2.25, NTAP/LATS91

TWAXT-97, SGX  
 SLIDE 2

**Attachment IV**

**X versus Y Graphs**

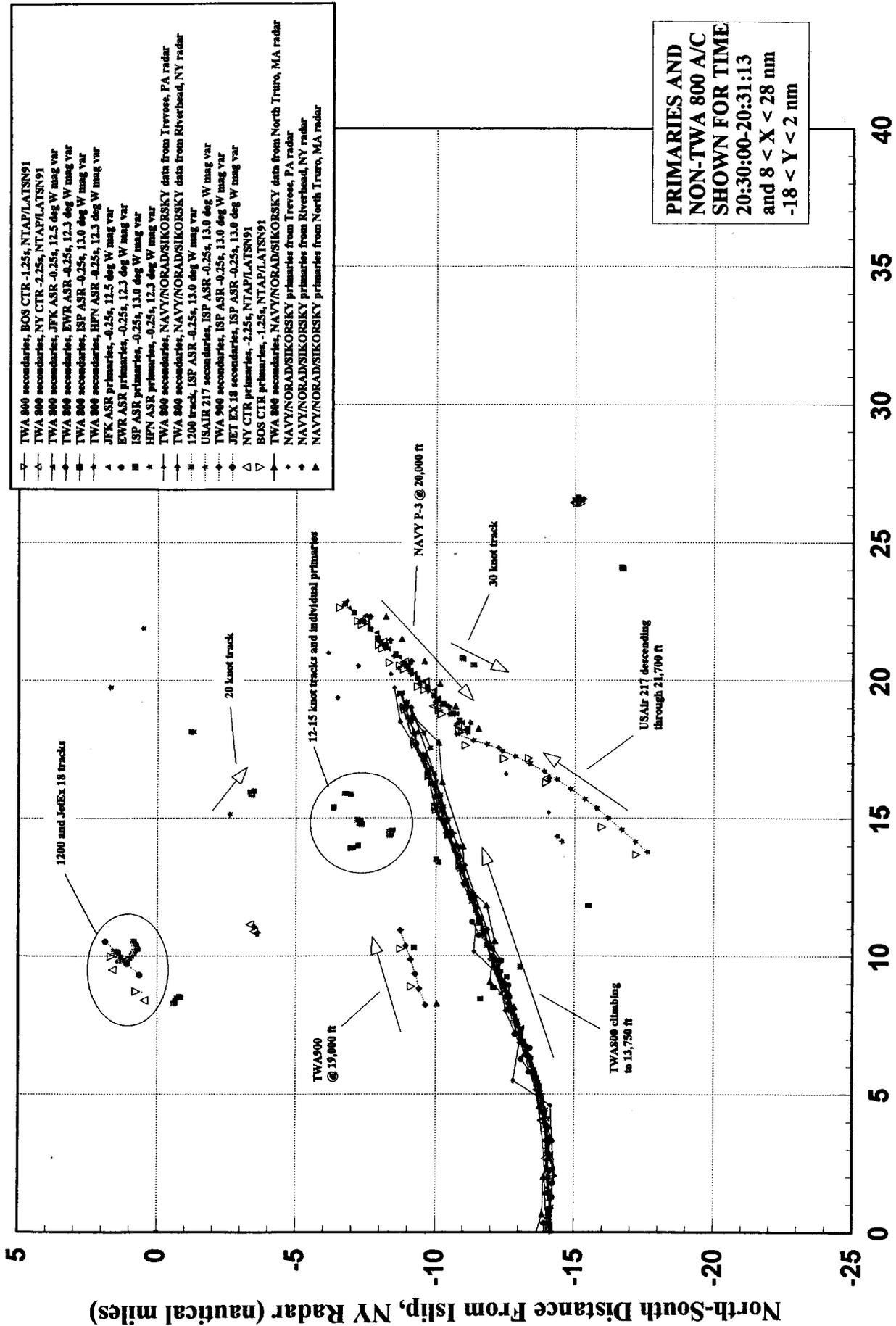
# TWA 747 Out of JFK July 17, 1996 Radar Data Overhead View From Takeoff To Last Secondary



East-West Distance From Islip, NY ASR-8 Radar (nautical miles)

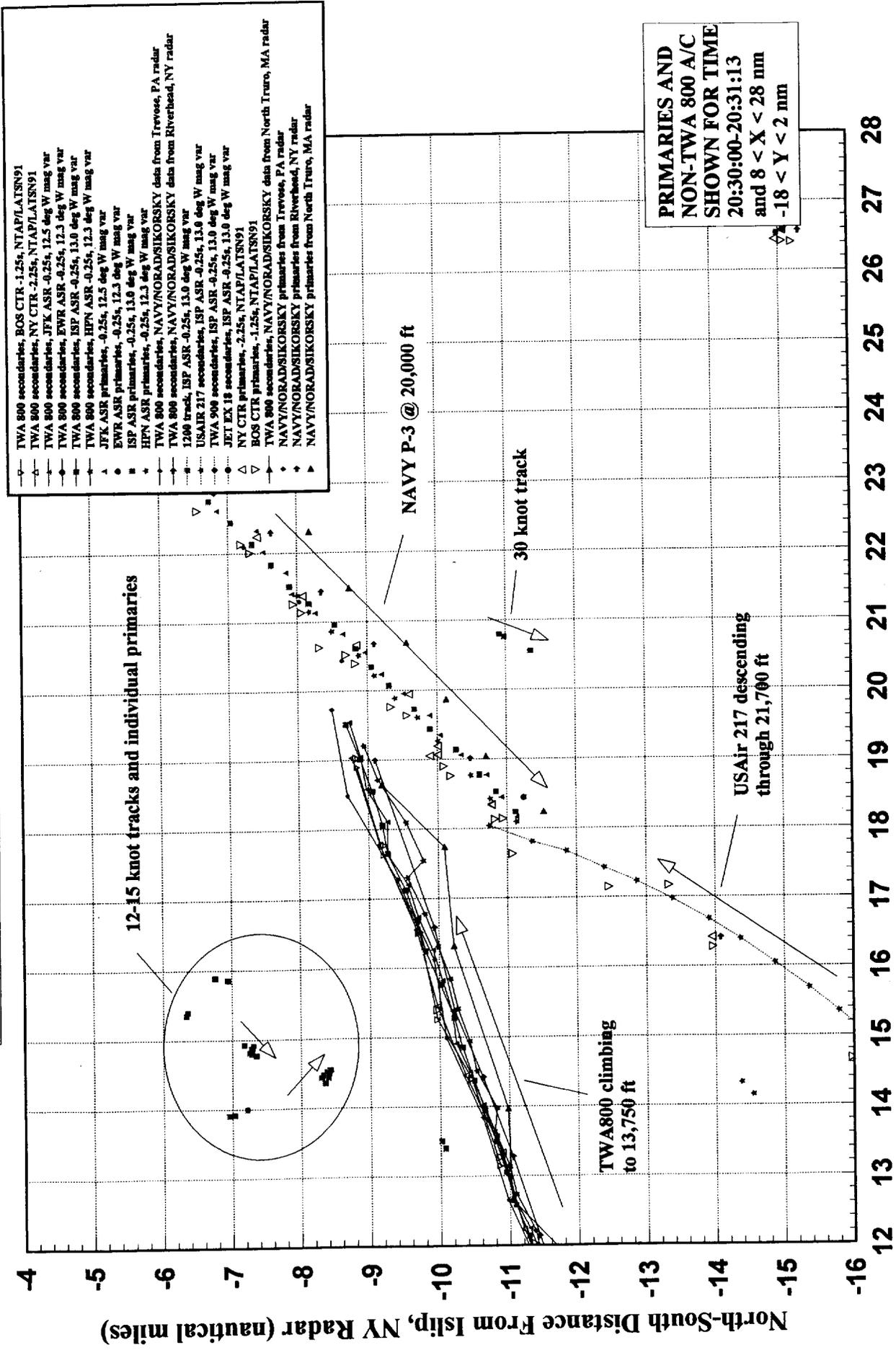
TWAXY.97.SGX  
SLIDE 5

# TWA 747 Out of Control, July 17, 1996 Radar Data Overhead View Up To Last Secondary



TWAX4-97.56X  
SLIDE 6

# TWA 747 Out of Control, July 17, 1996 Radar Data Overhead View Up To Last Secondary



- ▽ TWA 800 secondaries, BOS CTR -1.25, NTAP/LATS91
- △ TWA 800 secondaries, NY CTR -2.25, NTAP/LATS91
- TWA 800 secondaries, JFK ASR -0.25, 12.5 deg W mag var
- TWA 800 secondaries, EWR ASR -0.25, 12.3 deg W mag var
- ◆ TWA 800 secondaries, ISP ASR -0.25, 13.0 deg W mag var
- ▲ TWA 800 secondaries, HFN ASR -0.25, 12.3 deg W mag var
- JFK ASR primaries, -0.25, 12.5 deg W mag var
- EWR ASR primaries, -0.25, 12.3 deg W mag var
- ISP ASR primaries, -0.25, 13.0 deg W mag var
- HFN ASR primaries, -0.25, 12.3 deg W mag var
- TWA 800 secondaries, NAVY/NORAD/SIKORSKY data from Riverhead, NY radar
- TWA 800 secondaries, ISP ASR -0.25, 13.0 deg W mag var
- USAir 217 secondaries, ISP ASR -0.25, 13.0 deg W mag var
- JET EX 18 secondaries, ISP ASR -0.25, 13.0 deg W mag var
- NY CTR primaries, -2.25, NTAP/LATS91
- ▽ BOS CTR primaries, -1.25, NTAP/LATS91
- △ TWA 800 secondaries, NAVY/NORAD/SIKORSKY data from North Truro, MA radar
- NAVY/NORAD/SIKORSKY primaries from Riverhead, NY radar
- NAVY/NORAD/SIKORSKY primaries from North Truro, MA radar

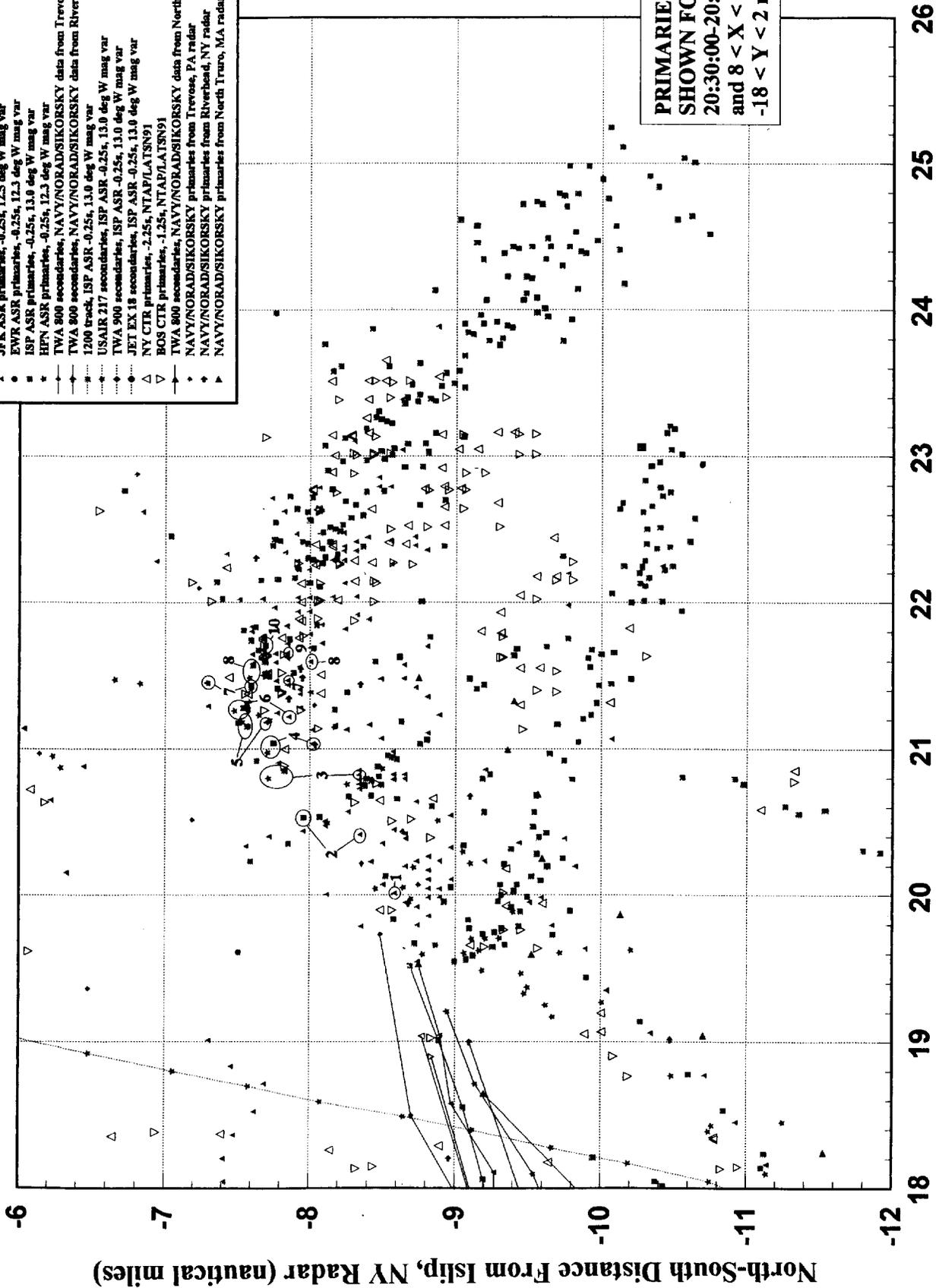
**PRIMARIES AND NON-TWA 800 A/C SHOWN FOR TIME 20:30:00-20:31:13 and 8 < X < 28 nm and -18 < Y < 2 nm**

East-West Distance From Isip, NY ASR-8 Radar (nautical miles)

TWAXY-97-SGX  
SLIDE 7

# IWA 747 Out of JFK, July 17, 1996

## Radar Data Overhead View Up To Last Secondary



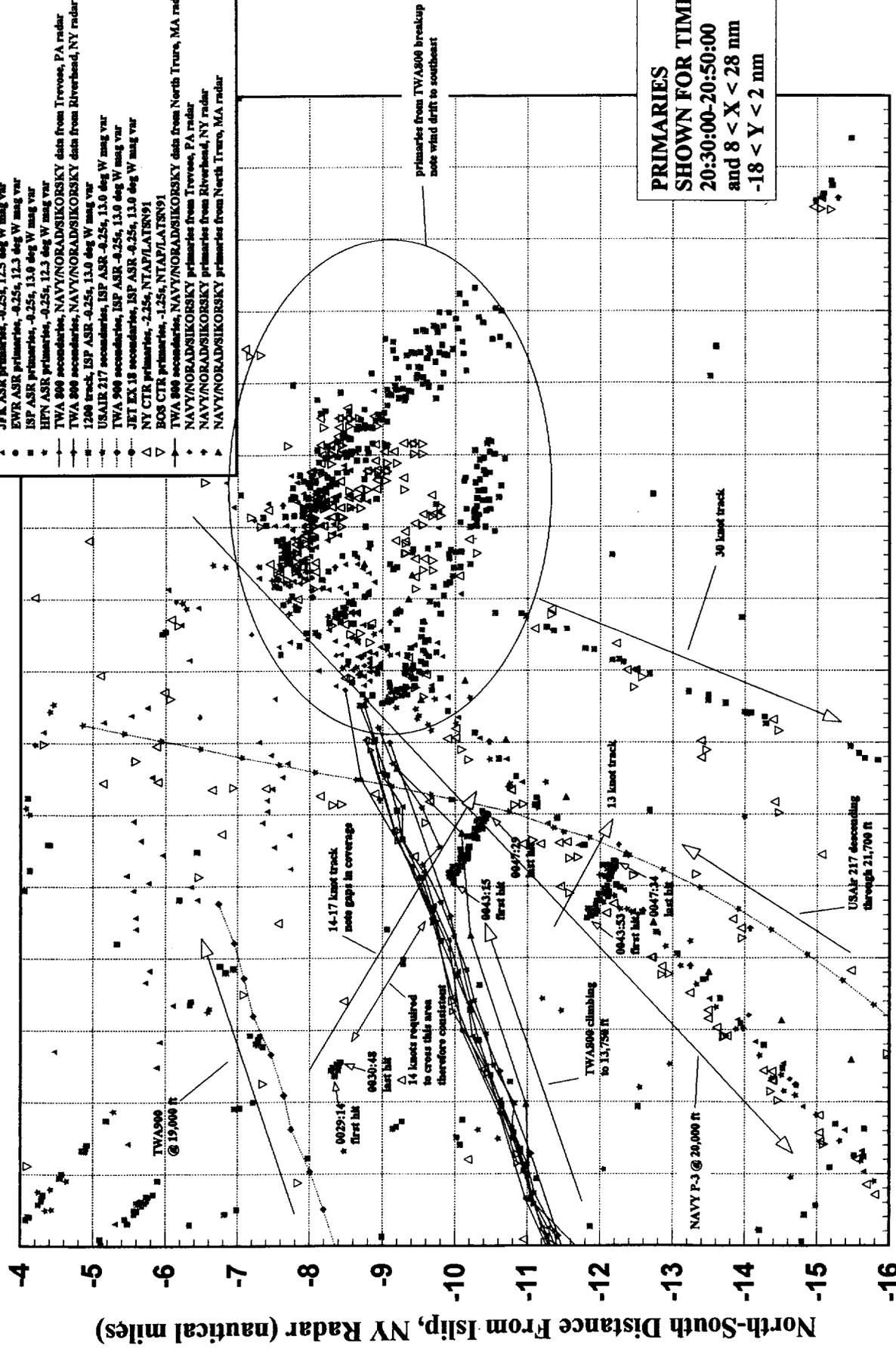
- ▽ TWA 800 secondaries, BOS CTR -1.25, NTAP/LATS91
- △ TWA 800 secondaries, NY CTR -2.25, NTAP/LATS91
- TWA 800 secondaries, JFK ASR -0.25, 12.5 deg W mag var
- TWA 800 secondaries, EWR ASR -0.25, 12.5 deg W mag var
- ◆ TWA 800 secondaries, ISP ASR -0.25, 13.0 deg W mag var
- ▲ TWA 800 secondaries, HPN ASR -0.25, 12.3 deg W mag var
- △ JFK ASR primaries, -0.25, 12.5 deg W mag var
- EWR ASR primaries, -0.25, 12.3 deg W mag var
- ◆ ISP ASR primaries, -0.25, 13.0 deg W mag var
- ▲ HPN ASR primaries, -0.25, 12.3 deg W mag var
- ▽ TWA 900 secondaries, NAVY/NORAD/SIKORSKY data from Riverhead, NY radar
- △ TWA 900 secondaries, NAVY/NORAD/SIKORSKY data from North Truro, MA radar
- 1200 track, ISP ASR -0.25, 13.0 deg W mag var
- USAIR 217 secondaries, ISP ASR -0.25, 13.0 deg W mag var
- ◆ TWA 900 secondaries, ISP ASR -0.25, 13.0 deg W mag var
- ▲ JET EX 18 secondaries, ISP ASR -0.25, 13.0 deg W mag var
- △ NY CTR primaries, -2.25, NTAP/LATS91
- ▽ BOS CTR primaries, -1.25, NTAP/LATS91
- NAVY/NORAD/SIKORSKY primaries from North Truro, MA radar
- ◆ NAVY/NORAD/SIKORSKY primaries from Riverhead, NY radar
- ▲ NAVY/NORAD/SIKORSKY primaries from North Truro, MA radar

**PRIMARIES  
SHOWN FOR TIME  
20:30:00-20:50:00  
and 8 < X < 28 nm  
-18 < Y < 2 nm**

East-West Distance From Islip, NY ASR-8 Radar (nautical miles)

# TWA 747 Out of JFK, July 17, 1996 Radar Data Overhead View From 20:30 - 20:50

- TWA 800 secondaries, BOS CTR -1.25, NTAP/LATS91
- TWA 800 secondaries, NY CTR -2.25, NTAP/LATS91
- TWA 800 secondaries, JFK ASR -0.25, 12.5 deg W mag var
- TWA 800 secondaries, EWR ASR -0.25, 12.5 deg W mag var
- TWA 800 secondaries, ISP ASR -0.25, 13.0 deg W mag var
- TWA 800 secondaries, HFN ASR -0.25, 12.3 deg W mag var
- ▲ JFK ASR primaries, -0.25, 12.5 deg W mag var
- EWR ASR primaries, -0.25, 12.5 deg W mag var
- HFN ASR primaries, -0.25, 12.3 deg W mag var
- TWA 800 secondaries, NAVYNORADSIKORSKY data from Trewes, PA radar
- TWA 800 secondaries, NAVYNORADSIKORSKY data from Riverhead, NY radar
- 1200 track, ISP ASR -0.25, 13.0 deg W mag var
- USAIR 217 secondaries, ISP ASR -0.25, 13.0 deg W mag var
- TWA 800 secondaries, ISP ASR -0.25, 13.0 deg W mag var
- JET EX 18 secondaries, ISP ASR -0.25, 13.0 deg W mag var
- NY CTR primaries, -2.25, NTAP/LATS91
- BOS CTR primaries, -1.25, NTAP/LATS91
- TWA 800 secondaries, NAVYNORADSIKORSKY data from North Truro, MA radar
- NAVYNORADSIKORSKY primaries from Trewes, PA radar
- NAVYNORADSIKORSKY primaries from Riverhead, NY radar
- NAVYNORADSIKORSKY primaries from North Truro, MA radar



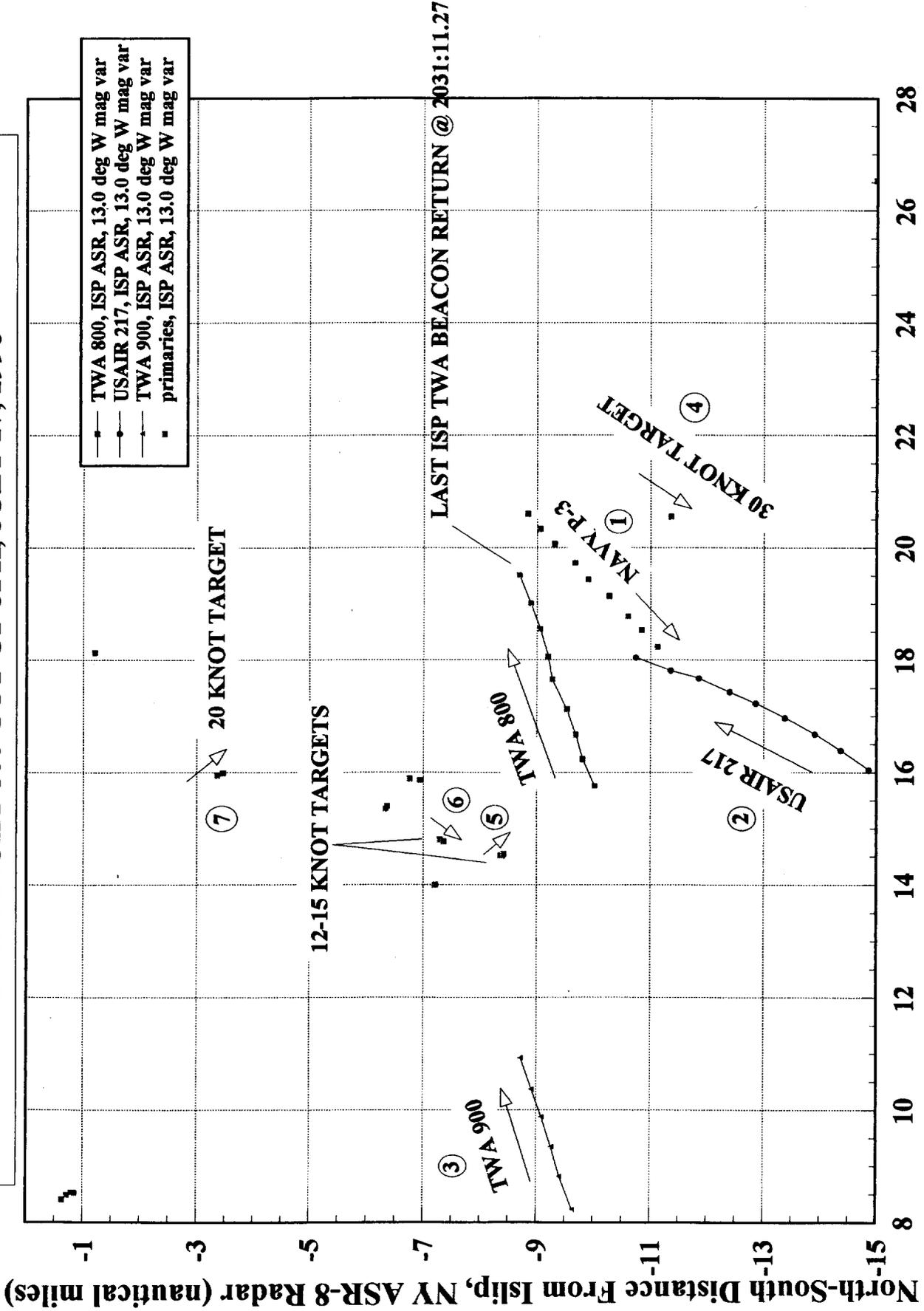
East-West Distance From Islip, NY ASR-8 Radar (nautical miles)

TWAXY-97. SGX  
SLIDE 9

**Attachment V**

**Vehicle/Object Identification Graphs**

**RADAR DATA PLAN VIEW, ISLIP RADAR, TIME 2030:30-2031:13 EDT  
TWA FLIGHT 800 OUT OF JFK, JULY 17, 1996**



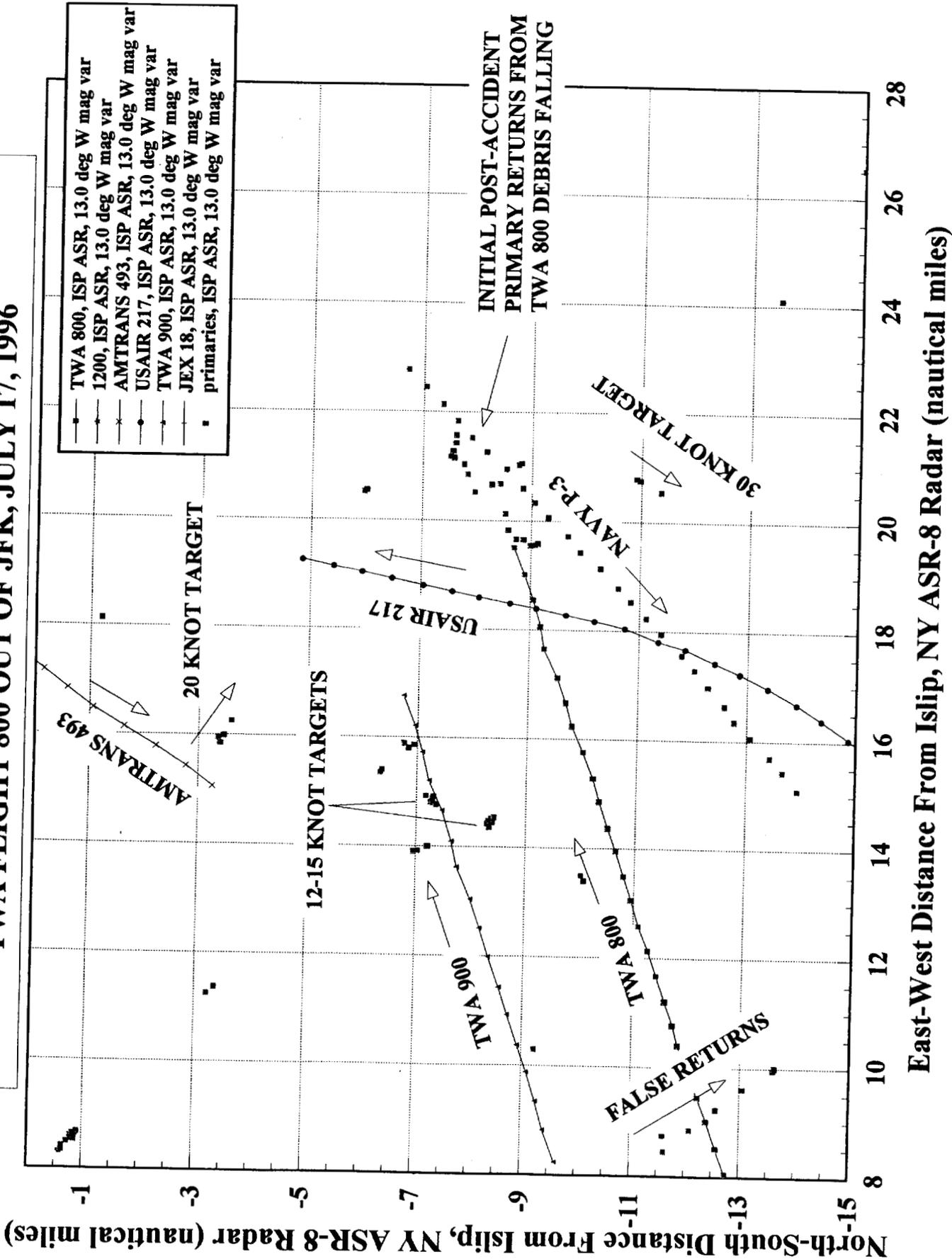
**East-West Distance From Islip, NY ASR-8 Radar (nautical miles)**

ESP797.56x  
SLIDE Z

**Attachment VI**

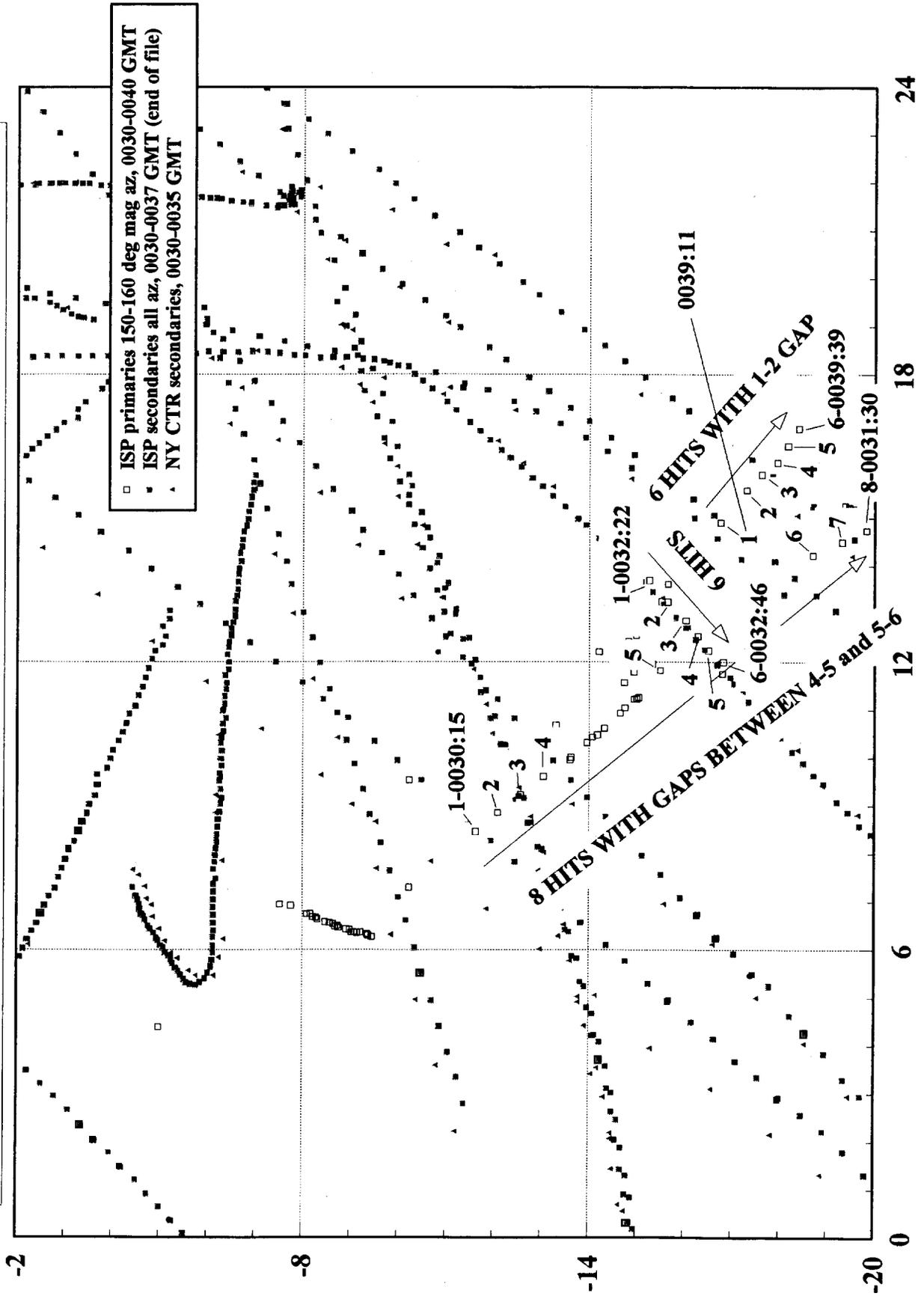
**Islip ASR False Primary Return Graphs And Related Information**

**RADAR DATA PLAN VIEW, ISLIP RADAR, TIME 2030-2032 EDT  
TWA FLIGHT 800 OUT OF JFK, JULY 17, 1996**



# TWA 800 Radar Data

## Examples of False Returns in 150-160 Degrees Azimuth for 0030-0040 GMT



FALSE1.SGX  
SLIDE 2

From 197

**FUNDAMENTALS OF PRIMARY AND SECONDARY  
SURVEILLANCE RADAR  
ETM 12-0-1**

**FIRST EDITION**

**SIXTEENTH PRINTING**

**AIR TRAFFIC BRANCH  
FEDERAL AVIATION ADMINISTRATION ACADEMY**

Published and Printed at the  
Mike Monroney Aeronautical Center  
Oklahoma City, Oklahoma  
December 1981

index of refraction of dry or dense air is greater than moist or less dense air, therefore radar beams will be bent in the direction of the dry or dense layers. Figure 17 depicts two conditions of anomalous propagation with the atmosphere in Fig. 17(a) causing a downward bending, and that in Fig. 17(b) causing an upward bending of the radar beams.

Under the conditions depicted in Fig. 17(a) targets hundreds of miles away may be detected even though they are far below the horizon, while under the condition depicted in Fig. 17(b) even relatively close targets cannot be detected. However, the latter condition is less common than the first.

The normal reaction to increased ground clutter or ambiguous returns is to reduce the IF gain. The adjustment of the IF gain to eliminate clutter, results in reduced radar coverage and should be carefully considered. •

#### FALSE TARGET

One of the most important operations the radar controller must master, is to interpret properly all targets depicted on the radar scope. The proficient radar controller will be quick to recognize temperature inversion as a false target indication. Such indications are often secondary reflections of radar energy from isolated refracting areas in a temperature inversion level. Correlation of radar reports with Weather Bureau records indicates that a temperature inversion is almost always present when unidentified flying objects appear on the scope. These inversions often travel across the radar at tremendous speeds and in changing directions. Apparently this phenomena is produced by isolated refracting areas traveling with the wind at or near temperature inversion levels. Although the exact size, shape, and composition of these isolated areas is not known, it is believed that they may be atmospheric eddies produced by a shearing action of dissimilar air strata. It appears that such eddies may reflect and focus the radar energy with a lens effect to produce small concentrations of ground return with sufficient strength to show up on the radar display.

#### RADAR JAMMING

Jamming as used in conjunction with radar is defined as an introduction of false radiation into radar and radar devices. False targets produced by radiation may clutter large portions of the radar area, and in some cases render the scope unusable. The effects of even the slightest amount of jamming may be disastrous, under certain conditions. For this reason, the controller must have some understanding of the effects of jamming.

Jamming may be classified into two main categories, active and passive. Active jammers are those that generate radar energy; i.e., continuous wave, modulated continuous wave, frequency modulated, or pulse modulated outputs. Passive jammers are those which act as parasitic radiators; i.e., chaff. Chaff is thin strips of aluminum or other metal, cut in a particular length. When released from aircraft at high altitudes, the strips float slowly to the ground and the resultant echoes cause large areas of the indicator to become intensified or cluttered.

The Air Training Command has equipped some of its aircraft with chaff dispensing bags attached to the underside of ejection seats. In event of crew ejection, chaff will be dispersed over a wide area and will remain visible in the form of clutter on radar scopes for a period of time up to 30 or 40 minutes, depending upon altitude of ejection. Such clutter is easily discernible to radar controllers (Figure 18).

#### *Controlled Jamming*

Controlled jamming operations are conducted by the military to provide essential training of military radar personnel. An agreement, to preclude interference with air traffic control radar, regulates, but does not arbitrarily curtail military operations. Personnel observing jamming operations, when no prior notification has been received, should forward information to the appropriate authority, since more military aircraft may dispense chaff when experiencing emergency situations.