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

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[1]), 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

[1] 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[2] and Cockpit Voice Recorder (CVR) transcript[3] 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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[2] See **Flight Data Recorder Factual Report**.
[3] 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[4] only - no primary radar[5] 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)

[4] 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.

[5] 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 Trevose, 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[6] 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

[6] 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 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.

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 noisey for both flight 1300 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 Dower 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

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 utill 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 maintence 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 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 discretes 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 discretes, the extended condition is recorded simultaneously with the first recording of “in-transit”. This also suggests, like the T/R discretes, that the extended discretes are actually “not-retracted” discretes.

The maintenance log contains the entry: “July 15th, 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, propably 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

[signature]

206-965-5401

Attachment II

Tabular Listings of the FAA/Sikorsky-Provided Facility Data

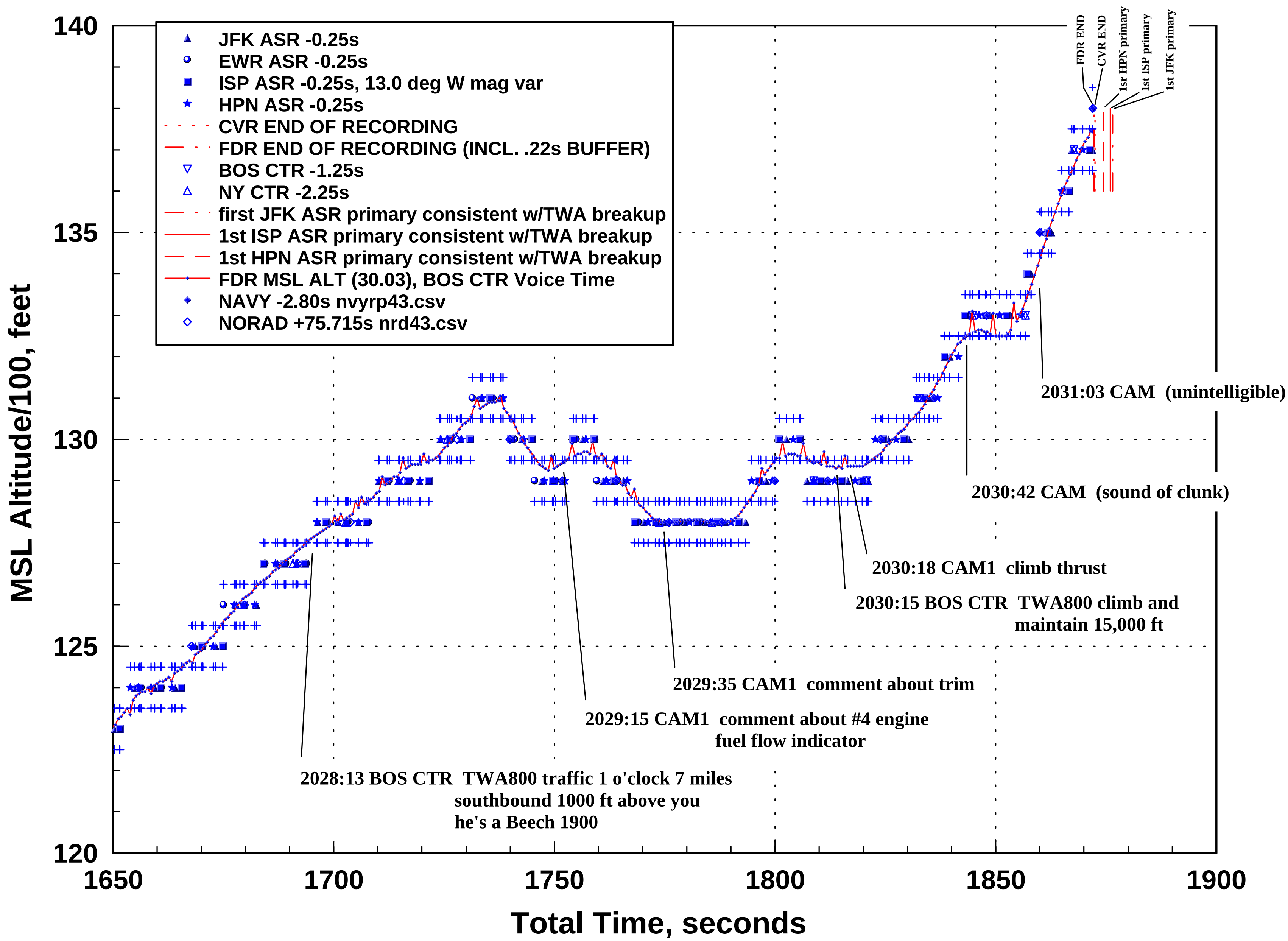
Radar Sites

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

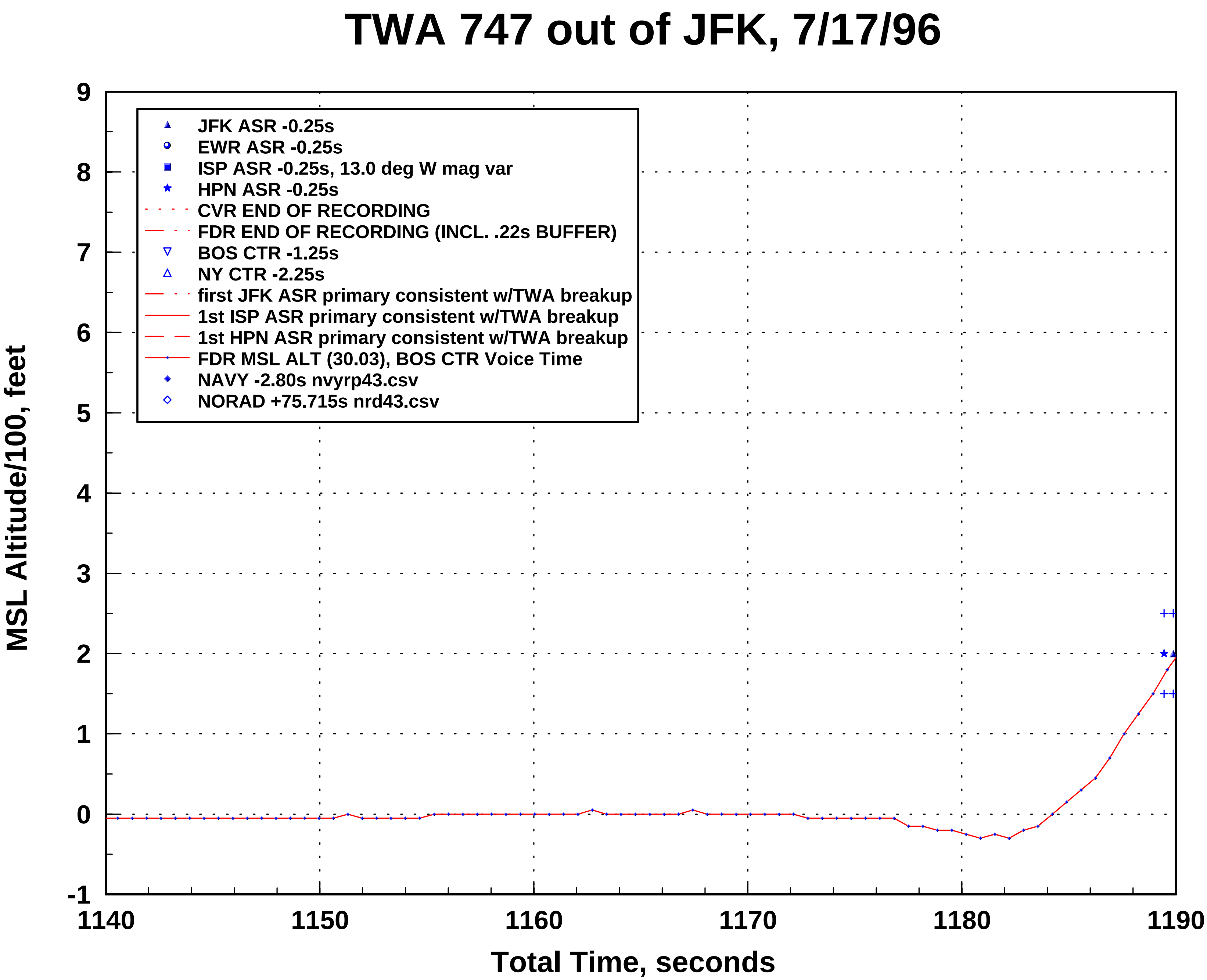
Attachment III

Altitude, X, and Y versus Time Graphs

TWA 747 out of JFK, 7/17/96



Attachment III-1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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
MSL Altitude/100, feet
Total Time, seconds
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1140
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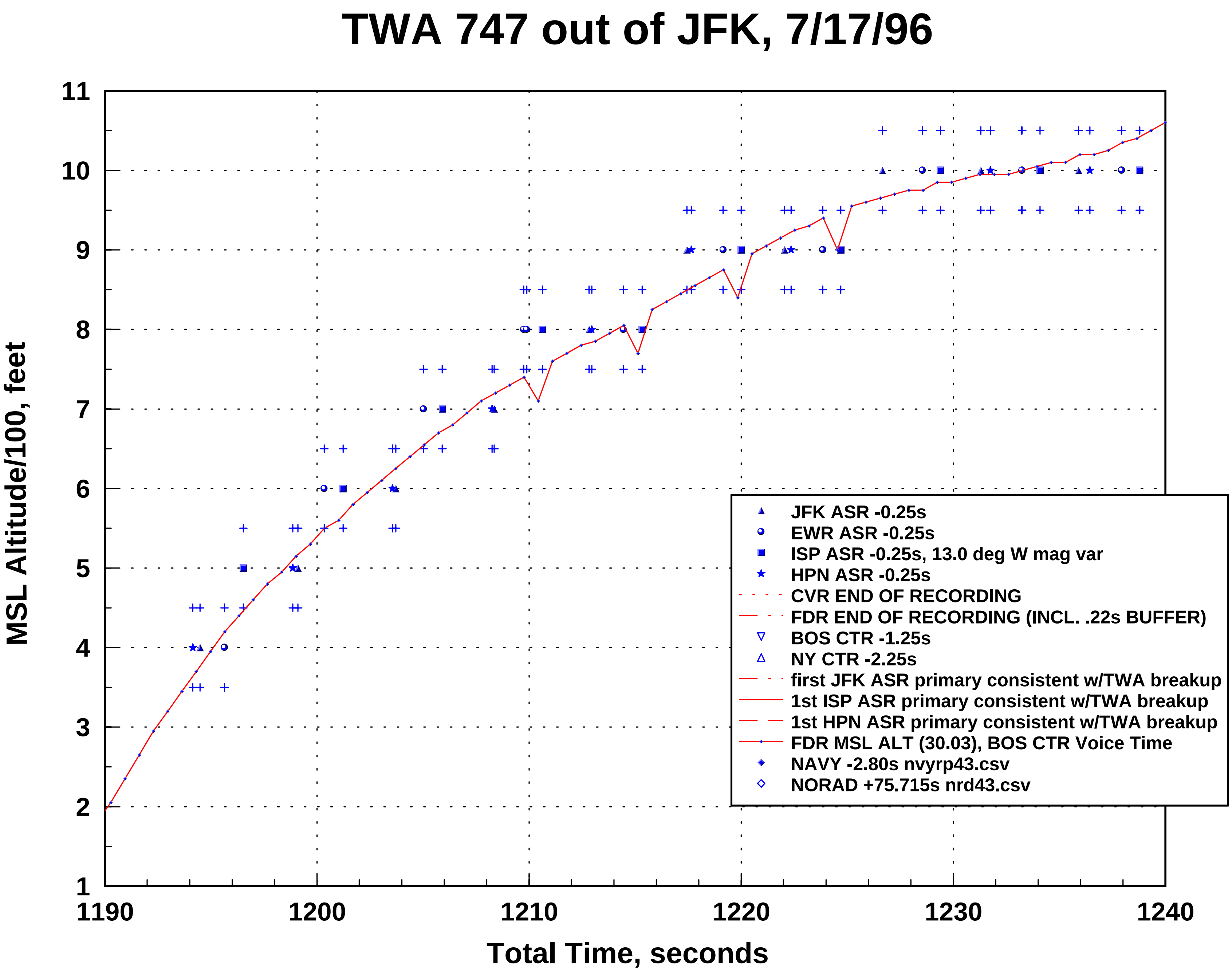
1170
1180
1190


TWA 747 out of JFK, 7/17/96
MSL Altitude/100, feet
Total Time, seconds
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1190
1200
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JFK ASR -0.25s
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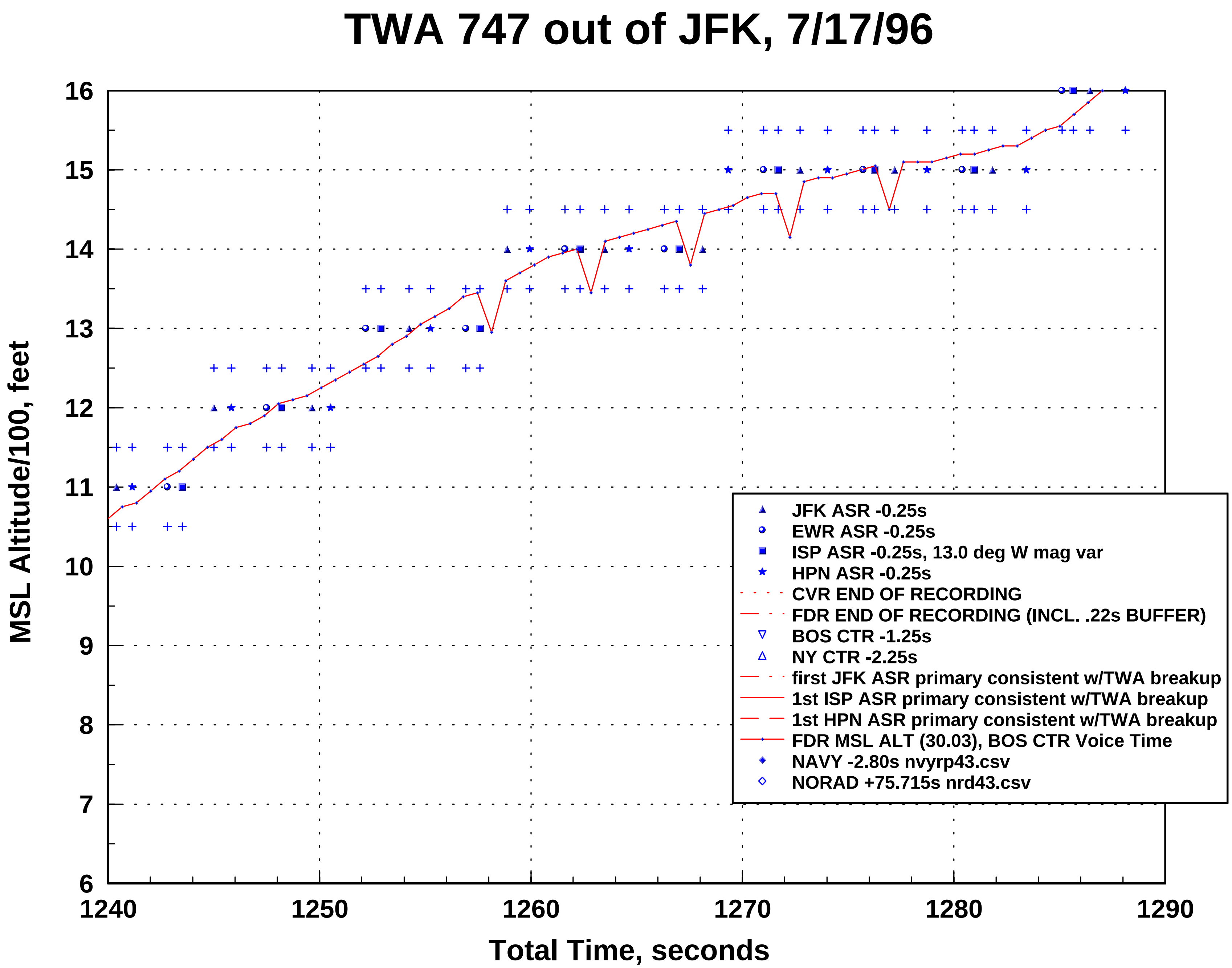
TWA 747 out of JFK, 7/17/96
MSL Altitude/100, feet
Total Time, seconds
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JFK ASR -0.25s
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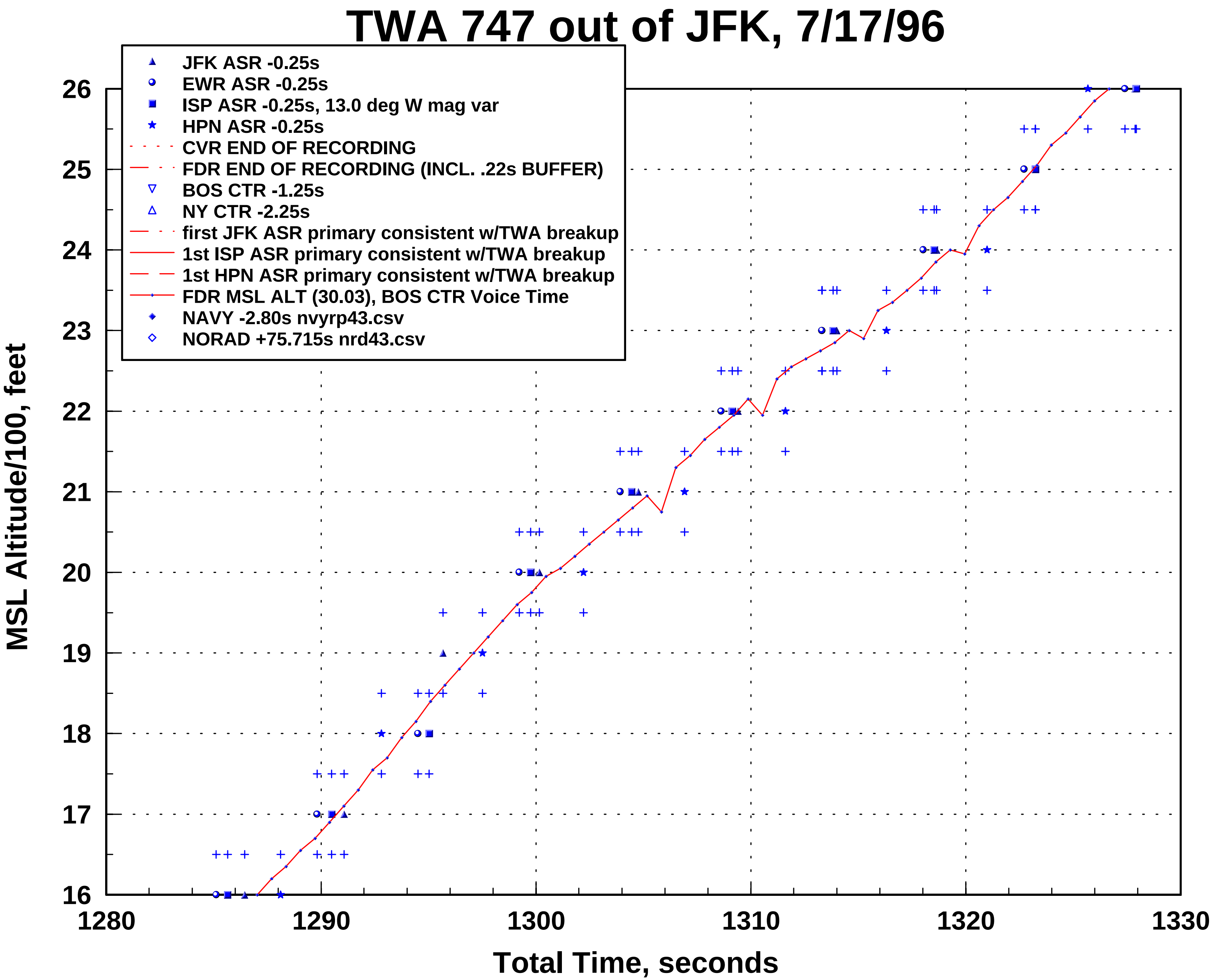

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MSL Altitude/100, feet
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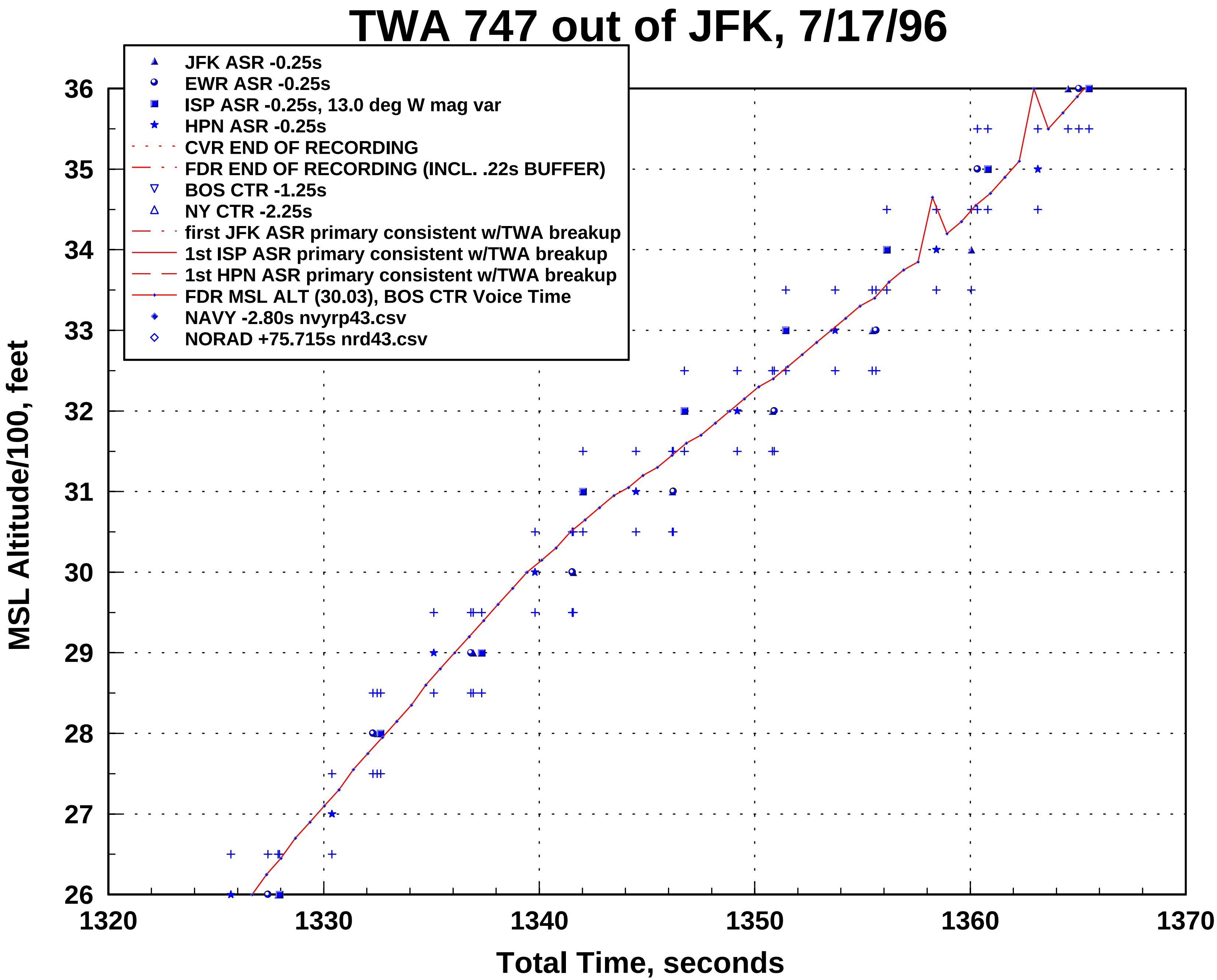

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1st HPN ASR primary consistent w/TWA breakup
FDR MSL ALT (30.03), BOS CTR Voice Time
NAVY -2.80s nvyrp43.csv
NORAD +75.715s nrd43.csv
MSL Altitude/100, feet
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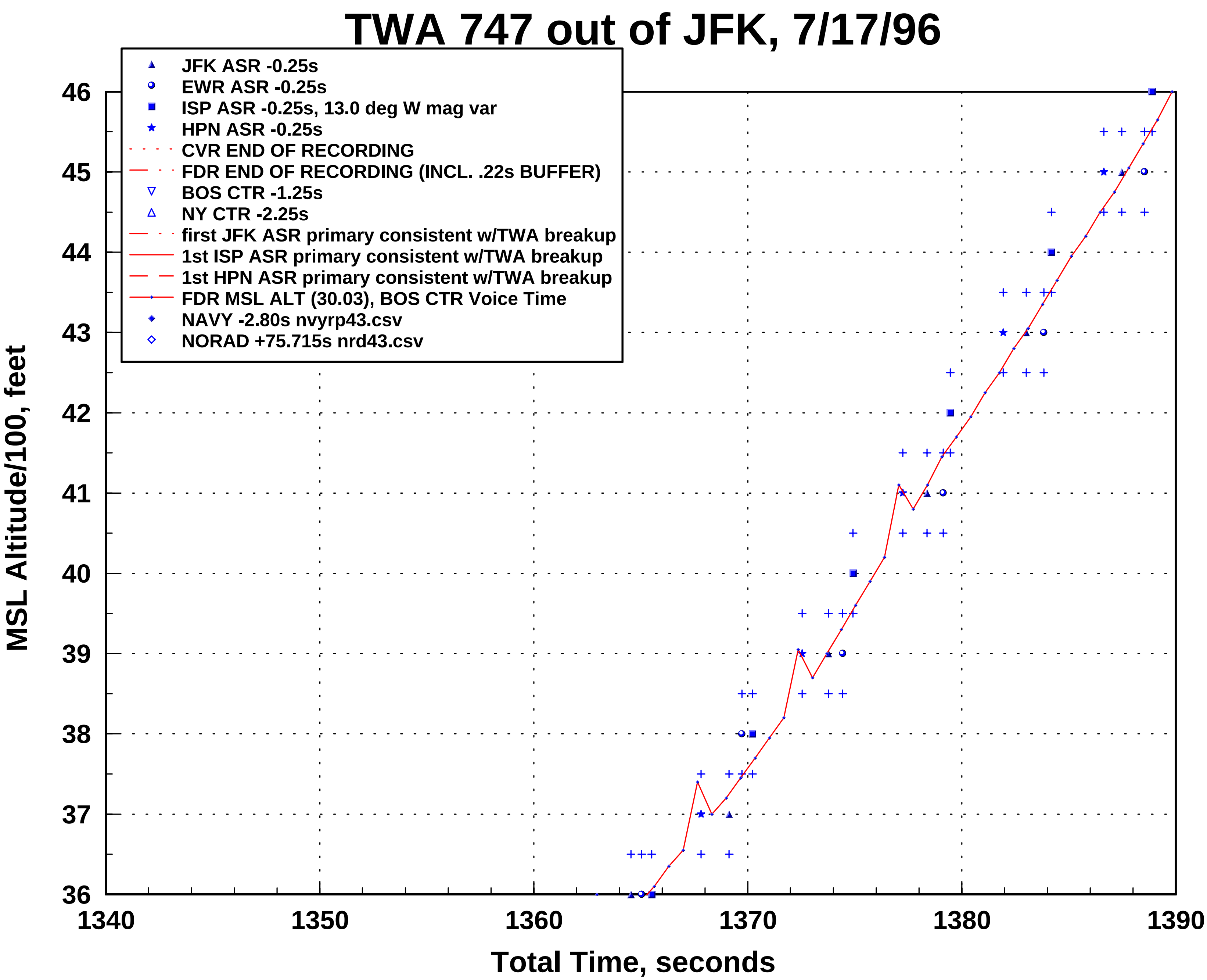
1340
1350
1360
1370
Total Time, seconds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NAVY -2.80s nvyrp43.csv
NORAD +75.715s nrd43.csv
MSL Altitude/100, feet
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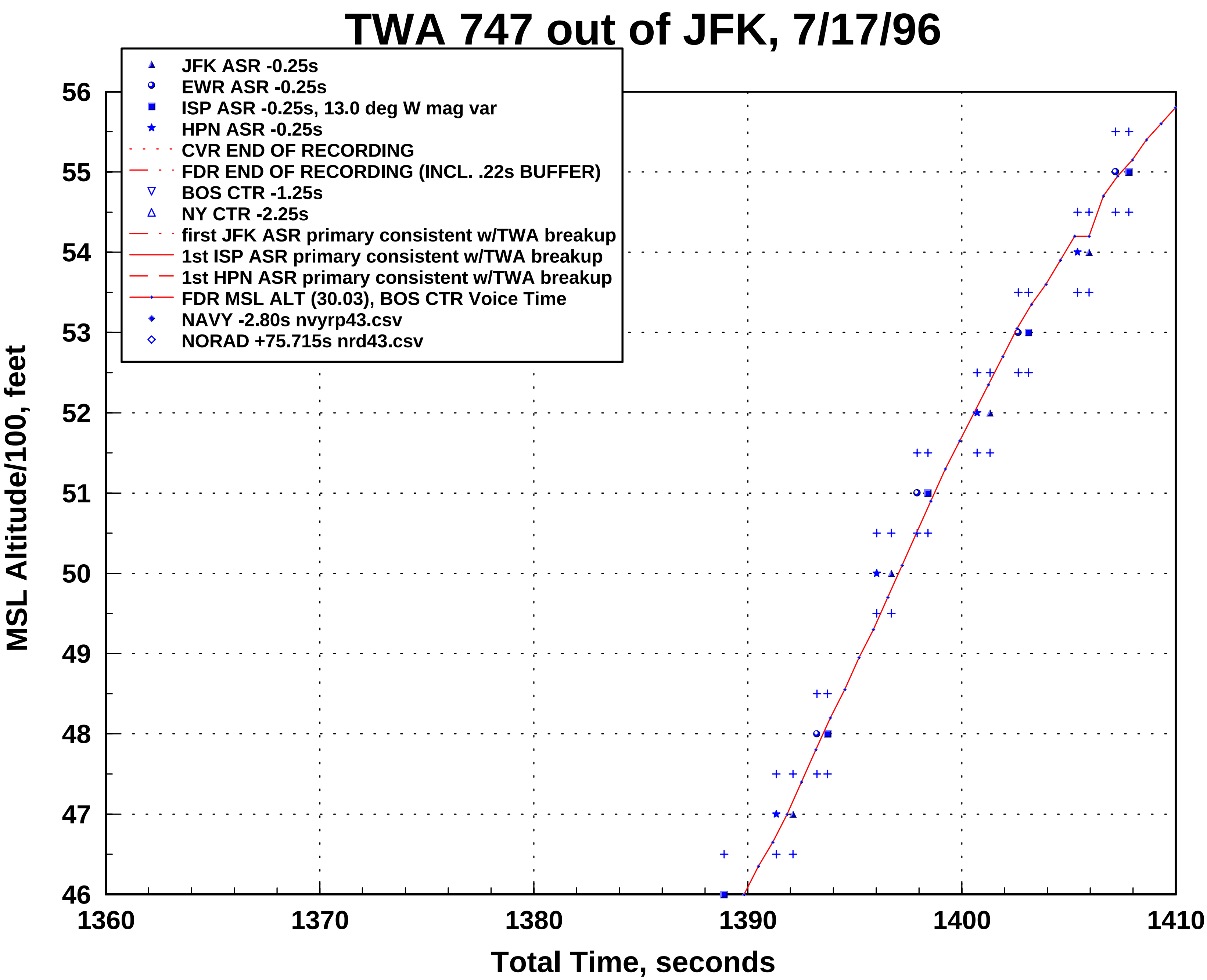
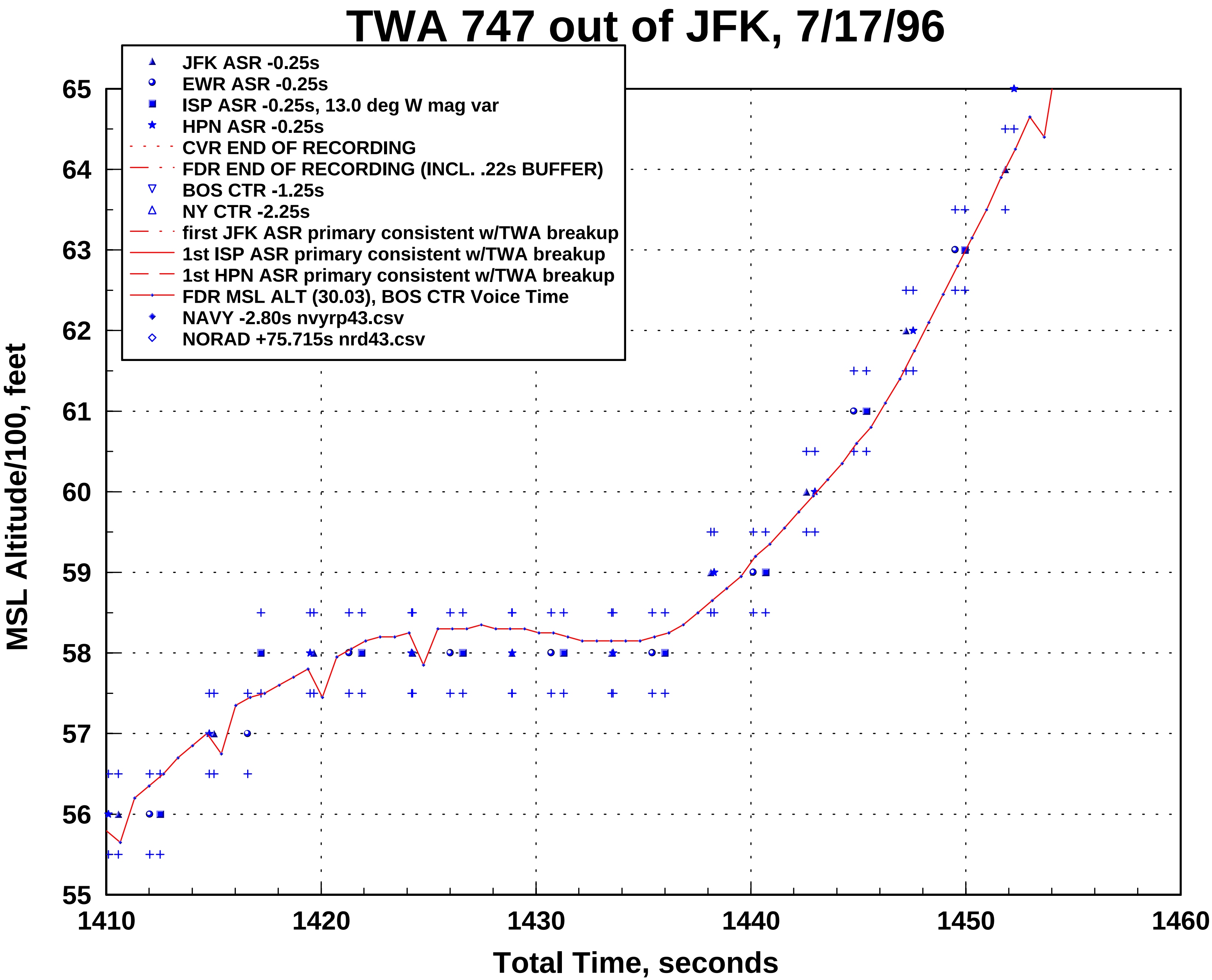
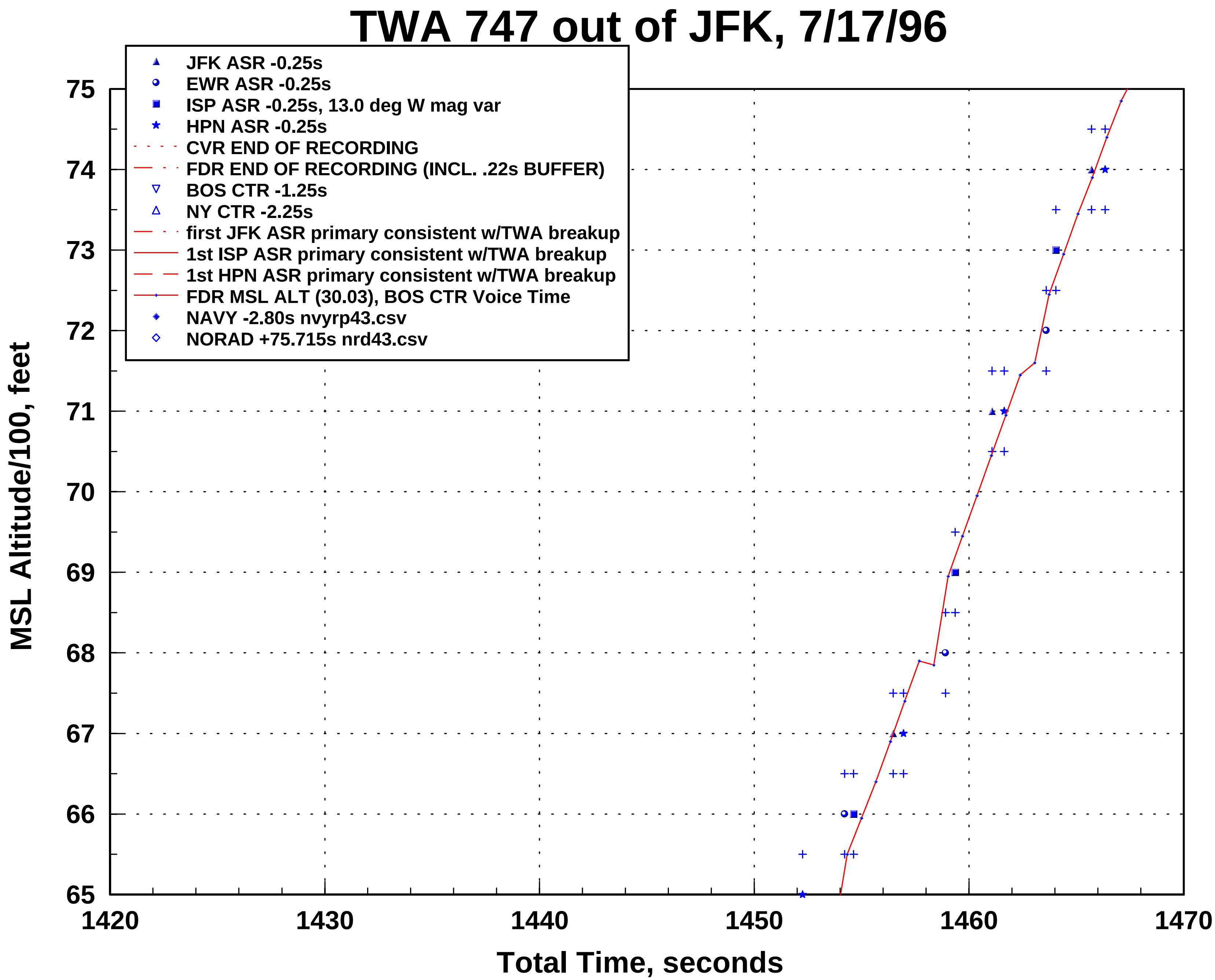
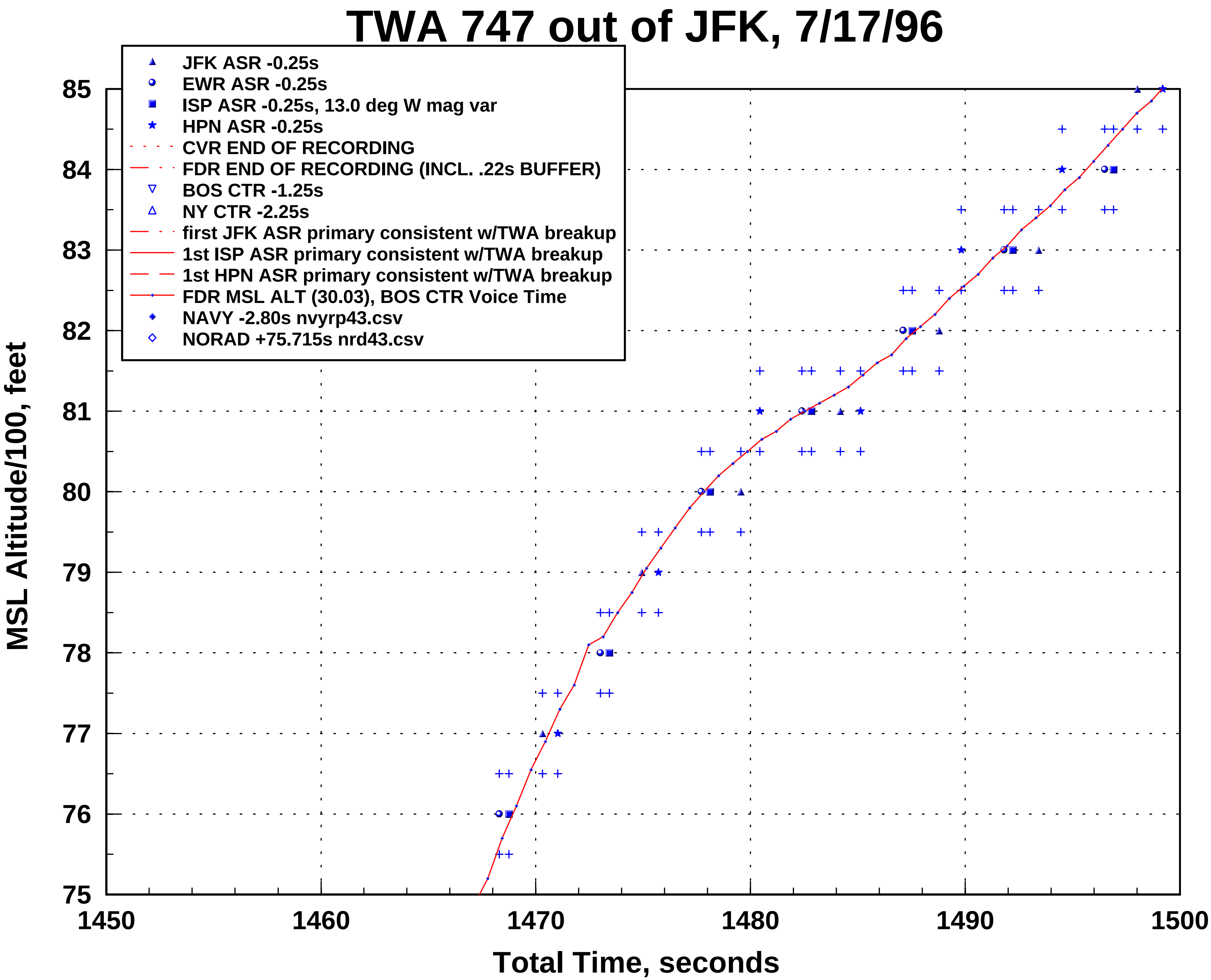
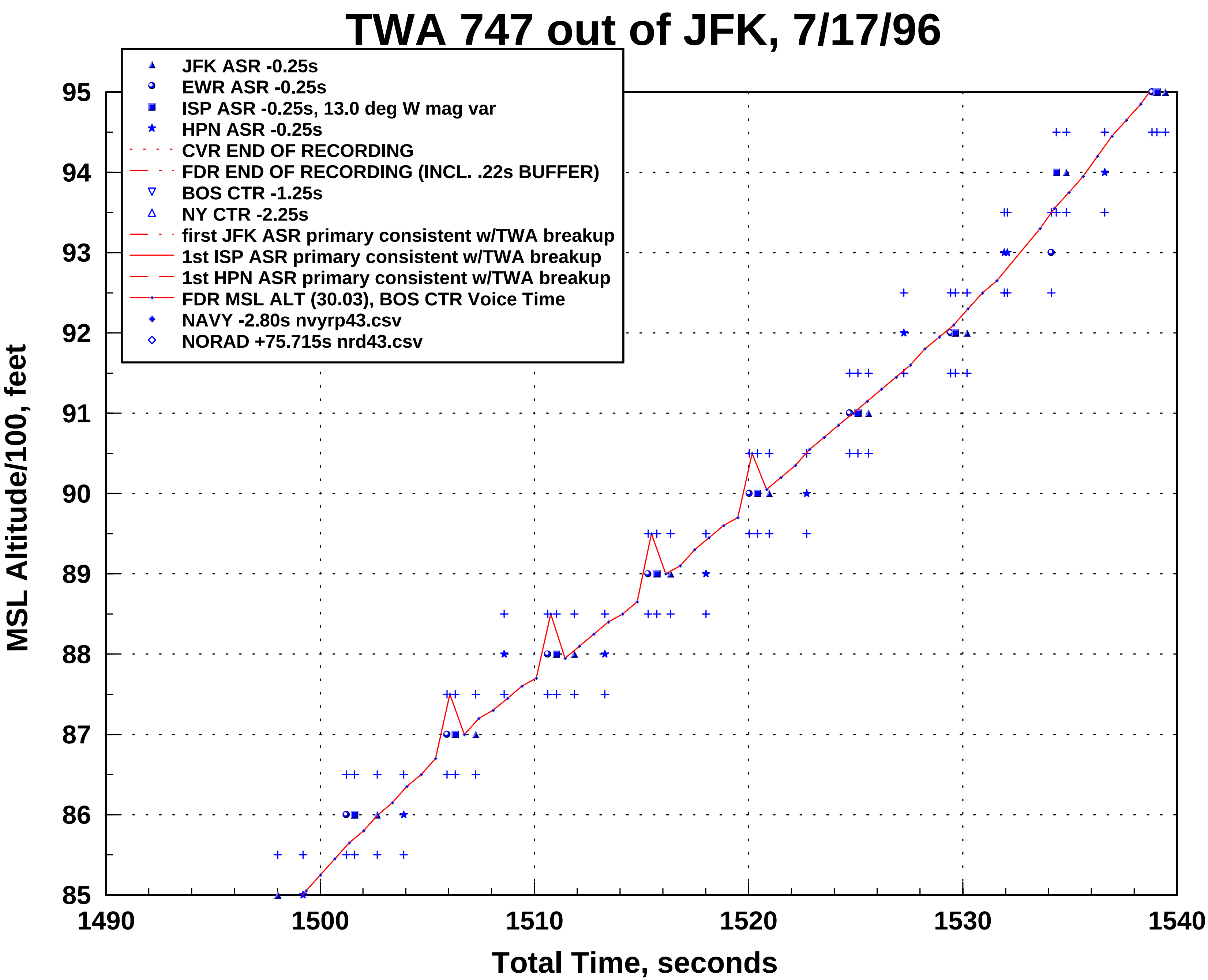
1380
1390
Total Time, seconds


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
MSL Altitude/100, feet
56
55
54
53
52
51
50
49
48
47
46
1360
1370
1380
1390
1400
1410
Total Time, seconds

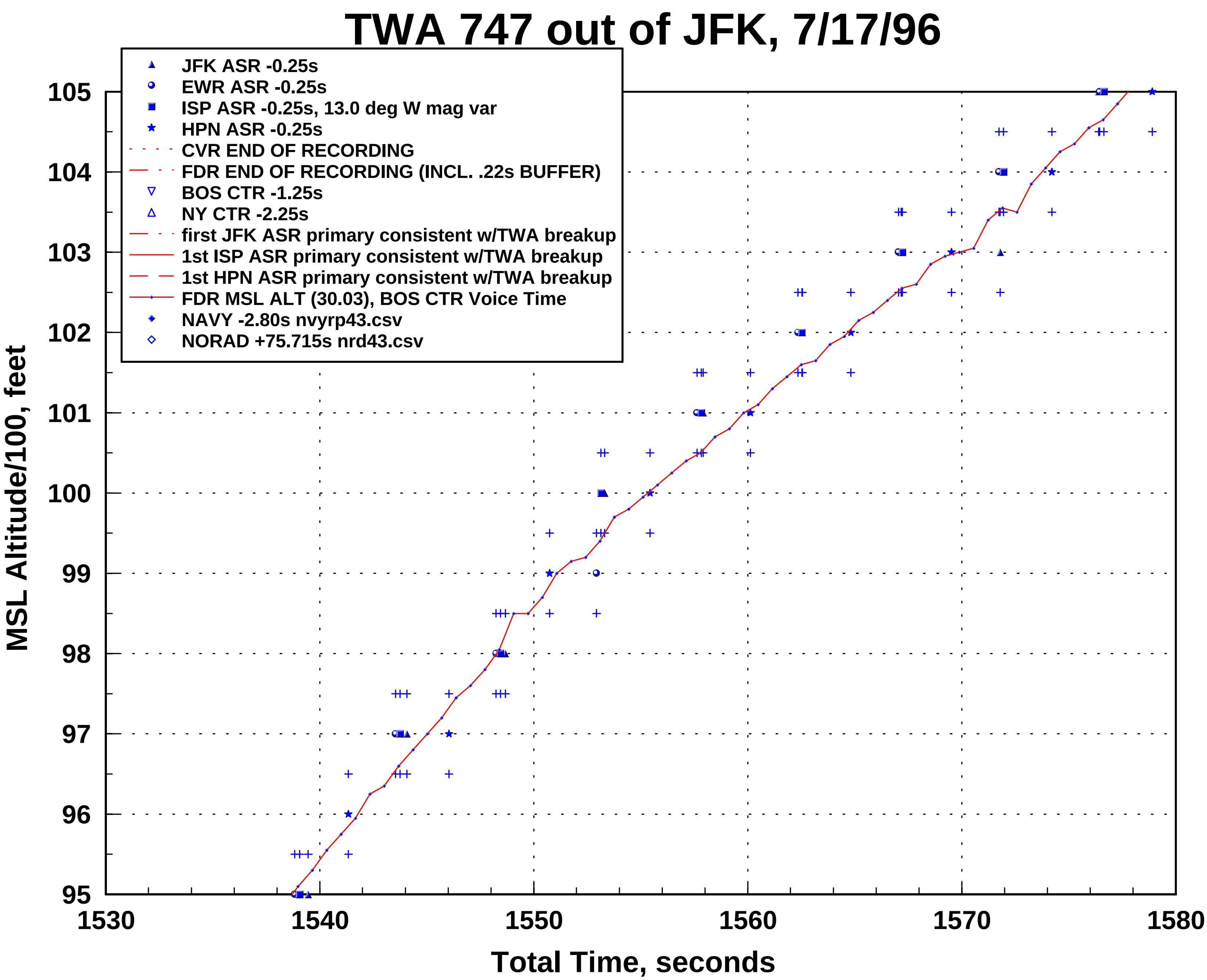

TWA 747 out of JFK, 7/17/96
JFK ASR -0.25s
EWR ASR -0.25s
ISP ASR -0.25s, 13.0 deg W mag var
HPN ASR -0.25s
CVR END OF RECORDING
FDR END OF RECORDING (INCL. .22s BUFFER)
BOS CTR -1.25s
NY CTR -2.25s
first JFK ASR primary consistent w/TWA breakup
1st ISP ASR primary consistent w/TWA breakup
1st HPN ASR primary consistent w/TWA breakup
FDR MSL ALT (30.03), BOS CTR Voice Time
NAVY -2.80s nvyrp43.csv
NORAD +75.715s nrd43.csv
MSL Altitude/100, feet
65
64
63
62
61
60
59
58
57
56
55
1410
1420
1430
1440
1450
1460
Total Time, seconds

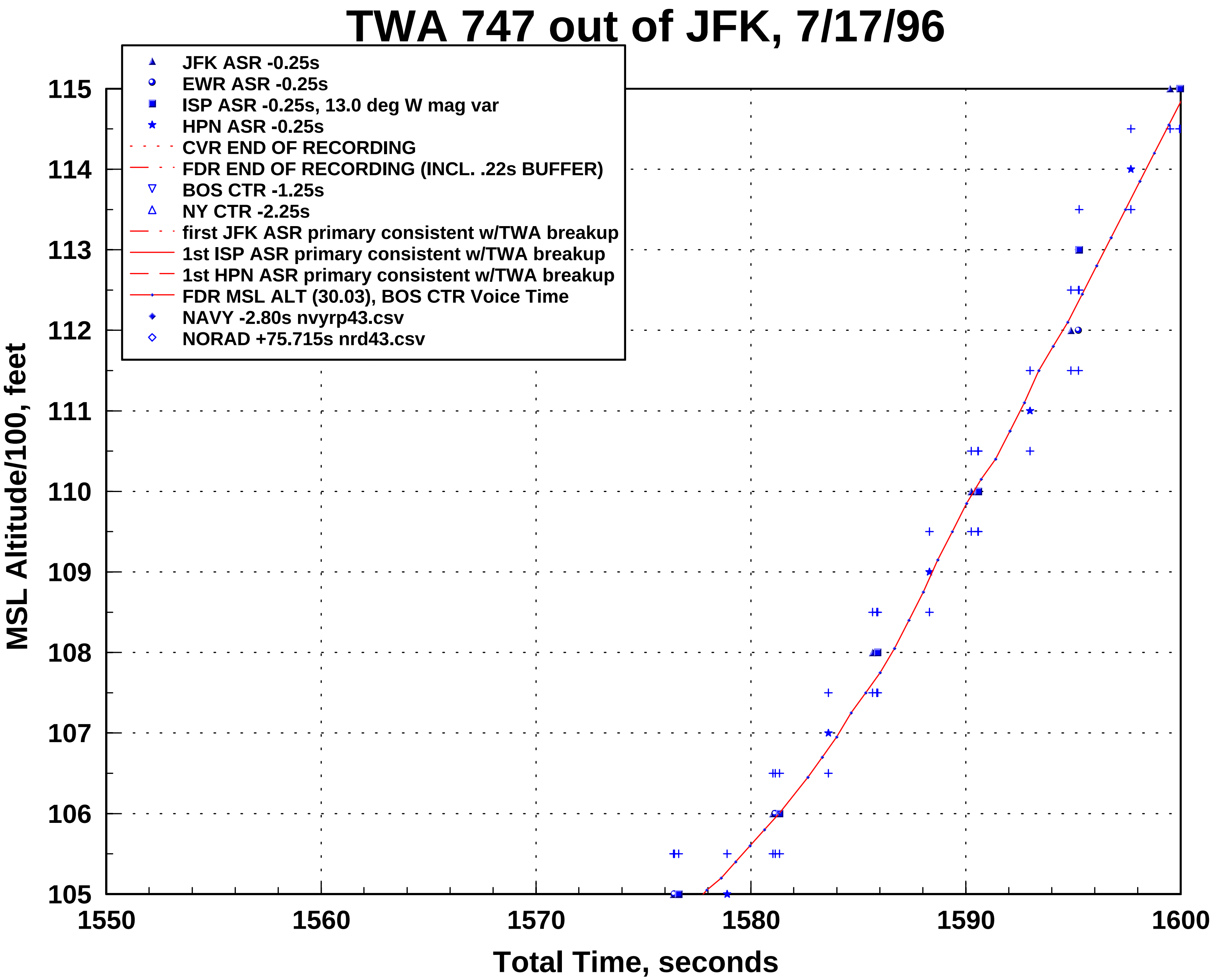

TWA 747 out of JFK, 7/17/96
JFK ASR -0.25s
EWR ASR -0.25s
ISP ASR -0.25s, 13.0 deg W mag var
HPN ASR -0.25s
CVR END OF RECORDING
FDR END OF RECORDING (INCL. .22s BUFFER)
BOS CTR -1.25s
NY CTR -2.25s
first JFK ASR primary consistent w/TWA breakup
1st ISP ASR primary consistent w/TWA breakup
1st HPN ASR primary consistent w/TWA breakup
FDR MSL ALT (30.03), BOS CTR Voice Time
NAVY -2.80s nvyrp43.csv
NORAD +75.715s nrd43.csv
MSL Altitude/100, feet
75
74
73
72
71
70
69
68
67
66
65
1420
1430
1440
1450
1460
1470
Total Time, seconds

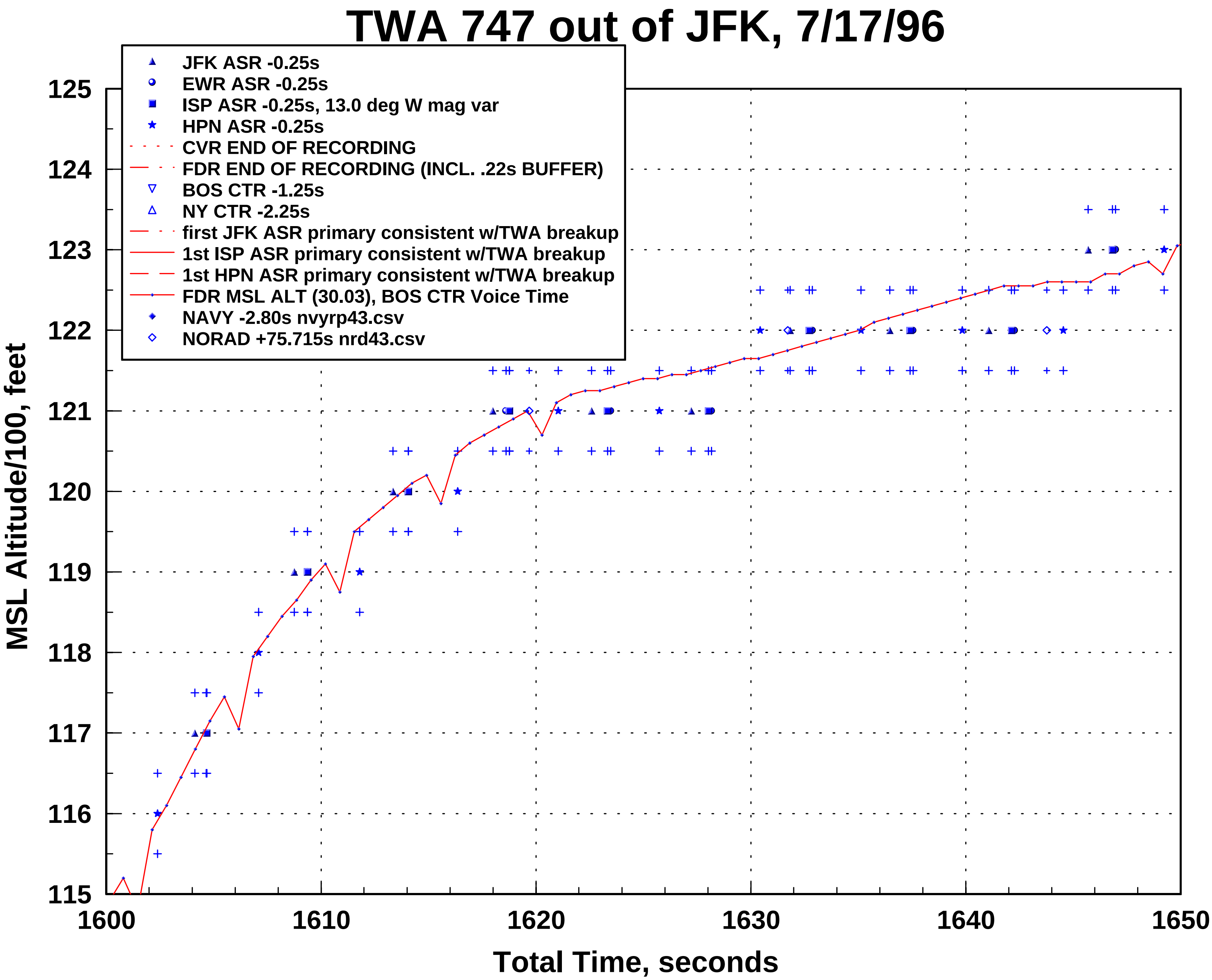

TWA 747 out of JFK, 7/17/96
JFK ASR -0.25s
EWR ASR -0.25s
ISP ASR -0.25s, 13.0 deg W mag var
HPN ASR -0.25s
CVR END OF RECORDING
FDR END OF RECORDING (INCL. .22s BUFFER)
BOS CTR -1.25s
NY CTR -2.25s
first JFK ASR primary consistent w/TWA breakup
1st ISP ASR primary consistent w/TWA breakup
1st HPN ASR primary consistent w/TWA breakup
FDR MSL ALT (30.03), BOS CTR Voice Time
NAVY -2.80s nvyrp43.csv
NORAD +75.715s nrd43.csv
MSL Altitude/100, feet
85
84
83
82
81
80
79
78
77
76
75
1450
1460
1470
1480
1490
1500
Total Time, seconds

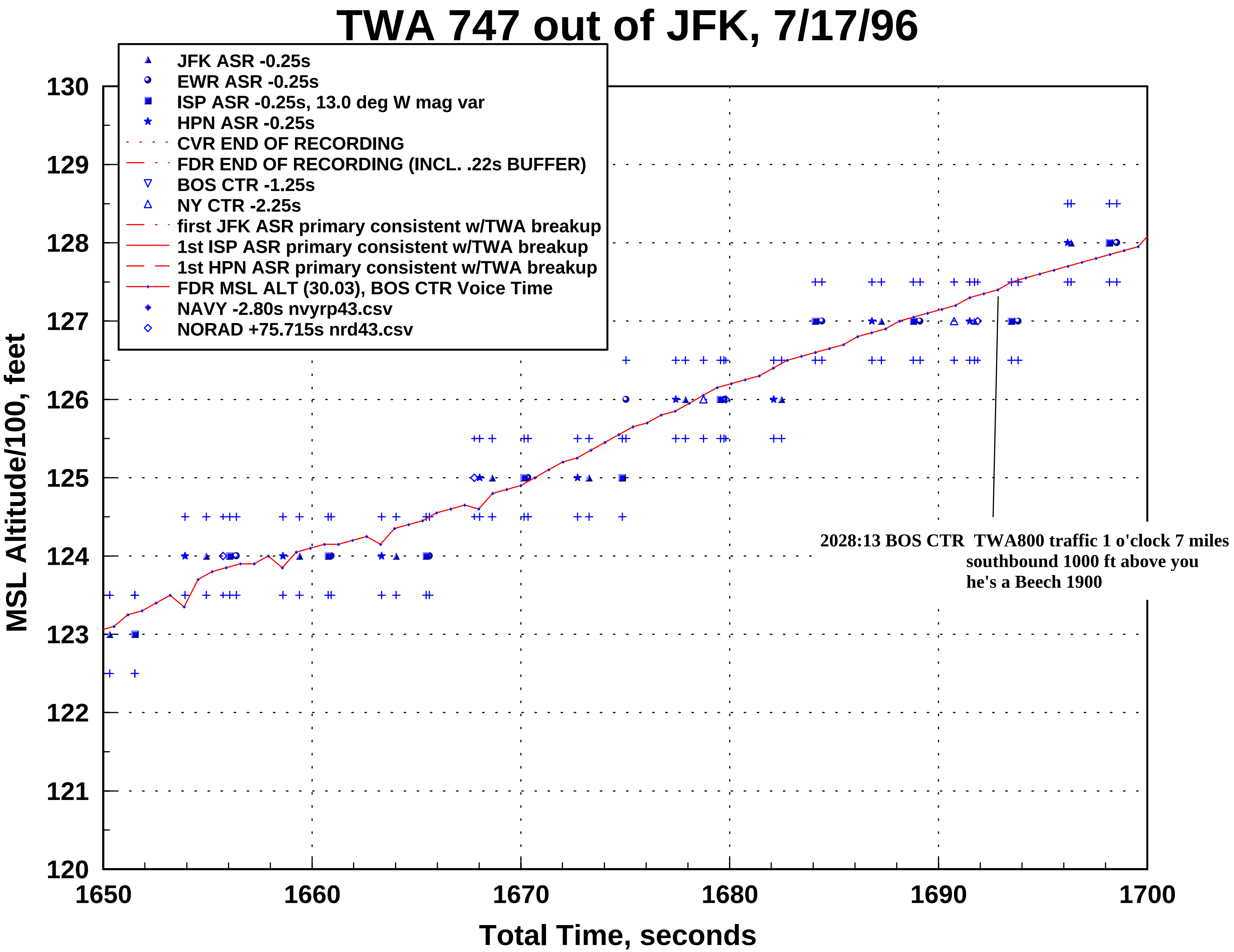


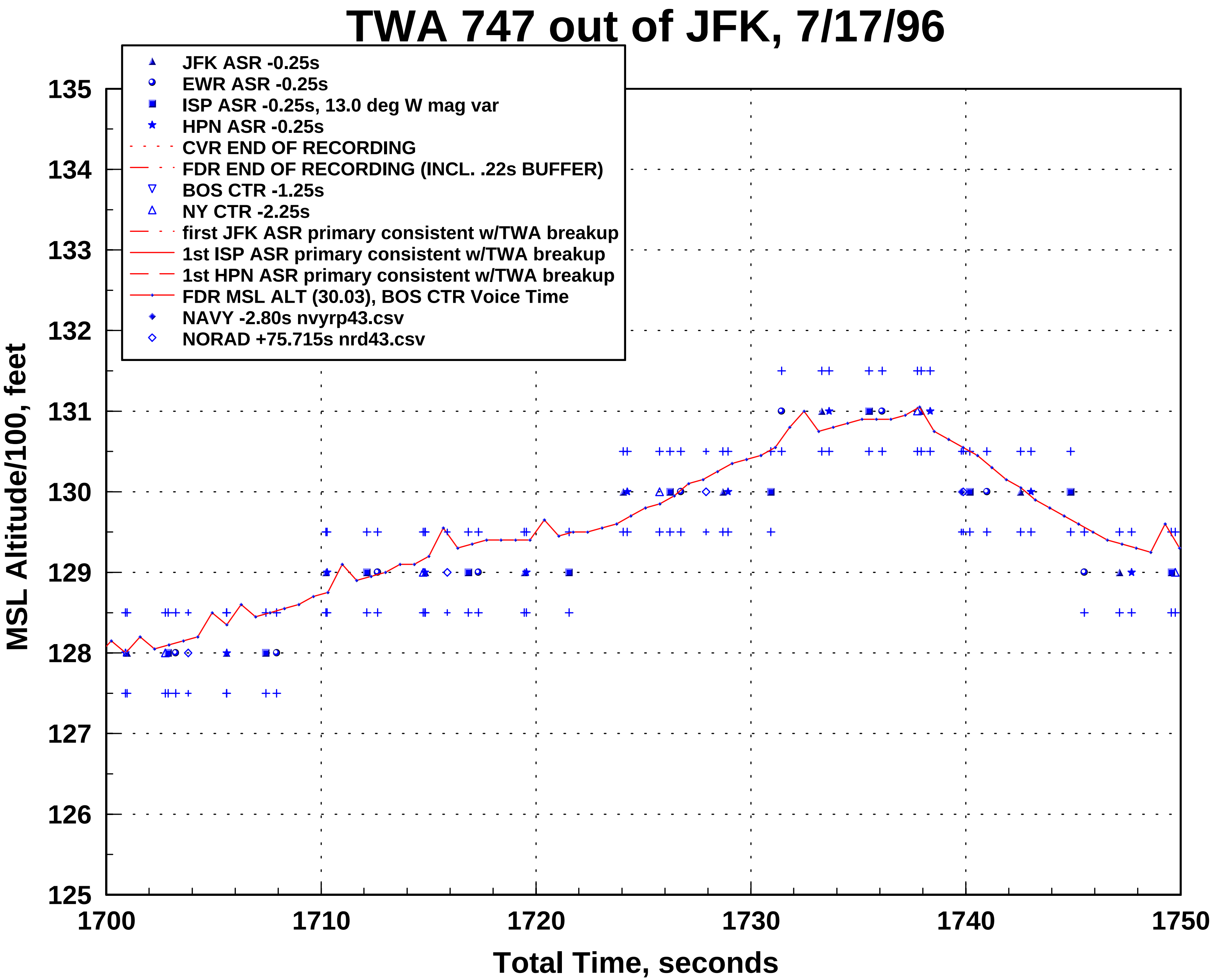
TWA 747 out of JFK, 7/17/96
JFK ASR -0.25s
EWR ASR -0.25s
ISP ASR -0.25s, 13.0 deg W mag var
HPN ASR -0.25s
CVR END OF RECORDING
FDR END OF RECORDING (INCL. .22s BUFFER)
BOS CTR -1.25s
NY CTR -2.25s
first JFK ASR primary consistent w/TWA breakup
1st ISP ASR primary consistent w/TWA breakup
1st HPN ASR primary consistent w/TWA breakup
FDR MSL ALT (30.03), BOS CTR Voice Time
NAVY -2.80s nvyrp43.csv
NORAD +75.715s nrd43.csv
MSL Altitude/100, feet
Total Time, seconds
95
94
93
92
91
90
89
88
87
86
85
1490
1500
1510
1520
1530
1540


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
MSL Altitude/100, feet
105
104
103
102
101
100
99
98
97
96
95
1530
1540
1550
1560
1570
1580
Total Time, seconds

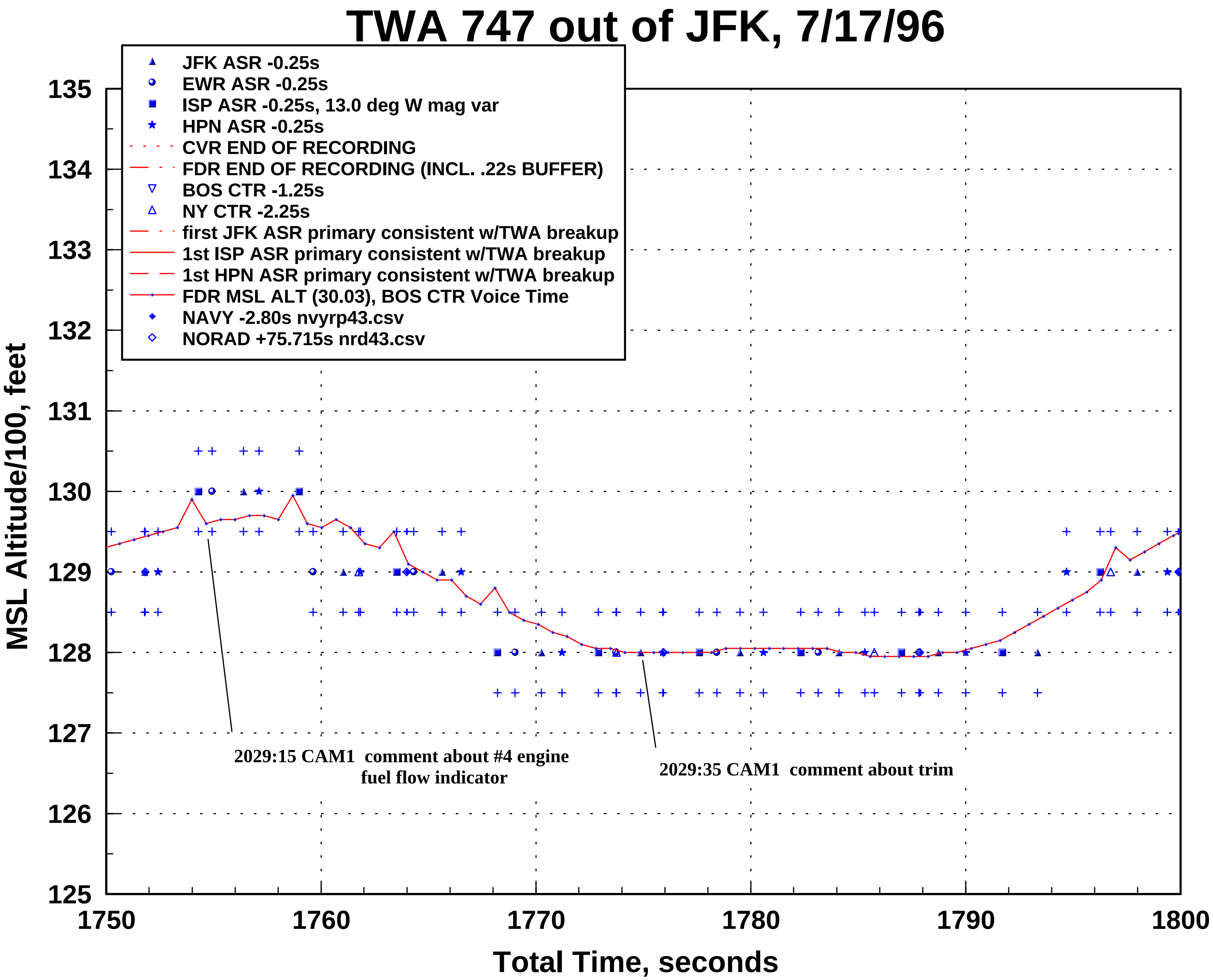

TWA 747 out of JFK, 7/17/96
JFK ASR -0.25s
EWR ASR -0.25s
ISP ASR -0.25s, 13.0 deg W mag var
HPN ASR -0.25s
CVR END OF RECORDING
FDR END OF RECORDING (INCL. .22s BUFFER)
BOS CTR -1.25s
NY CTR -2.25s
first JFK ASR primary consistent w/TWA breakup
1st ISP ASR primary consistent w/TWA breakup
1st HPN ASR primary consistent w/TWA breakup
FDR MSL ALT (30.03), BOS CTR Voice Time
NAVY -2.80s nvyrp43.csv
NORAD +75.715s nrd43.csv
MSL Altitude/100, feet
115
114
113
112
111
110
109
108
107
106
105
1550
1560
1570
1580
1590
1600
Total Time, seconds

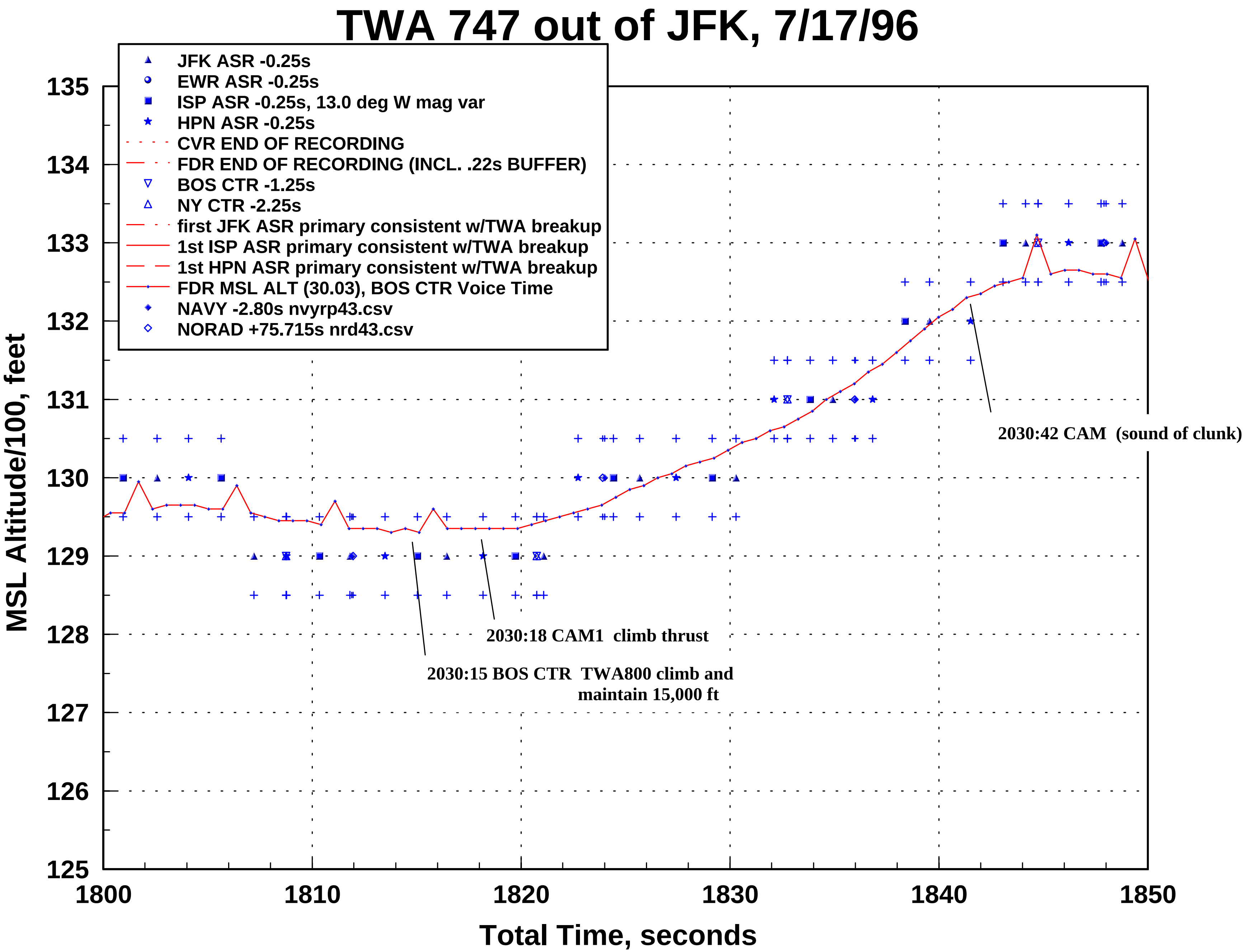

TWA 747 out of JFK, 7/17/96
JFK ASR -0.25s
EWR ASR -0.25s
ISP ASR -0.25s, 13.0 deg W mag var
HPN ASR -0.25s
CVR END OF RECORDING
FDR END OF RECORDING (INCL. .22s BUFFER)
BOS CTR -1.25s
NY CTR -2.25s
first JFK ASR primary consistent w/TWA breakup
1st ISP ASR primary consistent w/TWA breakup
1st HPN ASR primary consistent w/TWA breakup
FDR MSL ALT (30.03), BOS CTR Voice Time
NAVY -2.80s nvyrp43.csv
NORAD +75.715s nrd43.csv
MSL Altitude/100, feet
125
124
123
122
121
120
119
118
117
116
115
1600
1610
1620
1630
1640
1650
Total Time, seconds


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
2028:13 BOS CTR TWA800 traffic 1 o'clock 7 miles
southbound 1000 ft above you
he's a Beech 1900
MSL Altitude/100, feet
Total Time, seconds
130
129
128
127
126
125
124
123
122
121
120
1650
1660
1670
1680
1690
1700

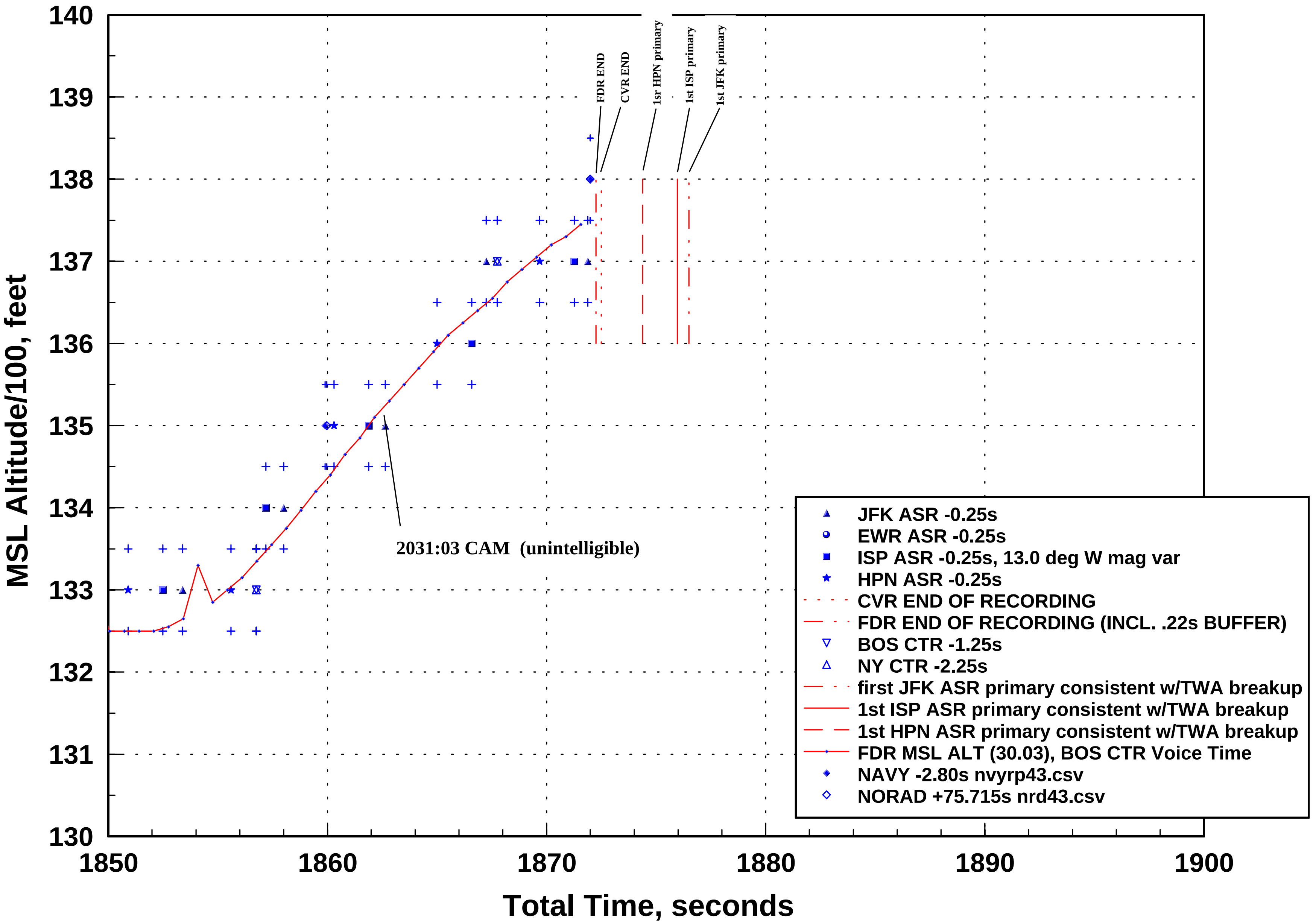


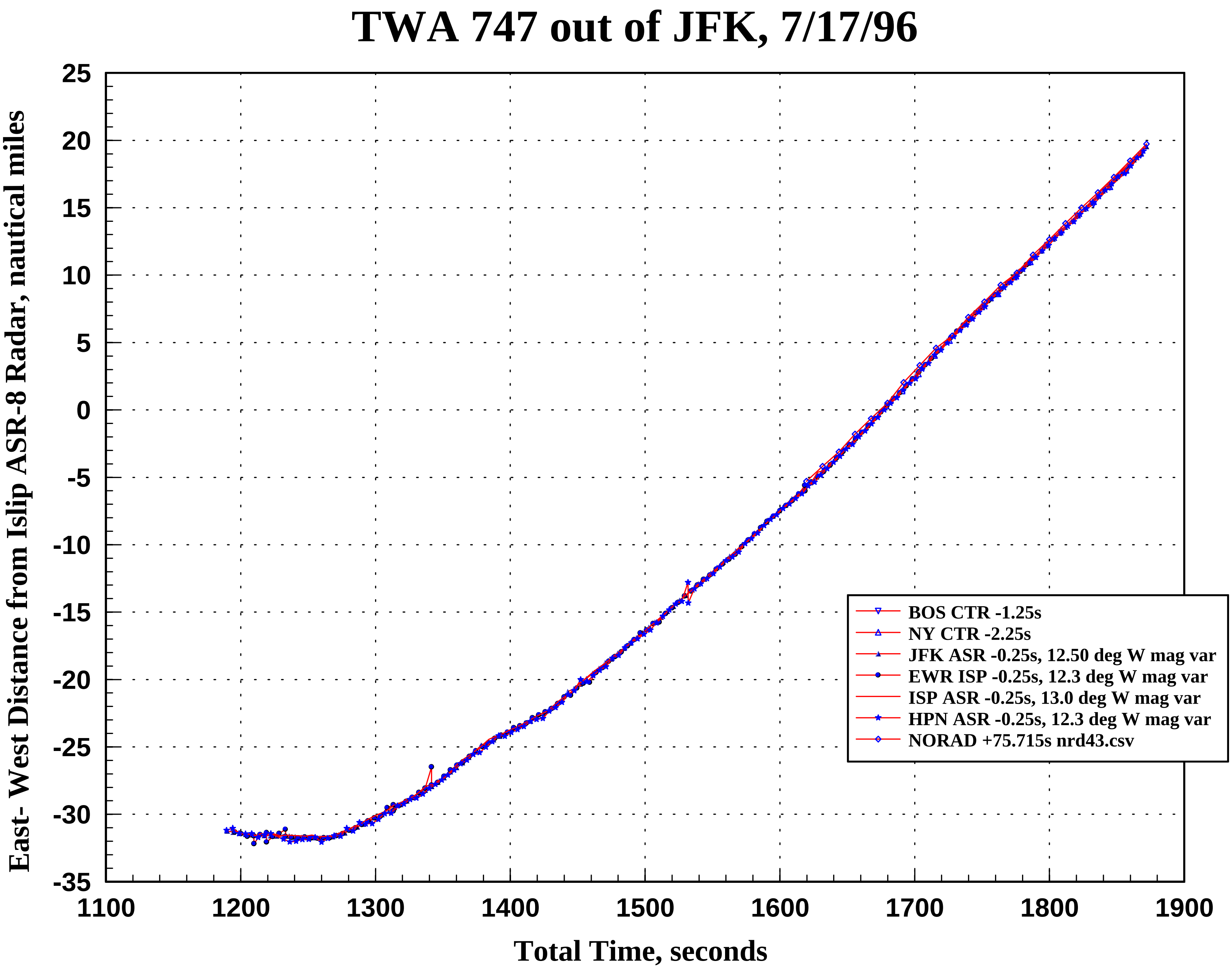
Attachment III-17


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
MSL Altitude/100, feet
135
134
133
132
131
130
129
128
127
126
125
1750
1760
1770
1780
1790
1800
Total Time, seconds
2029:15 CAM1 comment about #4 engine fuel flow indicator
2029:35 CAM1 comment about trim

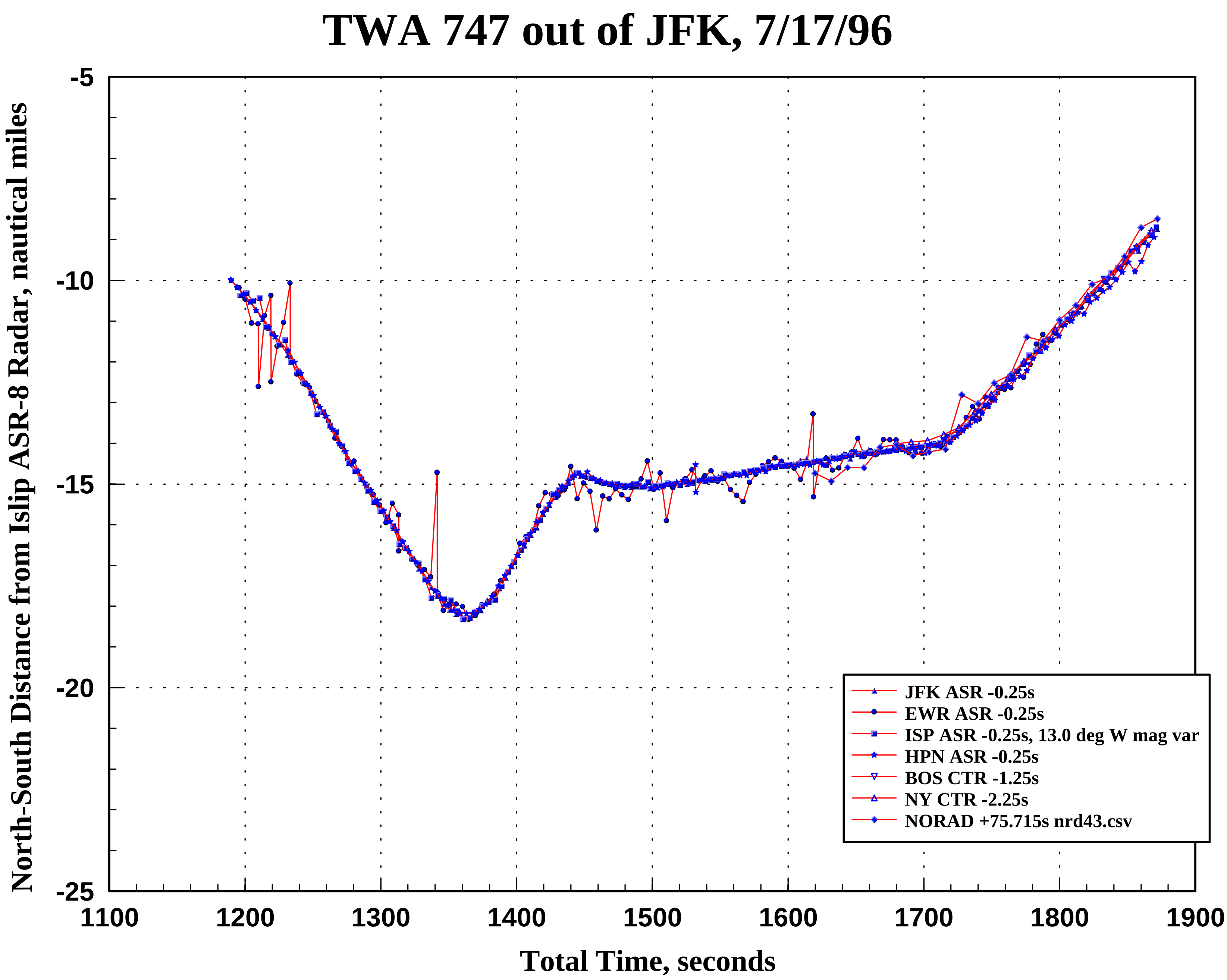

TWA 747 out of JFK, 7/17/96
JFK ASR -0.25s
EWR ASR -0.25s
ISP ASR -0.25s, 13.0 deg W mag var
HPN ASR -0.25s
CVR END OF RECORDING
FDR END OF RECORDING (INCL. .22s BUFFER)
BOS CTR -1.25s
NY CTR -2.25s
first JFK ASR primary consistent w/TWA breakup
1st ISP ASR primary consistent w/TWA breakup
1st HPN ASR primary consistent w/TWA breakup
FDR MSL ALT (30.03), BOS CTR Voice Time
NAVY -2.80s nvyrp43.csv
NORAD +75.715s nrd43.csv
MSL Altitude/100, feet
135
134
133
132
131
130
129
128
127
126
125
1800
1810
1820
1830
1840
1850
Total Time, seconds
2030:42 CAM (sound of clunk)
2030:18 CAM1 climb thrust
2030:15 BOS CTR TWA800 climb and
maintain 15,000 ft

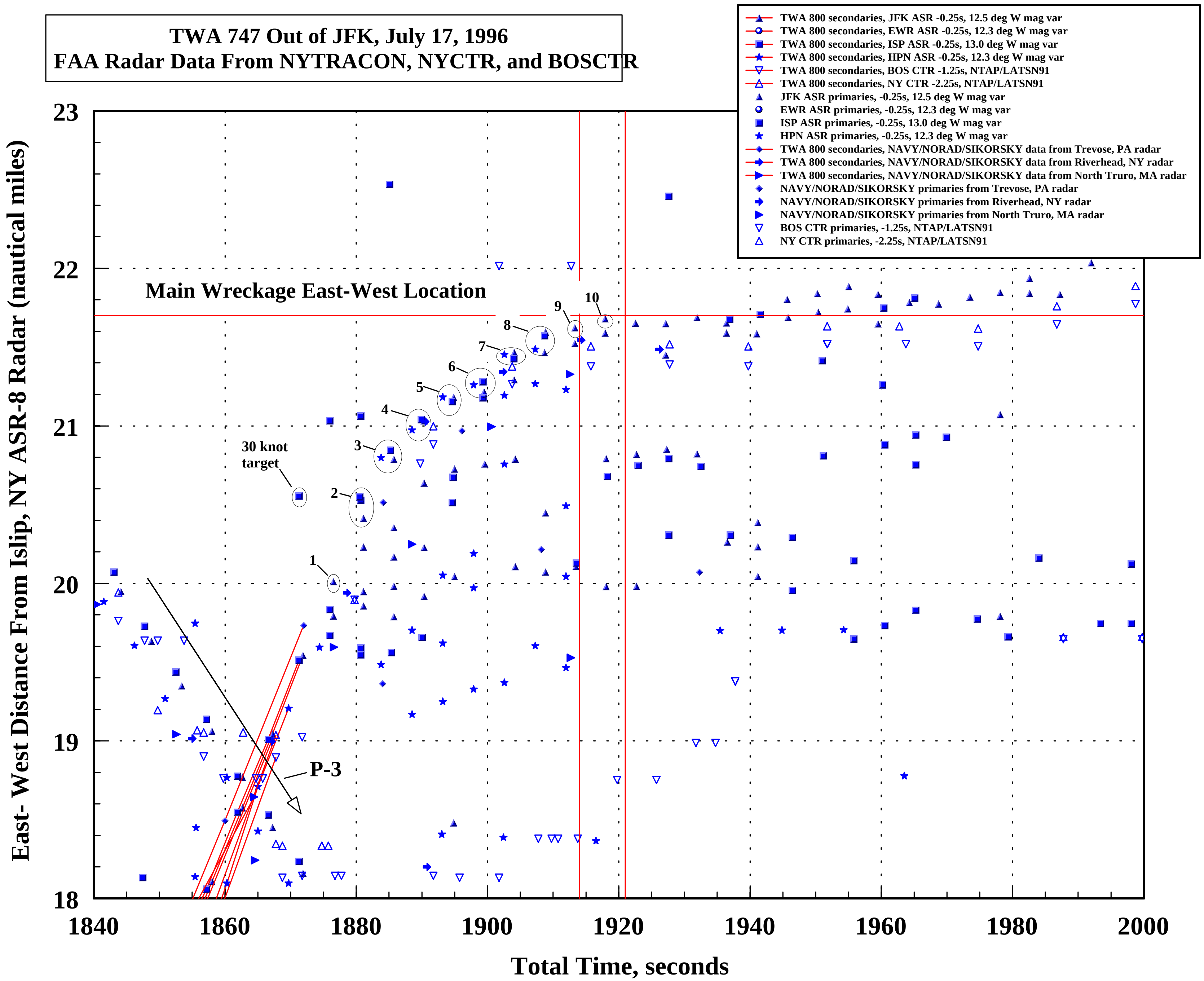
TWA 747 out of JFK, 7/17/96

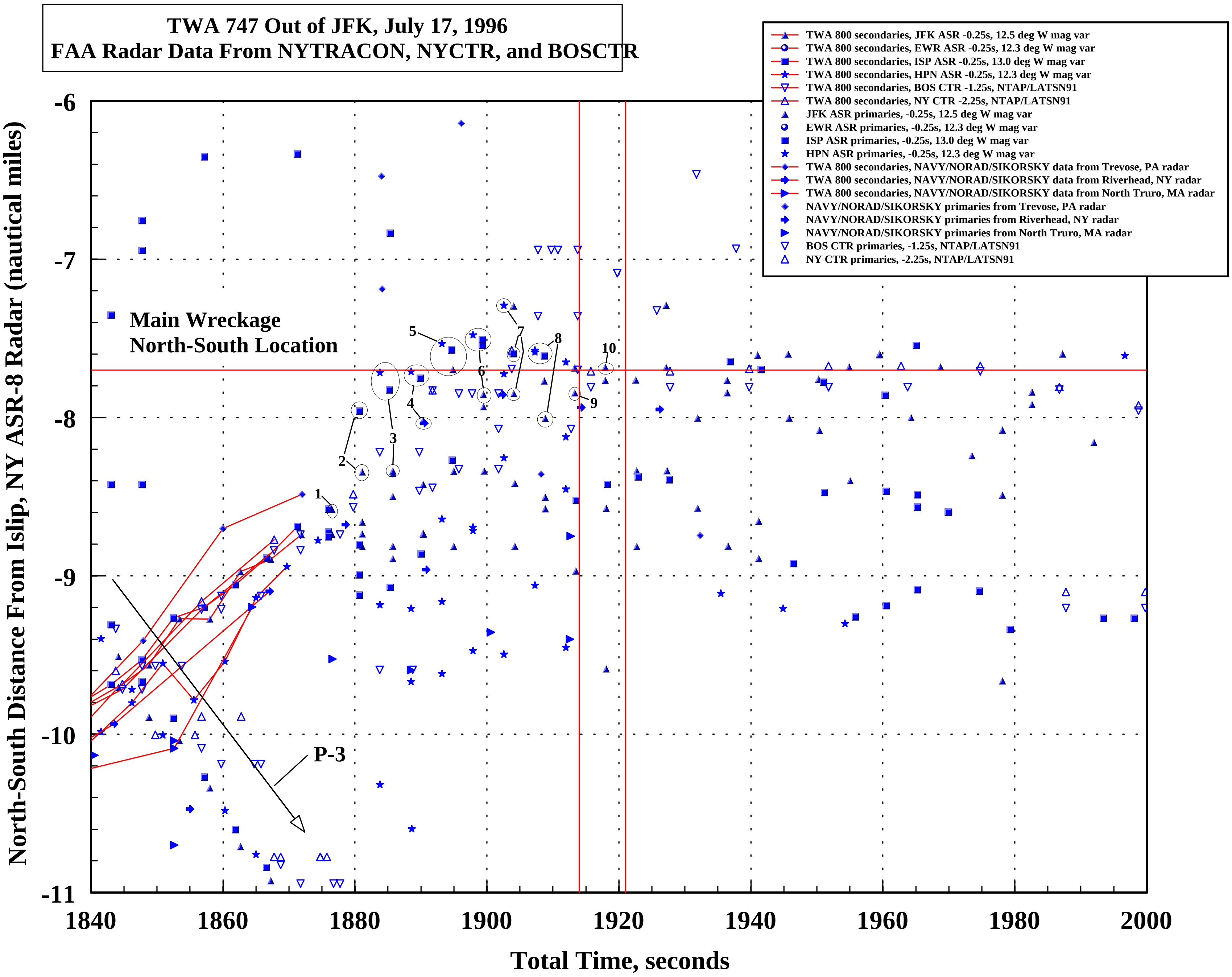




TWA 747 out of JFK, 7/17/96
East- West Distance from Islip ASR-8 Radar, nautical miles
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
1100
1200
1300
1400
1500
1600
1700
1800
1900
Total Time, seconds
BOS CTR -1.25s
NY CTR -2.25s
JFK ASR -0.25s, 12.50 deg W mag var
EWR ISP -0.25s, 12.3 deg W mag var
ISP ASR -0.25s, 13.0 deg W mag var
HPN ASR -0.25s, 12.3 deg W mag var
NORAD +75.715s nrd43.csv


TWA 747 out of JFK, 7/17/96
North-South Distance from Islip ASR-8 Radar, nautical miles
Total Time, seconds
-5
-10
-15
-20
-25
1100
1200
1300
1400
1500
1600
1700
1800
1900
JFK ASR -0.25s
EWR ASR -0.25s
ISP ASR -0.25s, 13.0 deg W mag var
HPN ASR -0.25s
BOS CTR -1.25s
NY CTR -2.25s
NORAD +75.715s nrd43.csv


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, HPN ASR -0.25s, 12.3 deg W mag var
TWA 800 secondaries, BOS CTR -1.25s, NTAP/LATSN91
TWA 800 secondaries, NY CTR -2.25s, NTAP/LATSN91
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
HPN ASR primaries, -0.25s, 12.3 deg W mag var
TWA 800 secondaries, NAVY/NORAD/SIKORSKY data from Trevose, PA radar
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 Trevose, PA radar
NAVY/NORAD/SIKORSKY primaries from Riverhead, NY radar
NAVY/NORAD/SIKORSKY primaries from North Truro, MA radar
BOS CTR primaries, -1.25s, NTAP/LATSN91
NY CTR primaries, -2.25s, NTAP/LATSN91
Main Wreckage East-West Location
30 knot target
P-3
1
2
3
4
5
6
7
8
9
10
East- West Distance From Islip, NY ASR-8 Radar (nautical miles)
Total Time, seconds
18
19
20
21
22
23
1840
1860
1880
1900
1920
1940
1960
1980
2000

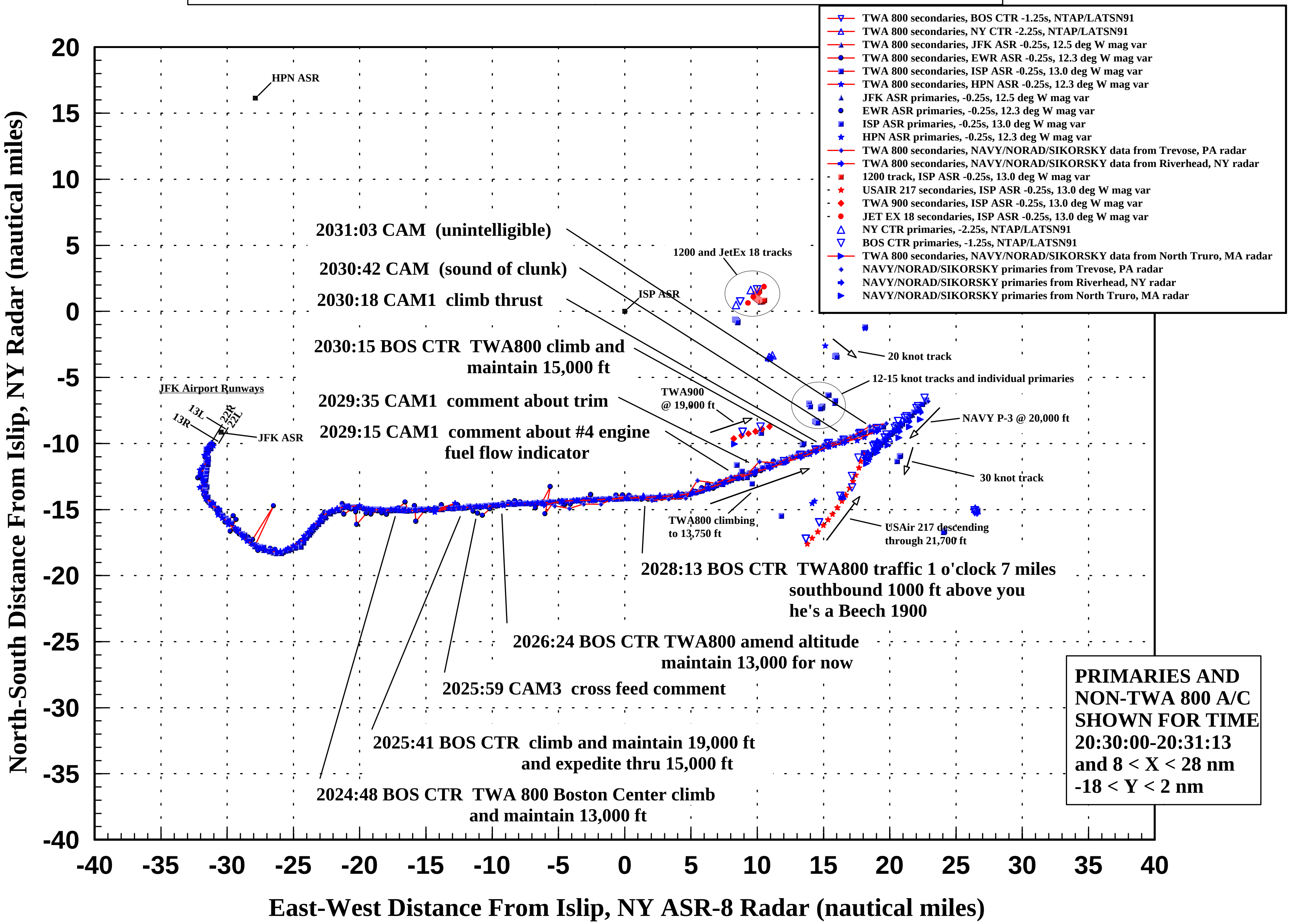


TWA 747 Out of JFK, July 17, 1996
FAA Radar Data From NYTRACON, NYCTR, and BOSCTR
TWA 800 secondaries, JFK ASR -0.25s, 12.5 deg W mag var
TWA 800 secondaries, EWR ASR -0.25s, 12.3 deg W mag var
TWA 800 secondaries, ISP ASR -0.25s, 13.0 deg W mag var
TWA 800 secondaries, HPN ASR -0.25s, 12.3 deg W mag var
TWA 800 secondaries, BOS CTR -1.25s, NTAP/LATSN91
TWA 800 secondaries, NY CTR -2.25s, NTAP/LATSN91
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
HPN ASR primaries, -0.25s, 12.3 deg W mag var
TWA 800 secondaries, NAVY/NORAD/SIKORSKY data from Trevose, PA radar
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 Trevose, PA radar
NAVY/NORAD/SIKORSKY primaries from Riverhead, NY radar
NAVY/NORAD/SIKORSKY primaries from North Truro, MA radar
BOS CTR primaries, -1.25s, NTAP/LATSN91
NY CTR primaries, -2.25s, NTAP/LATSN91
Main Wreckage
North-South Location
P-3
1
2
3
4
5
6
7
8
9
10
-6
-7
-8
-9
-10
-11
North-South Distance From Islip, NY ASR-8 Radar (nautical miles)
1840
1860
1880
1900
1920
1940
1960
1980
2000
Total Time, seconds

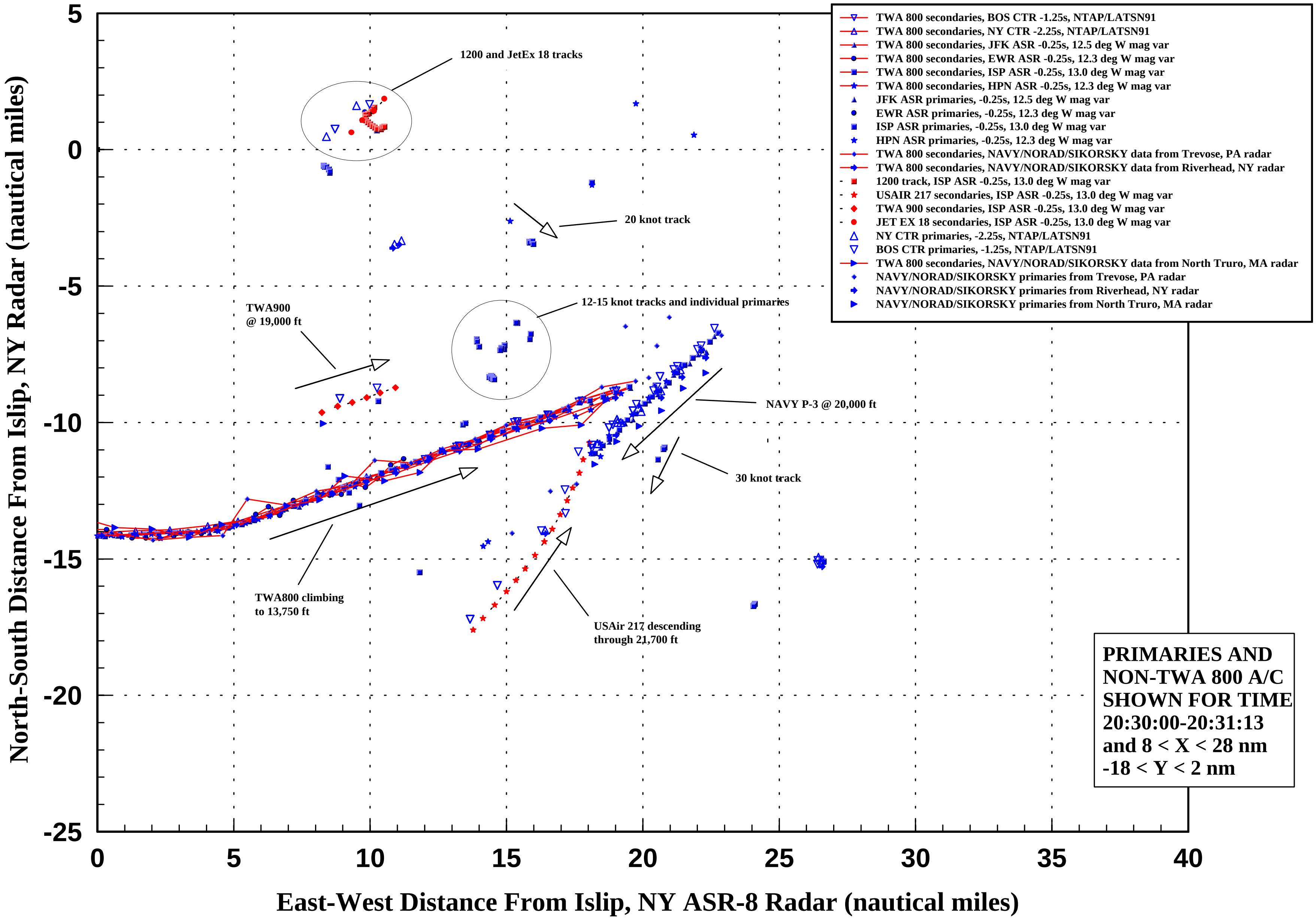
Attachment IV

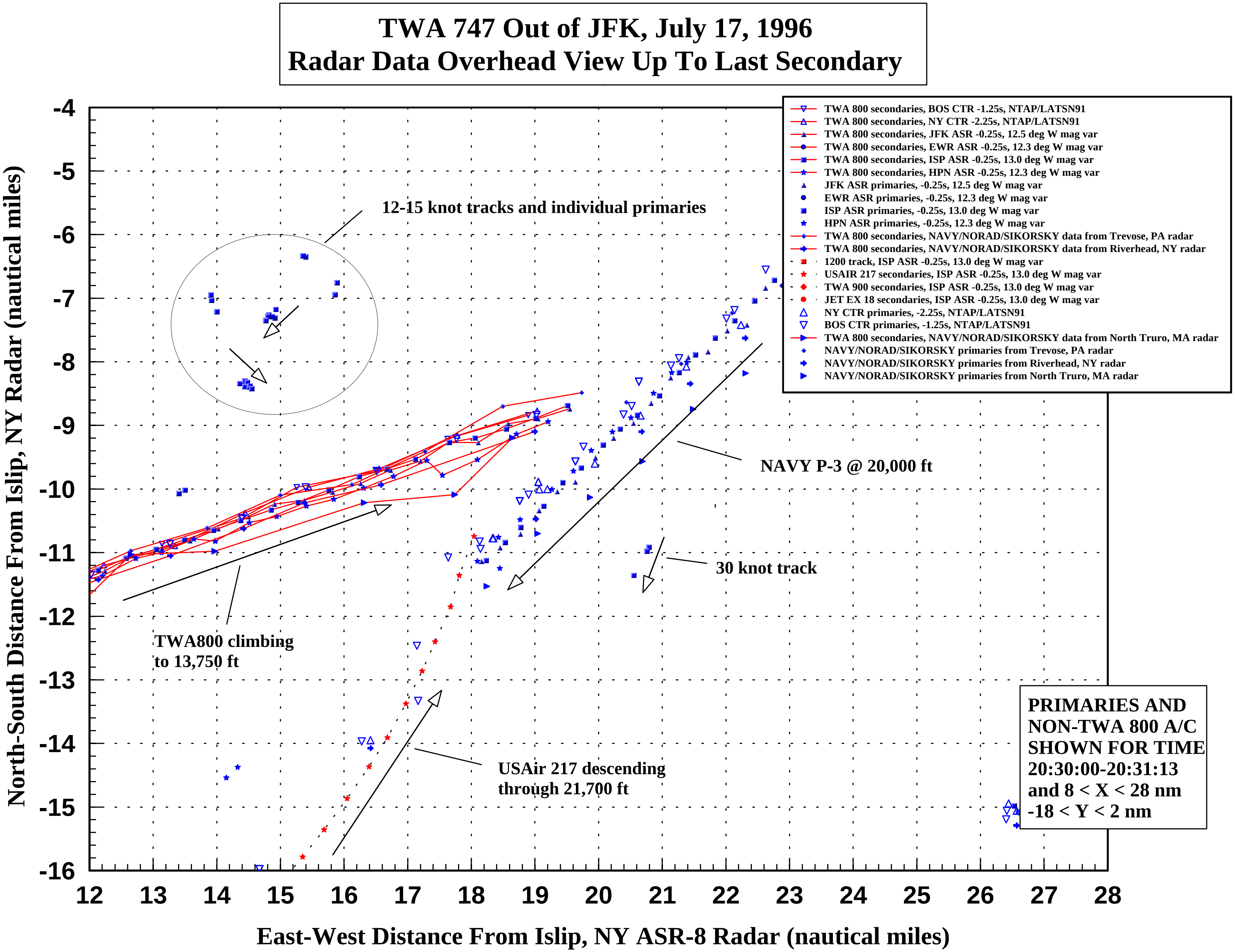
X versus Y Graphs

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

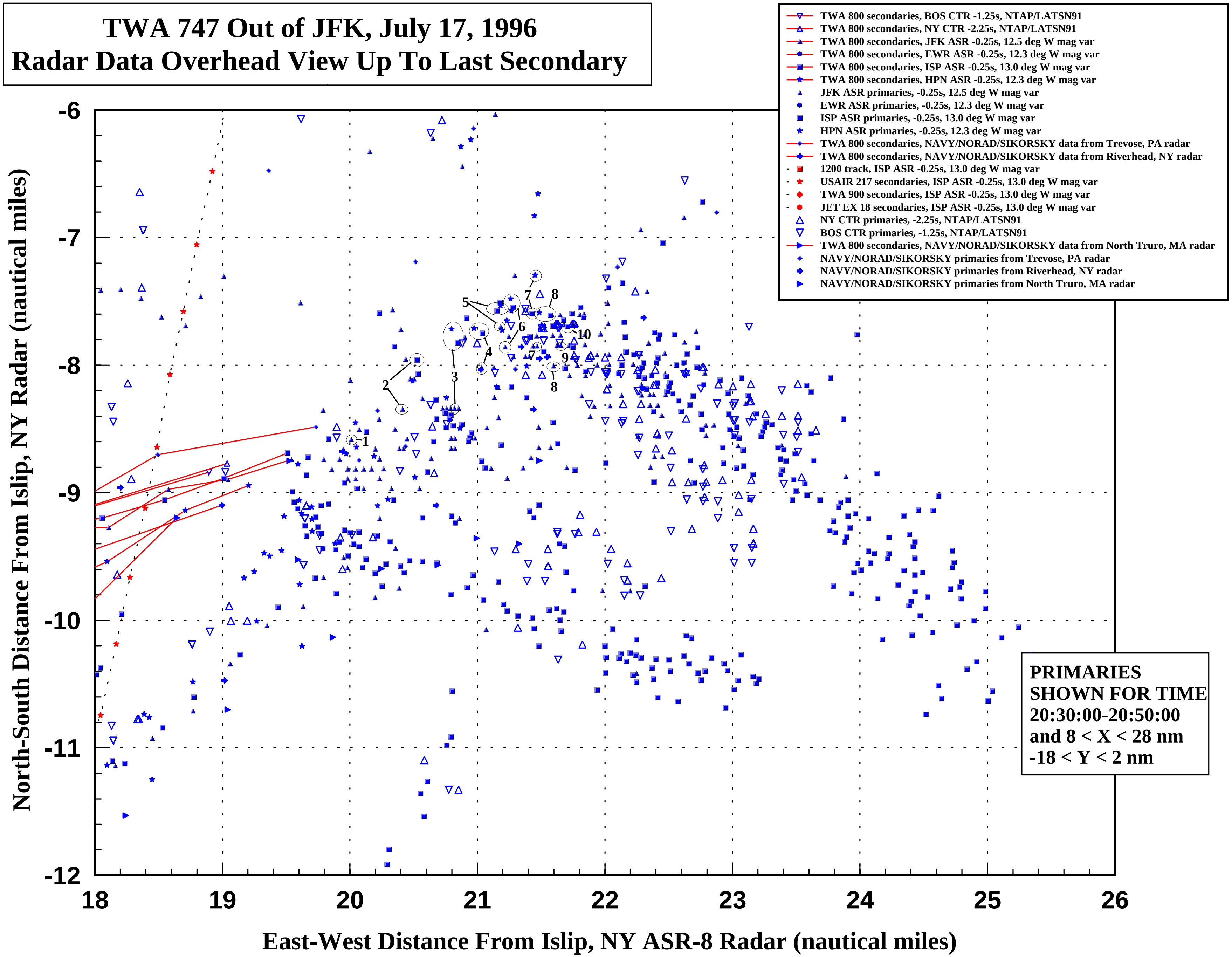


TWA 747 Out of JFK, July 17, 1996
Radar Data Overhead View Up To Last Secondary

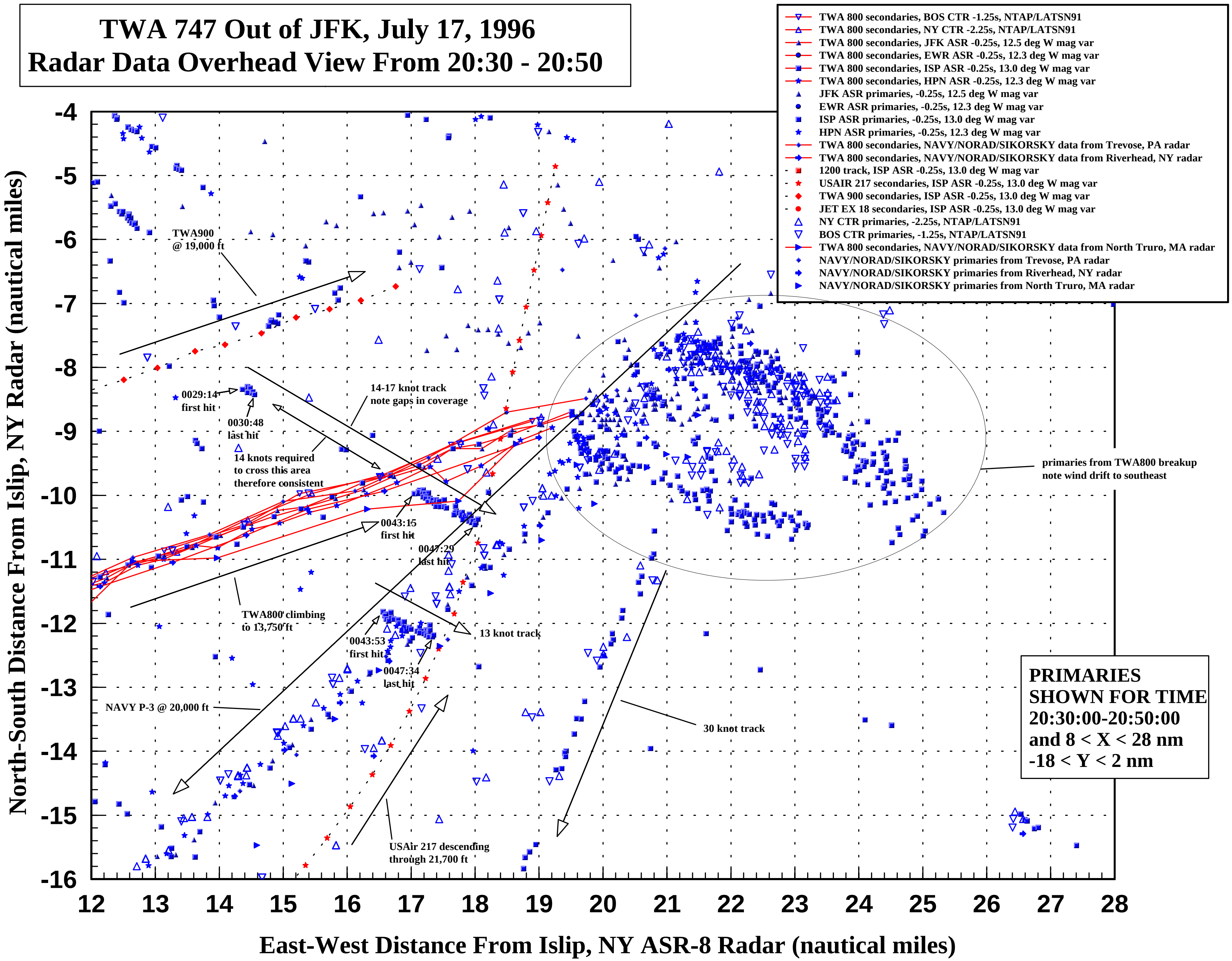




TWA 747 Out of JFK, July 17, 1996
Radar Data Overhead View Up To Last Secondary
TWA 800 secondaries, BOS CTR -1.25s, NTAP/LATSN91
TWA 800 secondaries, NY CTR -2.25s, NTAP/LATSN91
TWA 800 secondaries, JFK ASR -0.25s, 12.5 deg W mag var
TWA 800 secondaries, EWR ASR -0.25s, 12.3 deg W mag var
TWA 800 secondaries, ISP ASR -0.25s, 13.0 deg W mag var
TWA 800 secondaries, HPN ASR -0.25s, 12.3 deg W mag var
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
HPN ASR primaries, -0.25s, 12.3 deg W mag var
TWA 800 secondaries, NAVY/NORAD/SIKORSKY data from Trevose, PA radar
TWA 800 secondaries, NAVY/NORAD/SIKORSKY data from Riverhead, NY radar
1200 track, ISP ASR -0.25s, 13.0 deg W mag var
USAIR 217 secondaries, ISP ASR -0.25s, 13.0 deg W mag var
TWA 900 secondaries, ISP ASR -0.25s, 13.0 deg W mag var
JET EX 18 secondaries, ISP ASR -0.25s, 13.0 deg W mag var
NY CTR primaries, -2.25s, NTAP/LATSN91
BOS CTR primaries, -1.25s, NTAP/LATSN91
TWA 800 secondaries, NAVY/NORAD/SIKORSKY data from North Truro, MA radar
NAVY/NORAD/SIKORSKY primaries from Trevose, PA radar
NAVY/NORAD/SIKORSKY primaries from Riverhead, NY radar
NAVY/NORAD/SIKORSKY primaries from North Truro, MA radar
12-15 knot tracks and individual primaries
NAVY P-3 @ 20,000 ft
30 knot track
TWA800 climbing
to 13,750 ft
USAir 217 descending
through 21,700 ft
PRIMARIES AND
NON-TWA 800 A/C
SHOWN FOR TIME
20:30:00-20:31:13
and 8 < X < 28 nm
-18 < Y < 2 nm
North-South Distance From Islip, NY Radar (nautical miles)
East-West Distance From Islip, NY ASR-8 Radar (nautical miles)
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
-14
-15
-16
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28

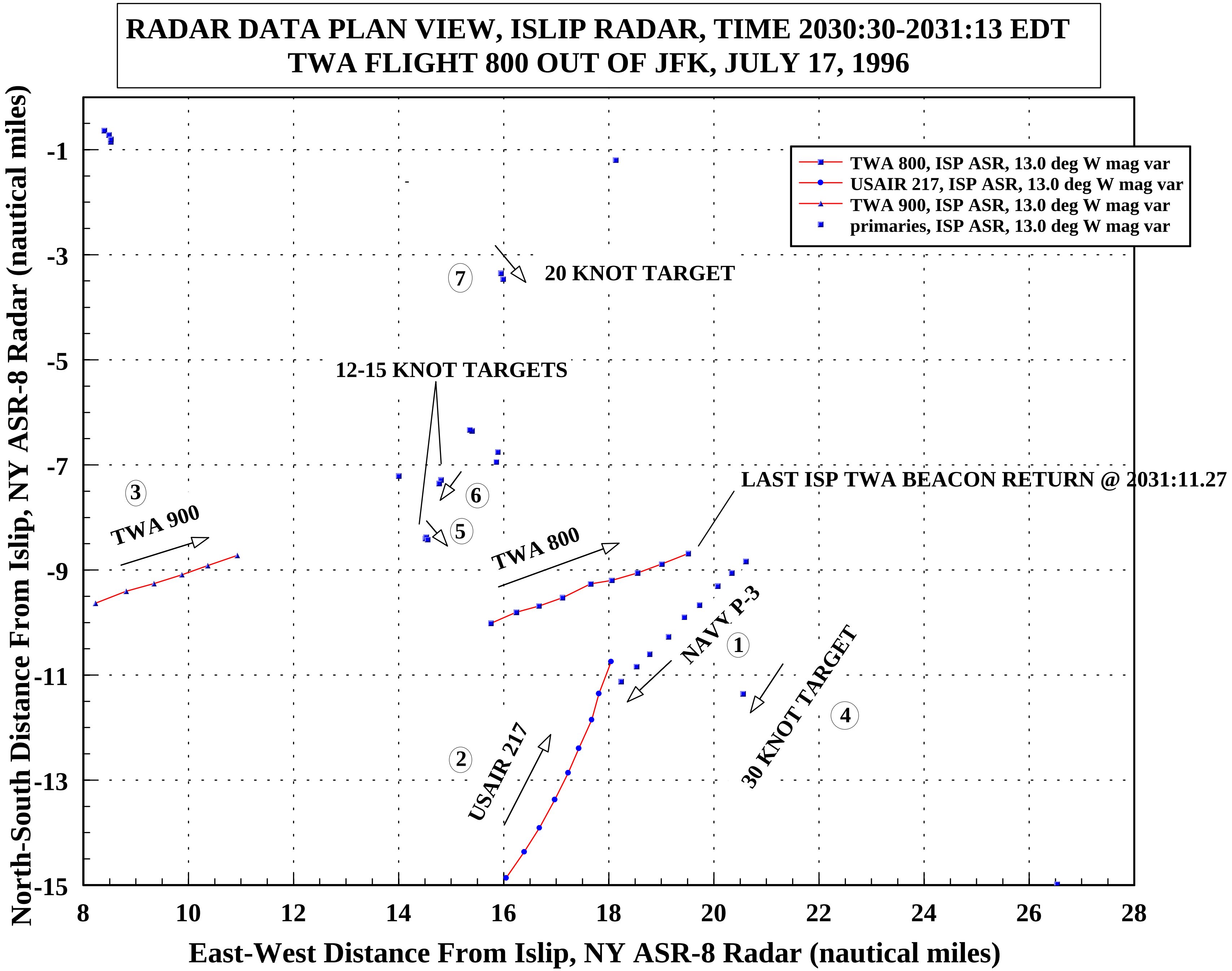


Attachment IV-4


TWA 747 Out of JFK, July 17, 1996
Radar Data Overhead View From 20:30 - 20:50
TWA 800 secondaries, BOS CTR -1.25s, NTAP/LATSN91
TWA 800 secondaries, NY CTR -2.25s, NTAP/LATSN91
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, HPN ASR -0.25s, 12.3 deg W mag var
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
HPN ASR primaries, -0.25s, 12.3 deg W mag var
TWA 800 secondaries, NAVY/NORAD/SIKORSKY data from Trevose, PA radar
TWA 800 secondaries, NAVY/NORAD/SIKORSKY data from Riverhead, NY radar
1200 track, ISP ASR -0.25s, 13.0 deg W mag var
USAIR 217 secondaries, ISP ASR -0.25s, 13.0 deg W mag var
TWA 900 secondaries, ISP ASR -0.25s, 13.0 deg W mag var
JET EX 18 secondaries, ISP ASR -0.25s, 13.0 deg W mag var
NY CTR primaries, -2.25s, NTAP/LATSN91
BOS CTR primaries, -1.25s, NTAP/LATSN91
TWA 800 secondaries, NAVY/NORAD/SIKORSKY data from North Truro, MA radar
NAVY/NORAD/SIKORSKY primaries from Trevose, PA radar
NAVY/NORAD/SIKORSKY primaries from Riverhead, NY radar
NAVY/NORAD/SIKORSKY primaries from North Truro, MA radar
TWA900
@ 19,000 ft
0029:14 first hit
0030:48 last hit
14-17 knot track
note gaps in coverage
14 knots required
to cross this area
therefore consistent
0043:15 first hit
0047:29 last hit
TWA800 climbing
to 13,750 ft
0043:53 first hit
0047:34 last hit
13 knot track
NAVY P-3 @ 20,000 ft
30 knot track
USAir 217 descending
through 21,700 ft
primaries from TWA800 breakup
note wind drift to southeast
PRIMARIES
SHOWN FOR TIME
20:30:00-20:50:00
and 8 < X < 28 nm
-18 < Y < 2 nm
North-South Distance From Islip, NY Radar (nautical miles)
East-West Distance From Islip, NY ASR-8 Radar (nautical miles)
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
-14
-15
-16
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28

Attachment V

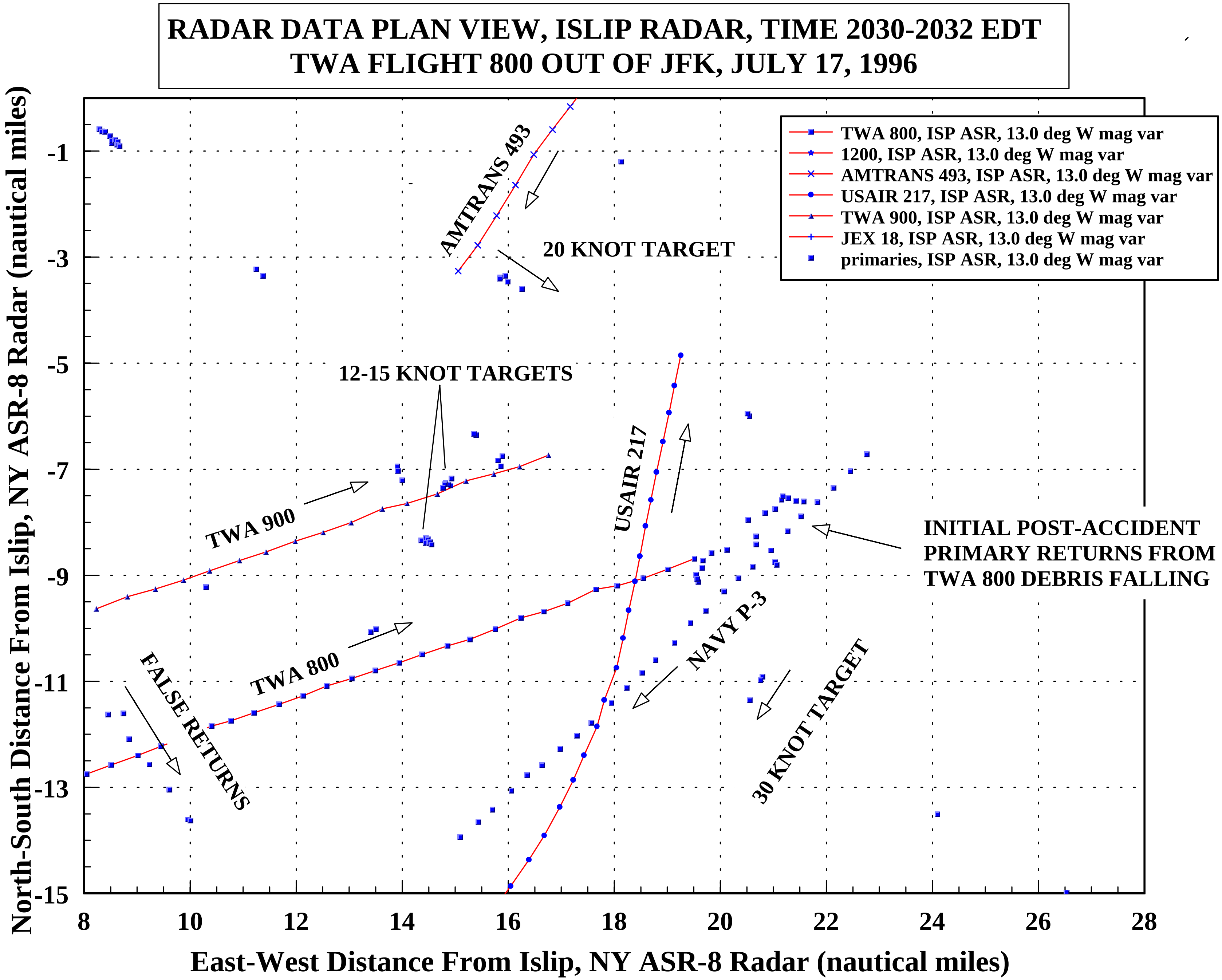
Vehicle/Object Identification Graphs



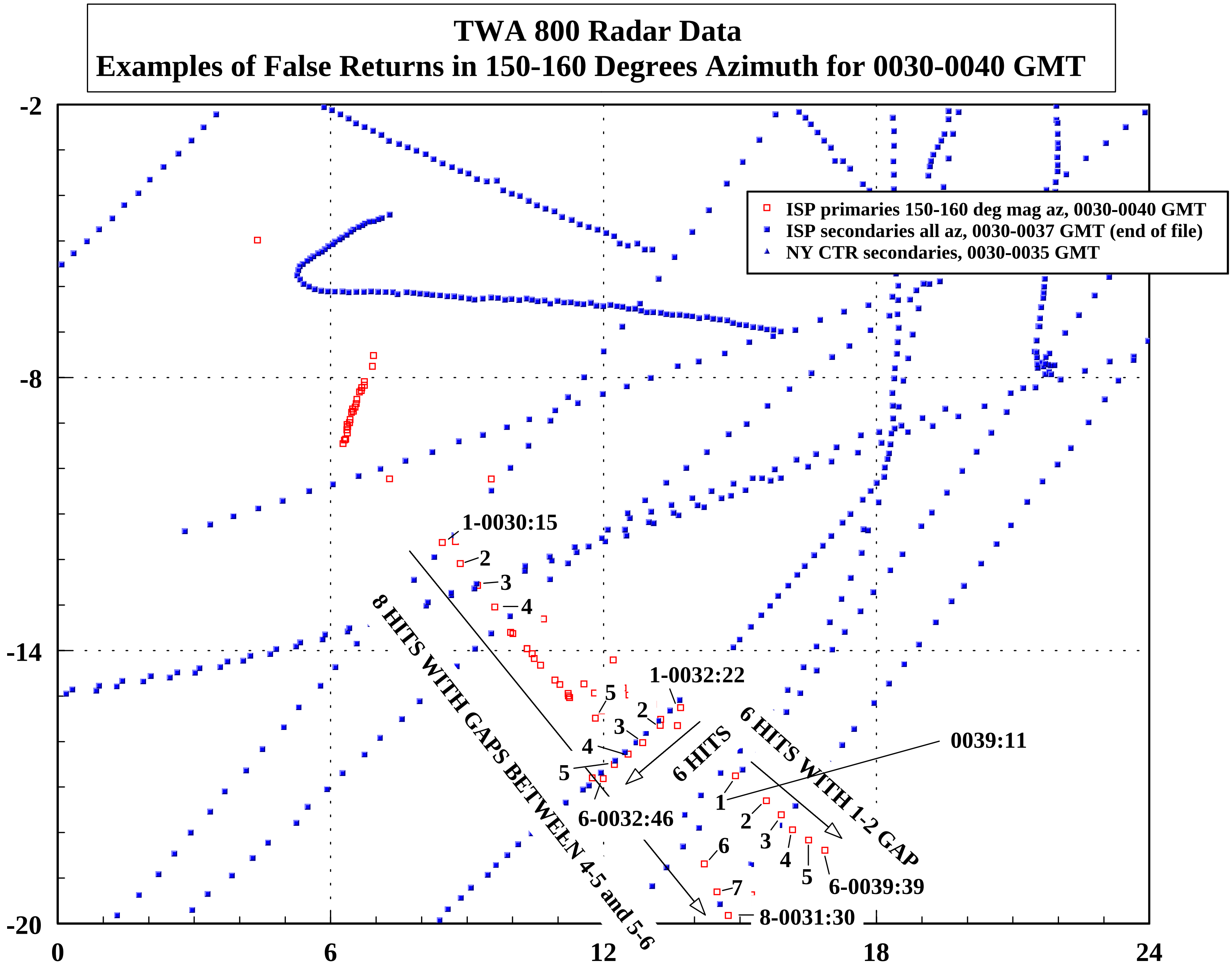
Attachment V-1

Attachment VI

Islip ASR False Primary Return Graphs



RADAR DATA PLAN VIEW, ISLIP RADAR, TIME 2030-2032 EDT
TWA FLIGHT 800 OUT OF JFK, JULY 17, 1996
TWA 800, ISP ASR, 13.0 deg W mag var
1200, ISP ASR, 13.0 deg W mag var
AMTRANS 493, ISP ASR, 13.0 deg W mag var
USAIR 217, ISP ASR, 13.0 deg W mag var
TWA 900, ISP ASR, 13.0 deg W mag var
JEX 18, ISP ASR, 13.0 deg W mag var
primaries, ISP ASR, 13.0 deg W mag var
AMTRANS 493
20 KNOT TARGET
12-15 KNOT TARGETS
USAIR 217
TWA 900
INITIAL POST-ACCIDENT
PRIMARY RETURNS FROM
TWA 800 DEBRIS FALLING
NAVY P-3
TWA 800
FALSE RETURNS
30 KNOT TARGET
-1
-3
-5
-7
-9
-11
-13
-15
8
10
12
14
16
18
20
22
24
26
28
North-South Distance From Islip, NY ASR-8 Radar (nautical miles)
East-West Distance From Islip, NY ASR-8 Radar (nautical miles)



Attachment VI-2

FUNDAMENTALS OF PRIMARY AND SECONDARY SURVEILLANCE RADAR

ETM 12-0-1

FIRST EDITION

SIXTEENTH PRINTING

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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 parastic 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.