Project Report
ATC-300

ASR-8/TDX-2000 Performance Analysis: Evaluation of Multiple-Time-Around-Detection (MTAD) Algorithm and Final Report

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16. Abstract

This report documents the analysis of and subsequent improvements to the performance of the ASR-8/TDX-2000 digitizer equipment combination. Working at the FAA's Palm Springs, CA and Williams (Mesa, AZ) ASR-8 facilities, data was methodically collected and analyzed to isolate the causes of reported correlated radar-only tracks that were being dropped or were never initiated. These problems were subsequently fixed via hard and soft parameter changes in the TDX-2000. A significant study was also undertaken in conjunction with the Sensis Corporation to improve the TDX-2000's capability to reject returns from multiple-time-around detections. The details of that algorithm modification and the results of follow-on testing and analysis are described. Final conclusions on the status of the project are also included.

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

1. PROGRAM HISTORY

In December of 1999, the Palm Springs terminal radar system was called out of service due to lack of acceptable radar coverage in the operational airspace. Local, regional, and national Federal Aviation Administration personnel formed a tiger team to investigate the many unsatisfactory condition reports (UCRs) that resulted in termination of service, with the immediate goal of restoring service and the long-range intention of improving the performance and reliability of the system. Issues included inadequate site power and grounding, poor overall system reliability, intermittent primary surveillance drops, intermittent secondary radar reflections, and communications problems between the radar site and the terminal radar approach control (TRACON) facility. In addition, the PSP ASR-8 radar site is located in an extremely challenging radar environment where it must contend with excessive stationary and moving ground clutter, as well as severe weather phenomena and anomalous propagation.

At the request of the Federal Aviation Administration (AAF-2), Lincoln Laboratory was asked in March of 2000 to conduct an independent evaluation of the Palm Springs system, focusing on the root causes of the primary radar performance problems. To that end, Laboratory personnel first visited the PSP site on 14-17 March 2000. Meetings with local and regional FAA personnel coupled with archived radar data yielded good preliminary information on the background and possible causes of the performance issues. Lincoln summarized these issues and offered near- and long-term recommendations for resolution in a letter dated 27 March 2000 (reference 92C-6192). The major impetus was to find the reason behind primary target 'drops' which could not be readily explained.

Follow-on visits to the site were conducted in April and May of 2000, to collect more radar data and information from site personnel. Key to the success of this testing was Lincoln's close working relationship not only with the radar technicians, but also with the air traffic controllers at the facility. It became clear that the poor primary surveillance performance was due to the combination of the ASR-8 and the TDX-2000 digitizer, as similar problems were being experienced at PSP and the Williams (IWA) ASR-8/TDX-2000 facility in Mesa, Arizona. There were three issues in common between the two systems: 1) incidents of 'drops' (i.e. missed hits) within well-established primary radar-only tracks; 2) incidents of primary radar-only tracks that never initiated; and, 3) excessive false alarms caused by multiple-time around detections (MTADs). The MTAD issue was severe at the IWA facility, particularly in the airspace surrounding the Scottsdale control tower, but was not a concern at the PSP facility. Working in tandem with FAA personnel and the Sensis Corporation (developers of the TDX-2000 digitizer), Lincoln conducted several systematic tests to isolate the track drop and track initiation problems. Subsequent analysis uncovered TDX-2000 track initiation parameters that had not been properly optimized for use with the ASR-8, and additional parameters that were inadvertently set incorrectly, resulting in poor tracker performance. New parameter values implemented by Sensis and the FAA demonstrated marked improvement in track initiation and maintenance during regression tests performed in late May. Details of this portion of the study can be found in a Lincoln letter to the FAA dated 7 June 2000 (reference 92C-6214).

A second level of study then began, to consider how best to mitigate the MTAD false alarms. The current Sensis algorithm in the TDX-2000 was preventing the majority of the false targets from correlating and ultimately appearing on the controller's displays as radar-only targets. However, due to the extreme nature of the phenomenon in the Scottsdale airspace, the system was still displaying an unacceptable number of false alarms. Sensis and Lincoln worked together again to develop several options for improvement of the algorithm, including use of extended secondary surveillance range, and use of track history. A technical plan to address the MTADs was issued by Lincoln (with Sensis' concurrence) in a letter dated 1 August 2000 (reference 92C-6223). At a technical interchange meeting (TIM) held the following week by the FAA, all parties agreed to an approach which would utilize track history and extended beacon range to improve the existing MTAD algorithm. Sensis began working on implementing this change in the fall of 2000.

Also during the August TIM, Air Traffic representatives from Palm Springs reported continuing target drop problems at the PSP facility. It was agreed that further data collection and analysis would be carried out to capture these and any other anomalies that were present. Lincoln returned to PSP on 13-17 November 2000 and executed another lengthy data collection. There was little evidence of any performance problems in the data collected during that week, and the consensus among local and Laboratory team members was that the system was operating at a level that one could not expect to exceed without major system modifications. Details of this study are in a 7 March 2001 Lincoln letter (reference 92C-6282).

Sensis completed work on the new MTAD algorithm in March of 2001. Lincoln personnel once again teamed with the FAA and Sensis to collect data and evaluate the performance of the new algorithm. A final data collection effort was launched at IWA on 27-28 March 2001. Details of the algorithm changes as well as the data collection effort and results follow. The report concludes with some final remarks on the Palm Springs effort.

2. MTAD ALGORITHM EVALUATION

2.1 MTAD THEORY

Multiple-time-around detections are inherent in pulsed radar systems (see Figure 1). In a radar's simplest form, a short burst of RF energy is released by the transmitter on a regular basis known as the pulse repetition interval (PRI). The inverse of the PRI is the pulse repetition frequency (PRF) of the radar. Refer to Figure 2. A radar operating with a PRF of 1000 Hz transmits a pulse every 1/1000 seconds (or 1 msec). Between transmitted pulses the radar 'listens' for energy returned from targets. In this case, this means that the receiver is open for energy returns for about 1 millisecond. If we divide this time by the 12.36 microsecond radar mile, this corresponds to 80.9 nautical miles of unambiguous range; that is, targets within 80.9 nmi of the radar will appear at their true range, and targets beyond 80.9 nmi will fold over in range into subsequent processing intervals. The normal processing range for a terminal airspace radar such as the ASR-8 is 60 nmi. Targets are processed out to the sixty mile range, are not processed from 60 nmi to the maximum unambiguous range (80.9 nmi here), and then resume being processed at zero range with the next transmit pulse.

Therefore, targets between 60 and 80.9 nmi will not appear. However, if a target beyond 80.9 nmi reflects adequate energy back to the receiver its return will fold over in range and appear at its true range minus the 80.9 nmi unambiguous range. As an example, a plane flying at 93 nmi will appear at 12.1 nmi during the next processing interval. This is an example of a second-time-around detection. These 'false' returns appear in most respects similar to real aircraft (i.e. they have a heading and velocity close to that of the real target) making them very difficult to eliminate without also eliminating real aircraft returns.

The ASR-8 has an option known as staggered PRF, where four different pulse repetition intervals are employed (see Figure 3). This is used primarily to help eliminate radar blind speeds (another inherent problem in pulsed radar systems), but is also useful in reducing false returns from MTADs. The bursts of transmit energy now come in a staggered pattern, repeating every four PRIs. Figure 3 shows the defined staggered PRIs for the ASR-8. The second PRI always corresponds to the average system PRF (site selectable), nominally 1040 Hz. If the selected site average PRF is higher or lower than 1040 Hz, the other pulse repetition frequencies increase or decrease proportionally as defined in Figure 3. Following the reasoning for a single PRF system given above, we find that each of the four PRIs corresponds to a unique unambiguous range. For the example shown in Figure 3, these ranges are 71, 78, 67, and 95 nmi. Given a target at 100 nmi from the radar, we see its return will fold over into the next processing interval for all four PRIs, yielding four false returns at 29, 22, 33, and 5 nmi, respectively. These ranges will increase or decrease as the true target's range from the radar increases or decreases, but the delta ranges between the false targets will remain the same.

In the case of a target whose range exceeds the sum of two consecutive pulse intervals, third-time-around reports result. For the example given, the third-time-around range starts at 145 nmi (i.e. 78 nmi + 67 nmi). For aircraft beyond this range, various combinations of second- and third-time reports can occur on the display, hence the reference to multiple-time-around detections. Although some of the resulting range deltas are the same as before, new ones are also introduced. Thus, it becomes more difficult to eliminate false returns strictly on the basis of the delta ranges between them.

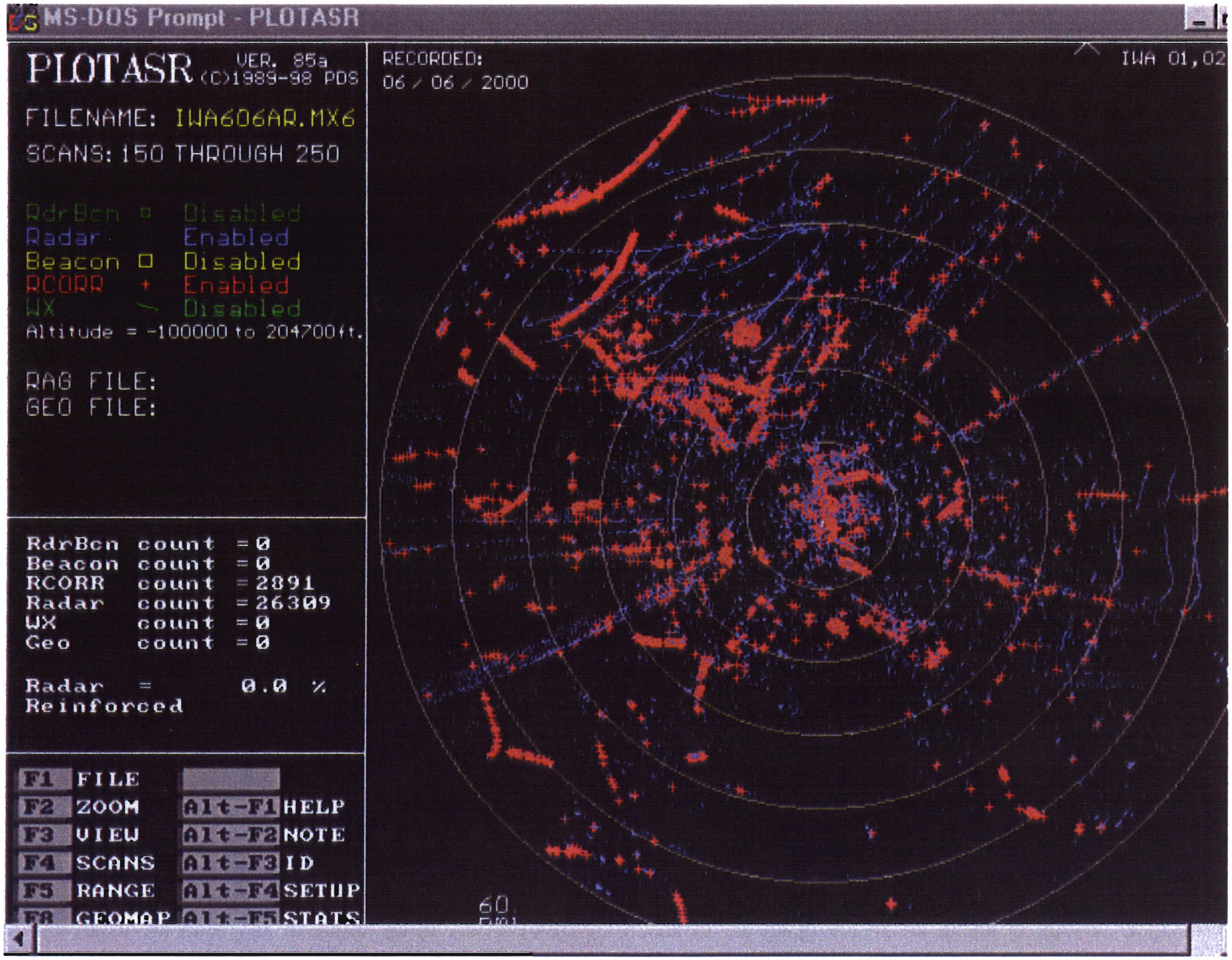

Figure 1. STAD Examples from IWA data.

Maximum Unambiguous Range for 1000 Hz PRF = (1/1000)/12.36 usec = 80.9 nautical miles

ASR-8 Processing Range = 60 nautical miles

True Target Range (for given example) = 93 nautical miles

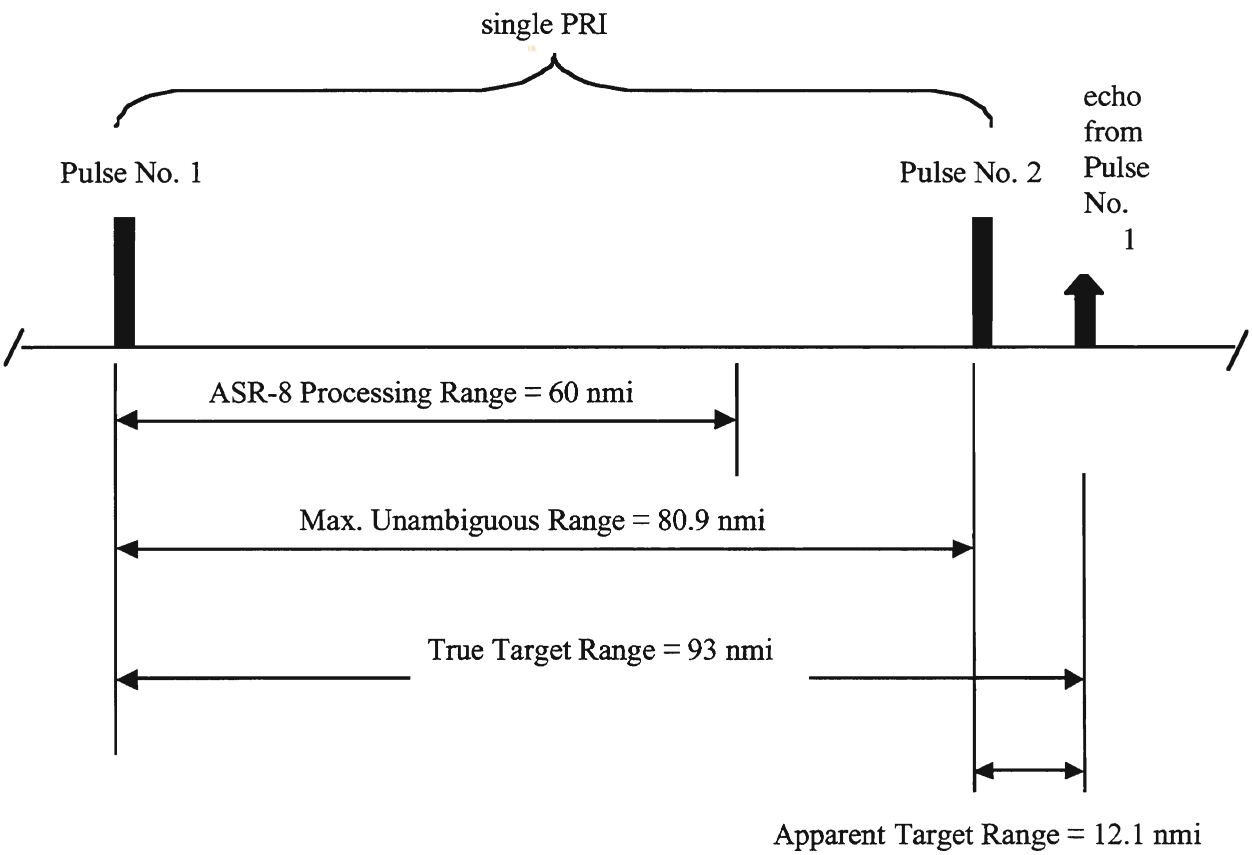

Figure 2. STADs for single PRF of 1000 Hz.

Defined ASR-8 pulse repetition intervals for nominal 1040 Hz PRF:

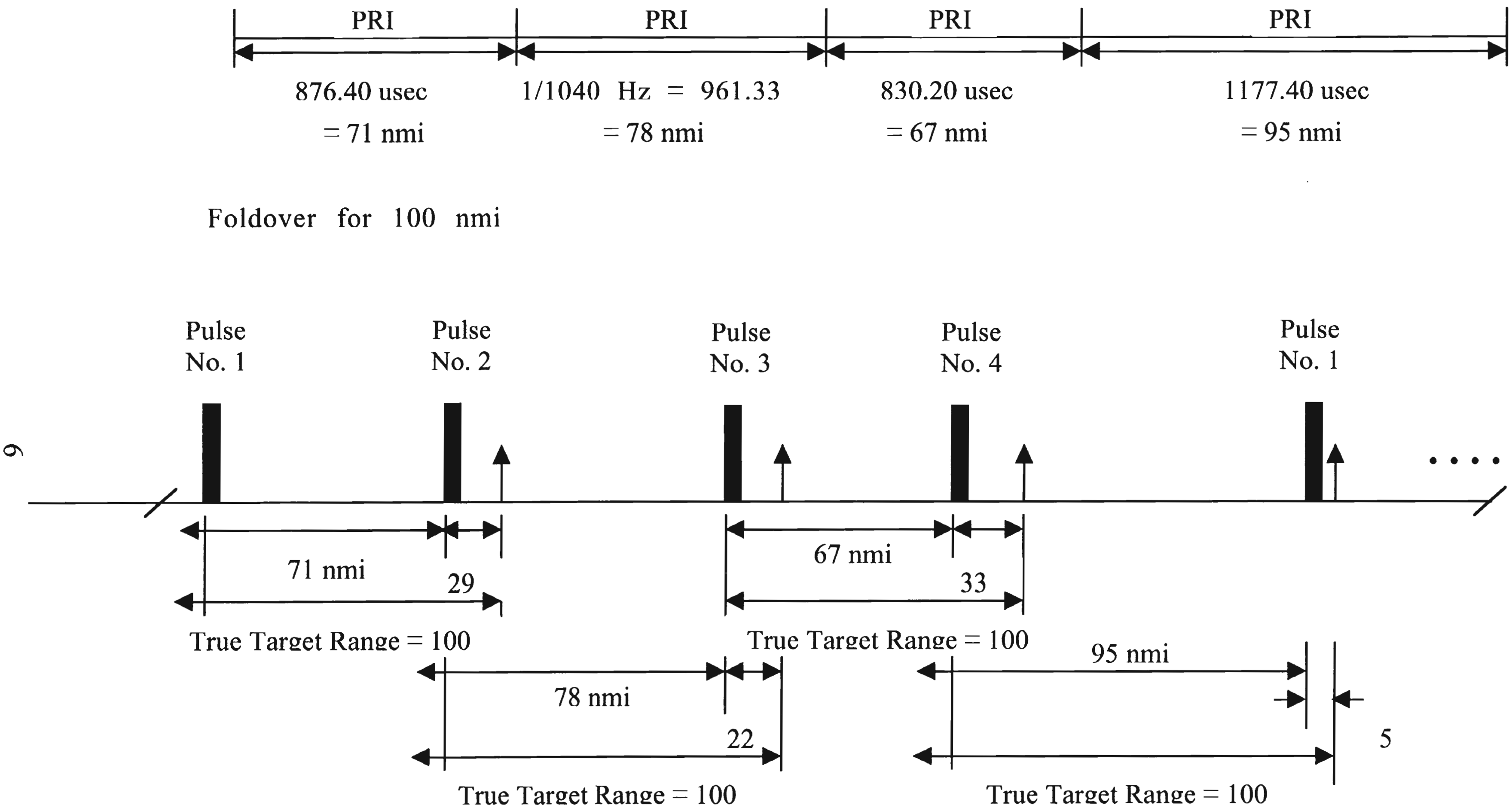

Figure 3. ASR-8 staggered PRF for 1040 Hz average.

2.2 MTAD DETECTION

The known delta range pattern is the key to eliminating false targets caused by MTADs. If the system PRIs are known, the processing interval can be searched for sets of primary radar-only targets offset from each other by the corresponding delta ranges. These sets of targets are identified as MTAD returns and flagged as false. Figures 4 and 5 show examples from the IWA data set of parabolic and radial second-time-around returns with consistent range offsets. Of course, one won't always have four false returns to work with. Given a target at 75 nmi using the same set of PRIs, we see that the target will yield a false return at 4 nmi in the first PRI, but will be at its true range in the second PRI (and in this case, it won't appear at all as the system does not process targets beyond 60 nmi). A false return will appear at 8 nmi in the third PRI, and will not appear in the fourth for the same reason given for the second PRI. Environmental reasons such as clutter can also cause a false target to disappear in a particular PRI, if the clutter return has larger amplitude than the second-time-around return. Multiple-time-around detections can also generate single returns.

As a final example, consider a long-range aircraft outbound from the radar. Its return will fold over one PRI at a time, creating first a single false target in the shortest interval, then another in the second shortest interval as the true target's range increases, and so on up to a maximum of four false returns. So, to operate with the ASR-8, the TDX-2000 MTAD algorithm must be flexible enough to work with anywhere from one to four false returns, eliminating MTAD targets, without compromising the declaration of true aircraft. This is not an insignificant task.

2.3 ORIGINAL SENSIS ALGORITHM

The original Sensis algorithm was designed to handle second-time-around detections (STADs) only, and required the operator to enter the four pulse repetition intervals from the radar into its database. From that, the TDX-2000 derived the delta ranges that would be evident between returns from second-time-around detections. An azimuth window must also be defined by the user (all second-time-around returns are expected to be within a small azimuth offset from each other), and a minimum velocity parameter (long-range aircraft seen by the radar tend to be at high altitudes, and hence moving at a minimum speed).

The algorithm looked one at a time at all primary radar-only target reports on a scan-by-scan basis and applied these range, azimuth, and velocity tests to them. First, the subject target was correlated to a track so that the minimum velocity test could be applied. Then if one or more other targets met the range and azimuth criteria relative to the subject report, it would be flagged as being a second-time-around detection. The other report or reports in this grouping would be tested in turn, and might or might not be labeled as second-time-around, depending upon the outcome of the velocity test. Thus it was possible for a real report to be labeled a STAD due to a coincidentally placed clutter return.

STAD information was then fed to the tracker. Tracks were maintained on all primary radar-only reports, even STADs, but this information was not fed back to the STAD algorithm to help with the STAD decision making process. Thus the algorithm did a good job of preventing correlation of STAD targets as long as there was more than one return from the four PRIs, but broke down when only one return was evident. Secondary radar (beacon) information was used to prevent real aircraft within the 60 nmi processing range that coincidentally met these range, azimuth, and velocity tests from being eliminated by the STAD algorithm.

The original Sensis algorithm had no way to detect single report STAD returns and flag them as false, nor was it designed to eliminate multiple-time-around returns due to the inconsistent range delta values that are created. As noted above, the single reports can be generated by long-range outbound aircraft that are only folding over in the shortest PRI, or because environmental reasons such as clutter are preventing declaration of false returns in the other PRIs. Long-range inbound aircraft will also generate one report when the true range becomes small enough to only fold over in the shortest interval.

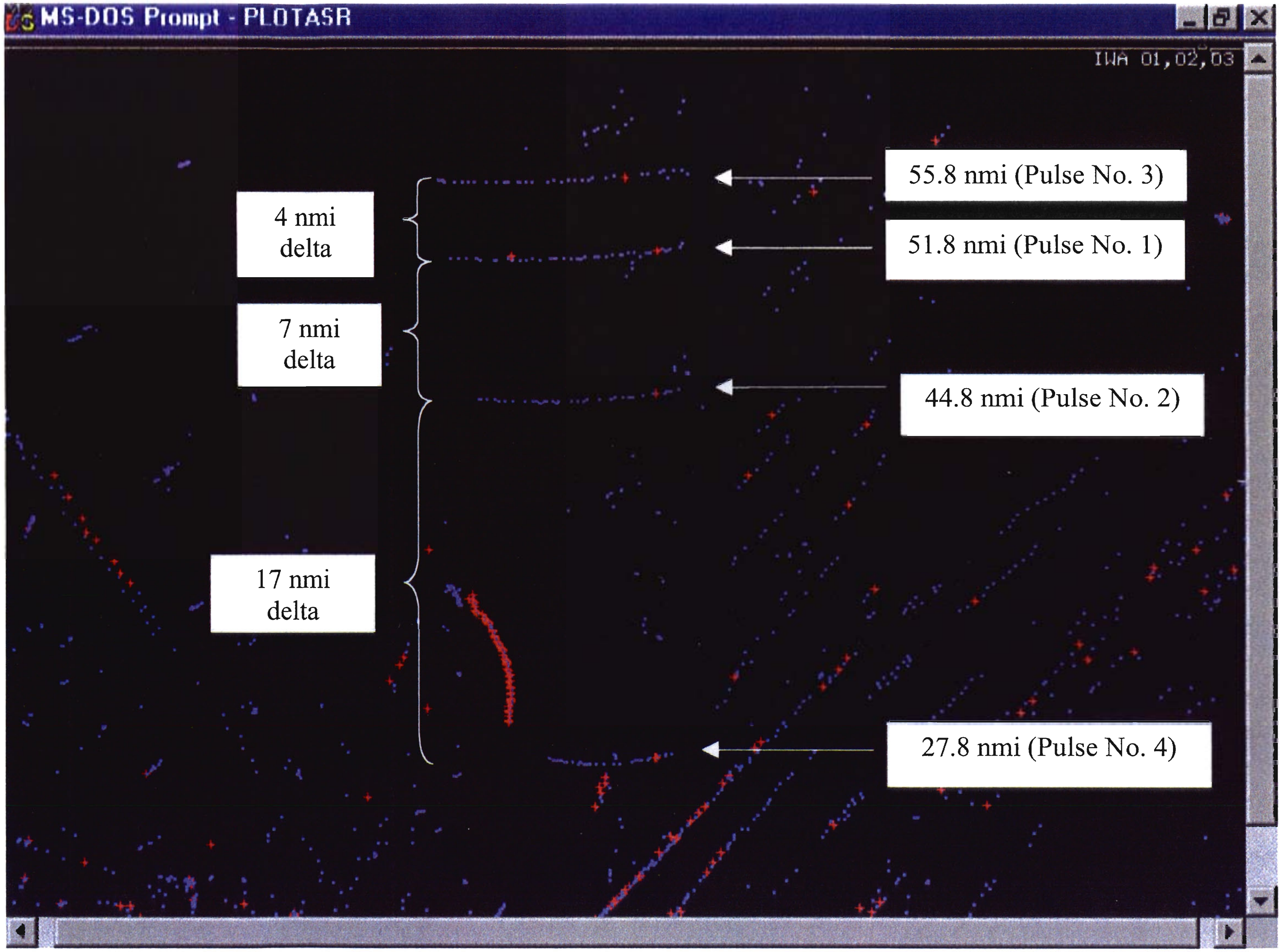

Figure 4. Parabolic STAD returns from IWA data.

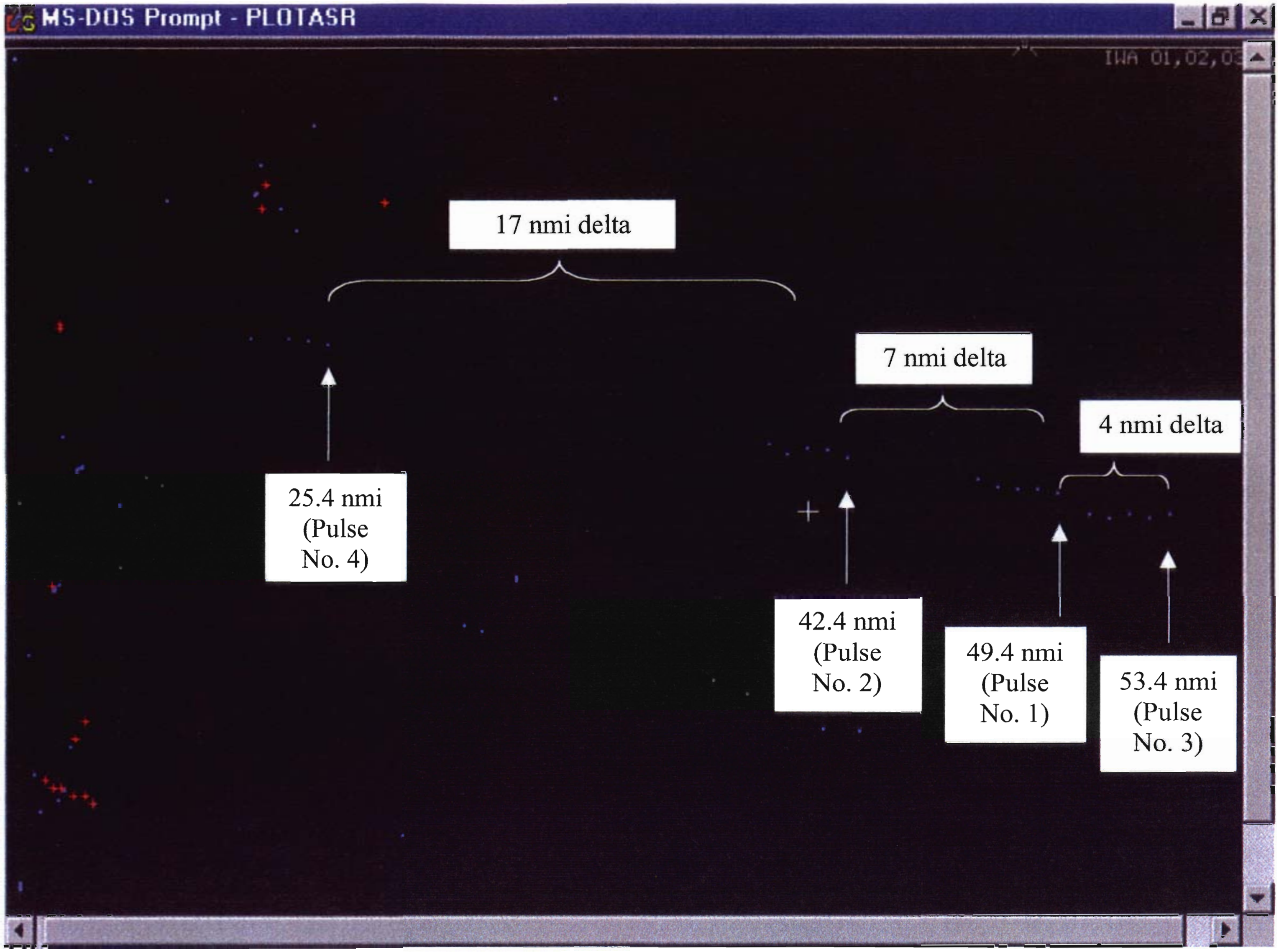

Figure 5. Radial STAD returns from IWA data.

2.4 MODIFIED SENSIS ALGORITHM

The new algorithm developed by Sensis in cooperation with Lincoln uses a three-fold approach to improve the detection and elimination of false alarms from multiple-time-around detections.[1] First, additional logic is added to the current PRI-based processing technique to score tracks as possible STADs. This logic increments or decrements the score based on whether a potential STAD plot associated with one or more other tracks at appropriate STAD ranges, or if it associated with a beacon reply. Second, the TDX beacon processing range is extended to 200 nmi and is used to associate with potential MTAD returns. Third, in the event that a plot does not meet any of the above criteria, the tracking logic may delete the plot based on prior track history. Scoring logic is added to determine the likelihood that a track is a STAD track; if so, plots that associate with STAD tracks will be removed.

The processing sequence retains the current PRI-based STAD detection technique. All plots, including those received beyond 60 nmi, are tracked via the existing tracking algorithm. Only plot data less than or equal to 60 nmi are output via the communication port. The CMC is modified to provide an Extended Range MTAD Processing parameters menu, where the maximum beacon processing range and range and azimuth tolerances are entered. Another parameter, N, defines the number of scans old a track can be to still be considered a real aircraft track. Tracks that have been updated within N scans are considered real aircraft. The multi-scan correlator maintains a counter (SC) on all tracks. This is used to determine if a track will be declared a MTAD track. A second parameter menu is provided to define the counter variables:

Max Value—the maximum value the SC can reach

Threshold—the value to which the SC is compared to determine if a track will be declared a MTAD track.

Start Value—the initial counter value assigned to all tracks. Also used as a reset value when a reset is required.

Increment #1—increments the SC by this amount when the plot under evaluation associates with one STAD in range using the original PRI-based technique.

Increment #2—increments the SC by this amount when the plot under evaluation associates with two or more STADs in range using the original PRI-based technique.

Increment #3—increments the SC by this amount when the plot under evaluation associates with an extended range beacon reply.

Decrement #1—decrements the SC by this amount when a track has a plot associated with it but does not meet the above increment criteria.

Decrement #2—decrements the SC by this amount when a track does not have an associated plot.

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[1] Reference Sensis memorandum dated 21 September 2000 from Tony Albanese to Bill Reytar (AND-410), "Approach to Reduce Multiple Time Around Detections"

For all tracks, if the track is updated with a beacon reply on the current scan the SC is reset. If a suspected STAD plot associates with one or more tracks using the existing PRI technique, or if it associates with a beacon reply, the SC is incremented using the rules described above. Beacon replies beyond the minimum PRI range as defined by the STAD processing menu are used to compute all MTAD ranges. A PRI calculation will determine the appropriate ranges for n-time-around detections. The smoothed range and azimuth from the extended range beacon information is used to provide the highest quality position data to the algorithm. The multi-scan correlator then uses the potential MTAD ranges and azimuths to determine the possible existence of MTADs. Plots that lie within these bounds are flagged and deleted from the plot stream as uncorrelates. This reduces the uncorrelate load presented to the automation system. If a plot associates with a track and said track has a SC value that exceeds Threshold, then this plot is flagged as a MTAD and is deleted from the plot stream as an uncorrelate. If a track has not been incremented as a MTAD on the current scan, the this track's SC value will be decremented. If a track has been updated with a beacon reply within the last N scans, then plots that associate with that track will not be deleted regardless of prior determination.

2.5 TEST APPROACH

To evaluate the performance of the modified Sensis algorithm, several levels of testing were carried out. FAA personnel (AOS-260) first did configuration control testing at their facility in Atlantic City. Lincoln then participated in field testing which was performed at the Williams ASR-8 site in Mesa, Arizona during the week of 26 March 2001.

The field test was structured to provide the greatest possible amount of control over the data, so that a clear evaluation of the impact of the algorithm could be made. First, both channels of the TDX-2000 were made as nearly identical as possible and optimized for maximum performance. Then a baseline data collection was done using the MX-6 interface that provides CD format primary and secondary radar data at the output of both channels of the TDX-2000 before it is sent to the TRACON facility. Finally, one channel of the TDX-2000 was modified with the new algorithm, the other remained unchanged, and a series of data collections were carried out over a period of two days. Analysis would include a manual comparison of the channel-to-channel performance differences, as well as a statistical evaluation of these differences. Lincoln wanted to assess not only the potential improvement in the false alarm rate, but also the potential impact to real target declarations using targets of opportunity.

A summary of the data collection sessions appears in Table 1:

Table 1. Summary of IWA Data Collection Sessions

SESSION	FILENAME	DATE	TIME (UTC)	# OF SCANS	NOTES
1	BASELINE.MX6	03/20/01	21:08-22:09	772	As-found recording
2	IWA0327B.MX6	03/27/01	16:30-17:31	787	Channel B only
3	IWA0327C.MX6	03/27/01	17:36-18:37	773	Normal operation
4	IWA0327D.MX6	03/27/01	20:35-21:35	771	Normal operation
5	IWA0327E.MX6	03/27/01	21:40-22:40	771	Normal operation
6	IWA0328A.MX6	03/28/01	16:48-17:04	199	Clutter map testing*
7	IWA0328B.MX6	03/28/01	16:24-16:40	202	Clutter map testing*
8	IWA0328C.MX6	03/28/01	17:15-18:15	772	Normal operation
9	IWA0328D.MX6	03/28/01	19:05-20:05	772	Normal operation
10	IWA0328E.MX6	03/28/01	20:10-21:10	771	Normal operation
11	IWA0328F.MX6	03/28/01	21:15-22:15	765	Normal operation
12	IWA0328G.MX6	03/28/01	22:20-23:20	771	Normal operation

** Not included in the manual or statistical analysis. Changes were being made to the clutter maps to test another portion of the TDX software modification.*

2.6 RESULTS OF THE MANUAL ANALYSIS

Using the PLOTASR radar data display program, a lengthy examination of each data file was undertaken. This included side-by-side comparison of the modified versus unmodified channel displays at all ranges, in short (approximately 100 scan) blocks. Particular care was taken to identify any instances of targets that appeared to be real aircraft that were eliminated in the modified channel but not in the unmodified channel. Any other anomalies were also noted. Approximately sixty hours of review were required to sort through the twelve data files listed in Table 1. From this review, anomalies were sorted into the following categories: Elimination of MTADs by the algorithm (i.e., deleted in the modified channel and not in the unmodified channel); MTADs not eliminated by the algorithm (i.e., appearing in the modified channel and not in the unmodified channel, or appearing in both channels); and Elimination of correlated radar-only targets (not necessarily MTADs), in either channel. The results are as follows:

(a) Elimination of MTADs by the algorithm. Figures 6 and 7 illustrate the substantial reduction in breakthrough from multiple-time-around detections after modification with the algorithm. Figure 6 shows the unmodified channel's representation of parabolic MTAD returns in an area to the northwest over the Scottsdale airspace, and radial MTAD returns to the east and west. Historically, these areas have been plagued with correlated MTAD returns. Note the numbers of correlated radar-only parabolic tracks (red targets), as well as the uncorrelated radar-only parabolic tracks (blue targets) over Scottsdale. The correlated radar-only (red) tracks will appear as real targets on the air traffic controller's display. The uncorrelated radar-only (blue) tracks are those that have been prevented from correlating by the original Sensis STAD algorithm. Figure 7 shows the same areas as represented by the modified channel. One can easily see that the algorithm has satisfactorily removed the correlated and uncorrelated MTAD returns, while maintaining track on all real aircraft in the airspace. This type of performance is evident throughout the coverage volume, and is consistent among the data sets.

(b) MTADs not eliminated by the algorithm. There were a few examples in the data of MTADs that were not eliminated by the algorithm. These either appeared in the modified channel and not in the unmodified channel, or they appeared in both channels. In the nine hours of data collected following the modification that were examined, only four instances of MTAD breakthrough were noted. These examples have been forwarded to Sensis for further evaluation. Using the extended range beacon information that was collected in the Sensis equipment, as well as other detailed algorithm performance information that is only available at Sensis, the reasons for this breakthrough may become clear. Once the cause is understood, it may be possible to modify the algorithm to capture these cases as well. This is not a terribly serious performance problem, as the instances of these cases are very infrequent and do not result in target deletion.

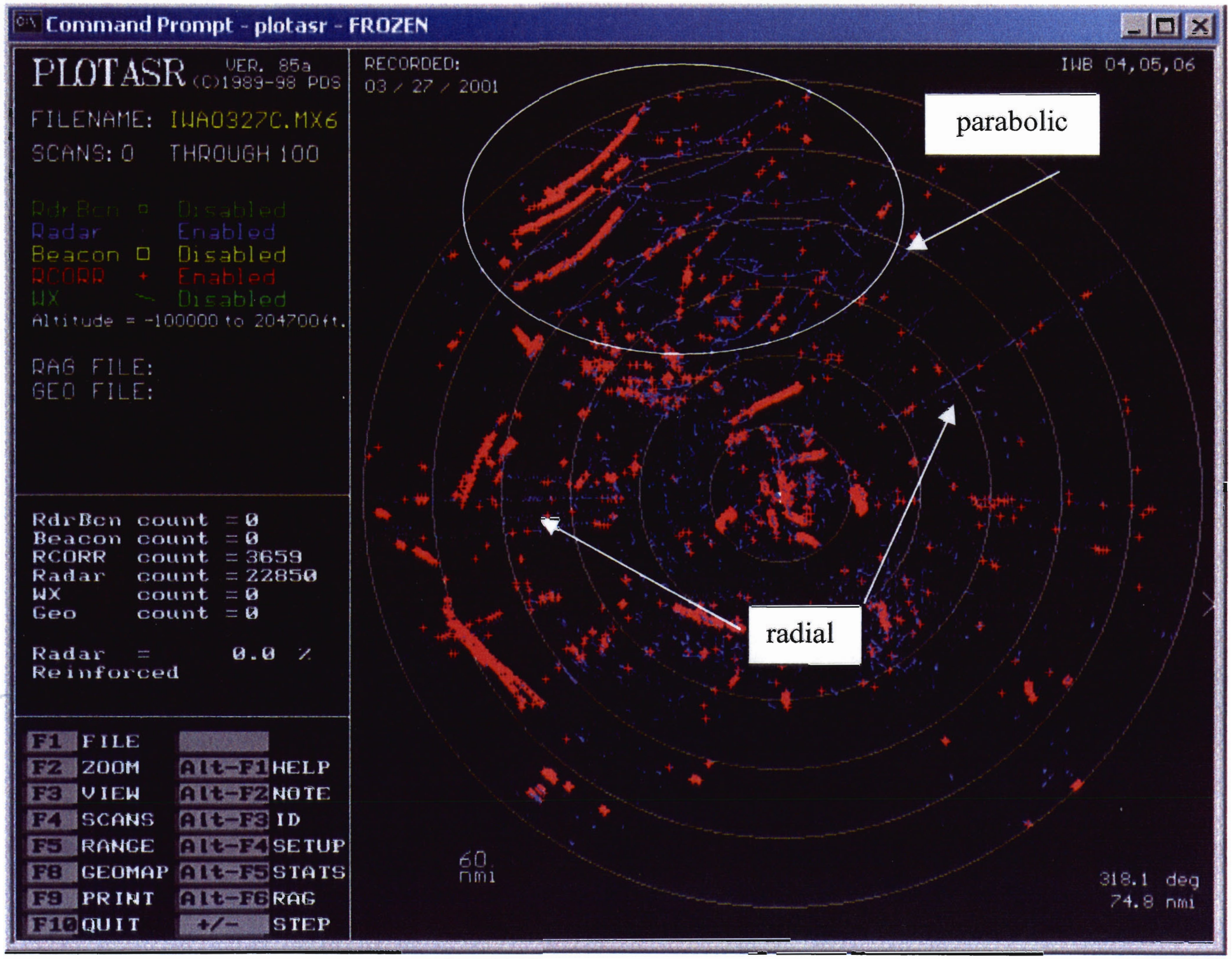

Figure 6. STAD returns, unmodified channel.

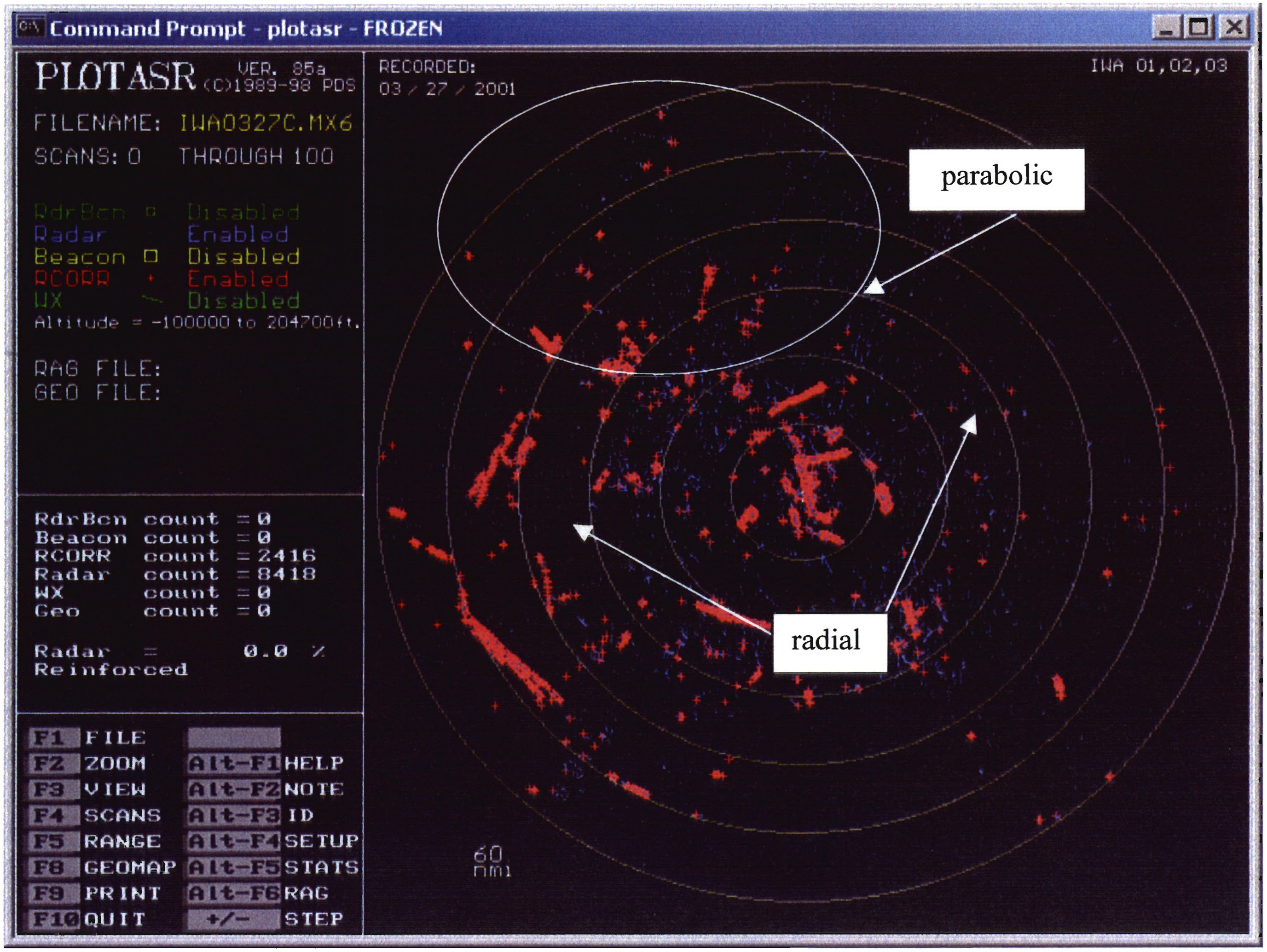

Figure 7. STAD returns, modified channel.

(c) Elimination of correlated radar-only targets. Some examples were captured of correlated radar-only tracks (that may or may not have been due to multiple-time-around returns) being eliminated in one channel and not in the other. Most often, the result was small holes (< 5 consecutive scans) in the track. On one occasion, a very large hole (roughly 45 scans) was noted. The phenomenon appeared to affect both channels nearly equally (six examples of target drop in the modified channel, four examples of target drop in the unmodified channel). Examples such as this are of some concern, as they result in target deletion. The one instance of a 45 scan drop in the modified channel which did not occur in the unmodified channel is of particular concern, and efforts are being made to fully understand the cause of this discrepancy. Possible explanations are channel-to-channel differences in sensitivity or dynamic threshold values such as CFAR or clutter map levels within the TDX-2000, or the problem may be within the new algorithm itself. This example is shown in Figures 8 and 9. Clearly, the track is a non-transponder equipped aircraft. Figure 8 shows the coverage from the unmodified channel, Figure 9 the same view from the modified channel. The area of target drop is indicated. Sensis is investigating the cause of this anomaly. Because this is only one instance in many hours of data, Lincoln does not feel at this point that there is need for a delay in field deployment of the modification. Once the cause of the problem is understood, it may be able to be fixed in software. However, it is very important that we fully understand what is causing the problem, and recommend continuing the development efforts with Sensis to rectify the issue if possible.

One possible explanation for the small holes in the other examples is the fact that, while the algorithm maintains track history on previously declared MTAD returns, it does not maintain track history on previously declared real aircraft returns. Therefore, if a real aircraft corresponds in PRI delta range to a small piece of coincident clutter, it can be eliminated by the MTAD algorithm for a short period of time (as long as the clutter continues to line up with the target in coincident range).

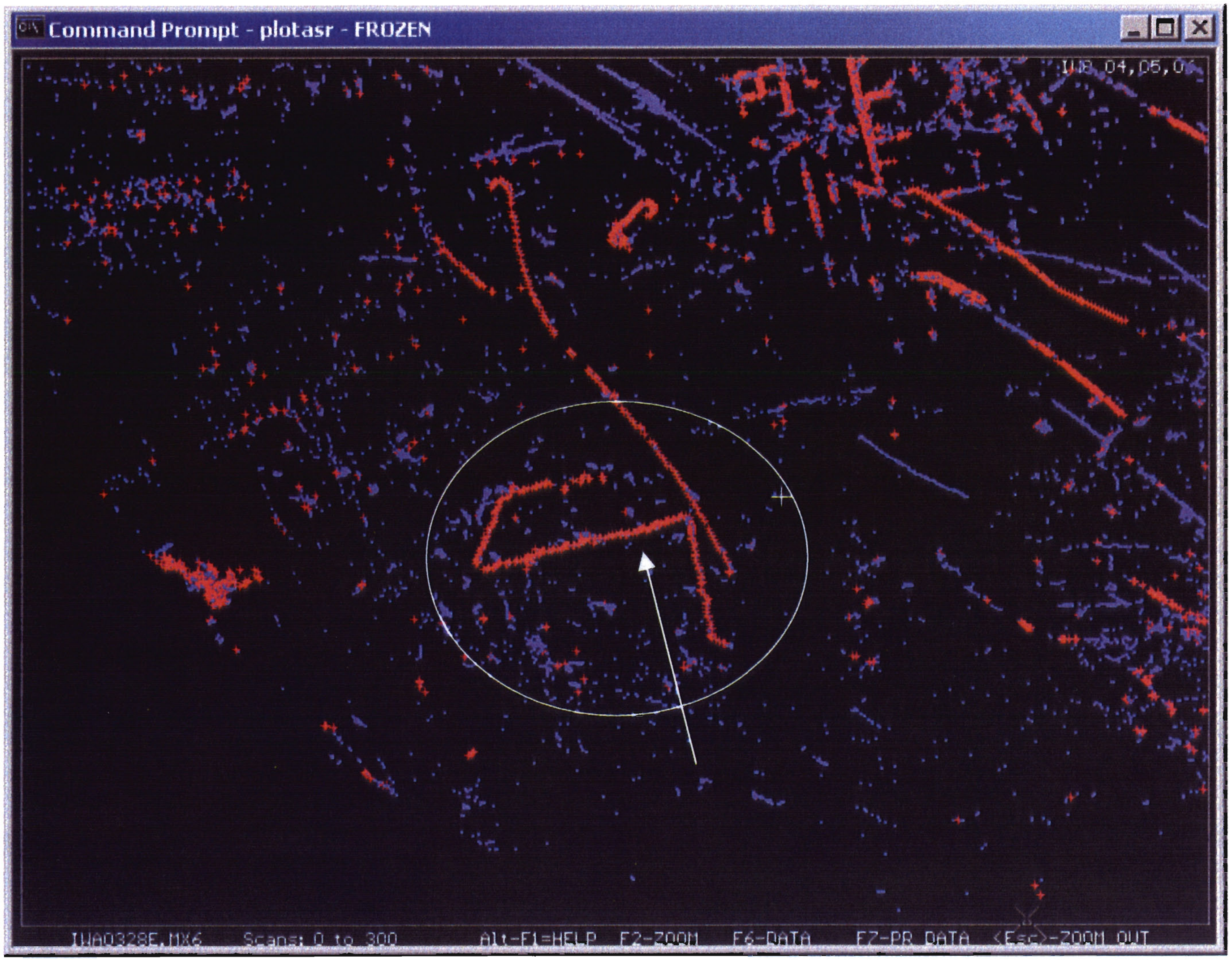

Figure 8. Radar-only target, unmodified channel.

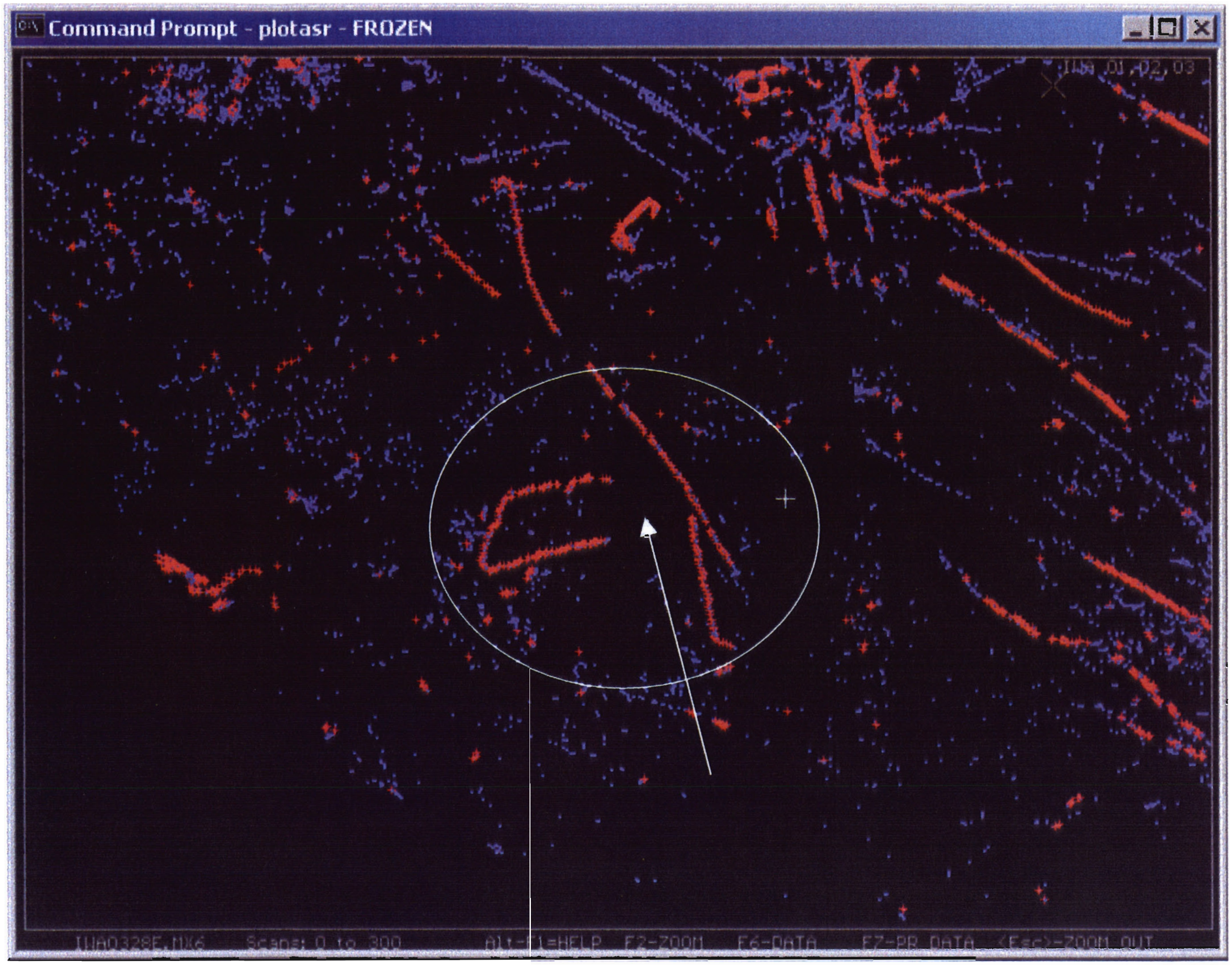

Figure 9. Radar-only, modified channel.

2.7 RESULTS OF THE STATISTICAL ANALYSIS

Three parameters were used to quantify the statistical performance of the modification:

1) Probability of detection;

2) Radar reinforcement rate; and

3) Correlated and uncorrelated radar-only target count.

Both the PLOTASR target statistics and the computations from the FAA's Surveillance Analysis statistics program were used to measure improvement. The PLOTASR Target Count Statistics are shown in Table 2, the Surveillance Analysis results in Table 3.

There were several factors taken into consideration when deciding how to fairly compare the statistics. An odd occurrence in the baseline file made it questionable for comparison in the statistics. Channel B (which eventually became the unmodified channel) was subject to a phenomenon that occasionally plagues the TDX, which results in some of the radar-reinforced beacon targets appearing with an extra correlated radar-only target. These extra correlated radar-only targets are factored into the statistics and skew the search probability of detection and radar reinforcement percentage. This coupled with the fact that the baseline file was in fact only one file inspired a straight comparison between the average performance of the modified channel versus that of the unmodified channel. Therefore the baseline file was not factored into this comparison, and all numbers referenced in the discussion that follows are strictly post-modification averages.

Note: *Due to errors in file format in two of the data collection sessions, the Surveillance Analysis program was unable to compute statistics. These appear as "data n/a" entries in Table 3. Because this affected one unmodified channel set and one modified channel set, these were simply bypassed in the calculations and statistics were generated using the remaining data sets.*

Probability of detection—refer to Table 3. Average search probability of detection in the modified channel was compared to the search probability of detection average for the unmodified channel:

Search PD average over all files, modified channel: 89.73%

Search PD average over all files, unmodified channel: 88.53%

This shows that the improvement in search probability of detection following the modification was 1.2%.

Table 2. PLOTASR Target Count Statistics

PLOTASR TARGET COUNT STATISTICS FOR IWA DATA, MARCH 2001

FILE NAME	TDX CHANNEL	# RADAR/BCN TARGERTS	# BEACON-ONLY TARGETS	# CORRELATED RADAR-ONLY TARGETS	# UNCORR. RADAR-ONLY TARGETS	% RADAR REINFORCED
BASELINE.MX6	A	66749	10662	27258	132576	86.2
BASELINE.MX6	B	64530	13273	27261	86286	82.9
IWA0327B.MX6	modified	79945	13357	17229	62967	85.7
IWA0327B.MX6	unmodified	76987	16047	25365	173193	82.8
IWA0327C.MX6	modified	76050	10603	18445	66299	87.8
IWA0327C.MX6	unmodified	74531	11742	25925	176919	86.4
IWA0327D.MX6	modified	70207	10106	19279	67791	87.4
IWA0327D.MX6	unmodified	68679	11299	25622	179086	85.9
IWA0327E.MX6	modified	70301	9981	15765	61084	87.6
IWA0327E.MX6	unmodified	68908	11021	22672	176941	86.2
IWA0328C.MX6	modified	84823	11867	17640	75901	87.7
IWA0328C.MX6	unmodified	82964	13286	28997	158395	86.2
IWA0328D.MX6	modified	67782	9096	21243	76969	88.2
IWA0328D.MX6	unmodified	66225	10298	18257	173941	86.5
IWA0328E.MX6	modified	76280	9636	22431	79277	88.8
IWA0328E.MX6	unmodified	74784	10738	19858	188865	87.4
IWA0328F.MX6	modified	72957	9606	21735	77125	88.4
IWA0328F.MX6	unmodified	71499	10832	18485	185244	86.8
IWA0328G.MX6	modified	65082	7542	20291	73918	89.6
IWA0328G.MX6	unmodified	63931	8422	16624	182188	88.4

Table 3. Surveillance Analysis Statistics
(page 1 of 2)

SURVEILLANCE ANALYSIS STATISTICS FOR IWA DATA, MARCH 2001

SURVEILLANCE ANALYSIS PARAMETERS

Site Identifier:	IWA/IWB
CD Record Format:	ASR9
Antenna Timing Message:	Search Sector Mark
Use adjusted time-of-day?:	No
Data Source:	ATCBI
Beacon delay on?:	No
Range in decimal?:	Yes
Azimuth in decimal?:	Yes
Number of antenna faces:	1
Elevation of antenna above MSL:	100.0 feet
Test number:	0
Minimum track life needed to use track in stats:	10
Range window:	1.00 nmi
Azimuth window:	5.00 deg
Limit at which tracks are dropped:	4

FILE NAME	TDX CHANNEL	TRACK LIFE	BEACON PD	SEARCH PD	TOTAL PD	RADAR REINFORCEMENT %
BASELINE.MX6	A	76245	98.22	87.74	99.53	87.94
BASELINE.MX6	B	76304	98.29	84.77	99.46	84.87
IWA0327B.MX6	modified	91951	98.00	87.22	99.31	87.60
IWA0327B.MX6	unmodified	data n/a	data n/a	data n/a	data n/a	data n/a
IWA0327C.MX6	modified	85059	98.22	89.50	99.43	89.84
IWA0327C.MX6	unmodified	84858	98.28	88.14	99.56	88.30
IWA0327D.MX6	modified	79023	98.08	89.15	99.43	89.49
IWA0327D.MX6	unmodified	78959	98.06	87.57	99.54	87.75

Table 3. Surveillance Analysis Statistics
(page 2 of 2)

FILE NAME	TDX CHANNEL	TRACK LIFE	BEACON PD	SEARCH PD	TOTAL PD	RADAR REINFORCEMENT %
IWA0327E.MX6	modified	data n/a	data n/a	data n/a	data n/a	data n/a
IWA0327E.MX6	unmodified	78599	98.19	88.21	99.48	88.47
IWA0328C.MX6	modified	94841	98.05	89.73	99.48	89.99
IWA0328C.MX6	unmodified	94741	98.00	88.01	99.49	88.23
IWA0328D.MX6	modified	75584	98.18	90.05	99.45	90.25
IWA0328D.MX6	unmodified	75445	98.15	88.37	99.53	88.43
IWA0328E.MX6	modified	84082	98.51	90.77	99.59	91.02
IWA0328E.MX6	unmodified	83893	98.53	89.31	99.66	89.43
IWA0328F.MX6	modified	81272	98.27	90.11	99.47	90.46
IWA0328F.MX6	unmodified	81185	98.26	88.62	99.59	88.80
IWA0328G.MX6	modified	71561	98.31	91.29	99.57	91.56
IWA0328G.MX6	unmodified	71438	98.31	89.98	99.62	90.14

Radar reinforcement rate—refer to Tables 2 and 3. Average radar reinforcement percentages in the modified channel were compared to radar reinforcement percentage averages in the unmodified channel using the results of both PLOTASR and the Surveillance Analysis program:

Radar reinforcement rate average, modified channel (PLOTASR):	87.91%
Radar reinforcement rate average, unmodified channel (PLOTASR):	86.29%
Radar reinforcement rate average, modified channel (SA):	90.02%
Radar reinforcement rate average, unmodified channel (SA):	88.69%

PLOTASR indicates a 1.62% improvement in radar reinforcement, while Surveillance Analysis shows a 1.33% improvement. The differences between the two programs' results may be a result of differing means of computing radar reinforcement coupled with the fact that PLOTASR had one more data point to work with (see Note above).

Correlated and uncorrelated radar-only target count—refer to Table 2. PLOTASR generates target counts automatically when the data is displayed. Target count averages for the modified and unmodified channels were calculated for both correlated and uncorrelated radar-only targets:

Correlated radar-only count average, modified channel:	19340
Correlated radar-only count average, unmodified channel:	22423
Uncorrelated radar-only count average, modified channel:	71259
Uncorrelated radar-only count average, unmodified channel:	177197

This is a 13.7% reduction in the number of correlated radar-only targets, and a 59.8% reduction in the number of uncorrelated radar-only targets.

The improvements to the system based on the statistical analysis may appear modest, but when considered in light of the excellent probability of detection and radar reinforcement numbers the results are very encouraging. The dramatic reduction in uncorrelated radar-only target count will have a significant positive impact on the automation systems that are associated with the ASR-8/TDX-2000.

3. CONCLUSIONS

The efforts of the past year have resulted in a substantial improvement in the performance and reliability of the ASR-8/TDX-2000. Through systematic testing and analysis, the ability of the system to detect and track real aircraft while minimizing the declaration of false alarms has been enhanced. There is no longer any evidence of the original track initiation and track maintenance problems, and the returns from multiple-time-around detections have been significantly reduced. While we still have some issues to conclude regarding the overall performance of the new MTAD algorithm (namely occasional occurrences of MTAD breakthrough and correlated radar-only track drop), Lincoln Laboratory feels that the system is now performing well, and that further improvements will only be realized via major system redesign. The one extended loss of track reported above is important enough to require further investigation, which Lincoln will continue to pursue with Sensis. However, due to the infrequent nature of the events we do not feel this issue should impact deployment of the modified algorithm.