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Flight Procedure Standards Branch
Flight Technologies and Procedures Division
Flight Standards Service

RISK ANALYSIS OF REJECTED LANDING PROCEDURE FOR LAND AND HOLD SHORT OPERATIONS AT MIAMI INTERNATIONAL AIRPORT, RUNWAYS 12 AND 9R

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Final Report

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12. Abstract

The Flight Procedure Standards Branch, AFS-420, of the Flight Standards Service, was directed to develop an evaluation and risk analysis methodology for rejected landings occurring during land and hold short operations (LAHSO) that was applied in this report to the Miami International Airport (MIA). LAHSO allows simultaneous independent operations to intersecting runways and has been in use as a capacity enhancement tool at various airports in the United States for over 30 years. In recent years, concern has been expressed by various pilot groups about the safety of LAHSO. Therefore, the FAA agreed to perform a case-by-case risk study of each runway pair being considered for the operation that would require a rejected landing procedure (RLP) beginning with Chicago O'Hare International Airport (ORD). The RLP is intended to safely transition the aircraft on the LAHSO runway from a very-low-altitude pilot-initiated aborted landing that may involve ground contact back into terminal airspace. AFS-420 was selected to develop the appropriate system for these studies because of its demonstrated expertise in simulation and risk analysis centered on the Airspace Simulation and Analysis for TERPS (ASAT) system. Flight simulator testing involving more than 100 crews (200 pilots) and eight flight simulators generated over 1,200 landings and takeoffs (with emphasis on the rejected landing) to provide operational data for a Monte Carlo simulation. Simultaneously, ASAT was reconfigured to analyze the flight simulator data and incorporate it into a Monte Carlo simulation of two scenarios. This report is concerned with the second scenario involving an aircraft executing a rejected landing procedure (RLP) while a second aircraft is also airborne while departing an intersecting runway. It was found that certain assumptions about the RLP rate were necessary in order to meet the target level of safety. It was recommended that consideration be given to the establishment of operational guidelines for LAHSO at MIA that would not allow the initiation of departures while the approaching (LAHSO) aircraft is between the threshold and 1½ NM from the threshold of runway 12.

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LAHSO ASAT Miami International Airport MIA Monte Carlo simulation	Controlled by AFS-420
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EXECUTIVE SUMMARY

Land and hold short operations (LAHSO) allow simultaneous independent operations to intersecting runways with the special requirement the pilot landing on the LAHSO runway accepts responsibility for either stopping the aircraft prior to the intersection or safely missing the aircraft on the other runway if a rejected landing becomes necessary. The rejected landing procedure (RLP) is intended to safely transition the aircraft on the LAHSO runway from a very low-altitude pilot initiated aborted landing that may involve ground contact back into terminal airspace. The maneuver is complicated by the probable presence of another aircraft taking off or landing on the crossing runway.

Since the magnitude of the risk inherent with LAHSO was unknown, the Flight Procedure Standards Branch (AFS-420), of the Flight Standards Service, was directed to develop an evaluation and risk analysis methodology for rejected landings occurring during land and hold short operations. Chicago O'Hare International (ORD) was selected as the first site for application of this analysis tool and a report of the results of the ORD analysis has been published. The subject of this report is the analysis of LAHSO operations at Miami International Airport (MIA). At MIA, departures may be conducted from runway 9R while simultaneous LAHSO operations are conducted to runway 12. The results described in this report is site specific to MIA.

LAHSO has been in use as a capacity enhancement tool at various airports in the United States for over 30 years. The operation was introduced at ORD in 1968 as Simultaneous Operations on Intersecting Runways. According to an Air Traffic Operations Program survey performed in the fall of 1998, by the Federal Aviation Administration (FAA), Office of the Assistant Administrator For System Safety, entitled "Land and Hold Short Operations Risk Assessment", eighty-one airports reported using LAHSO for approximately 2.6 million operations in 1998.

In recent years, various pilot groups have expressed concern about the safety of LAHSO. In some cases, pilots have even refused to accept LAHSO clearances. Although no accidents have occurred during LAHSO operations, there have been close encounters causing one or both aircraft to take evasive action. The runway lengths and conditions allowed by the LAHSO order (FAA Order 7110.199) for bringing the airplane to a stop have always been a major topic of concern, but the ability to safely perform a go-around from low altitude has also been a critical issue for pilots.

As part of the FAA's most recent agreement with the pilot groups to facilitate the acceptance of LAHSO, the FAA agreed to perform a case-by-case risk study of each runway pair being considered for the operation. AFS-420 was selected to develop the appropriate system for these studies because of its demonstrated expertise in simulation and risk analysis centered on the Airspace Simulation and Analysis for TERPS (ASAT) system. After being tasked in late May and funded in early June, an initial ORD report was issued 3 July 2000. This report summarizes those results and addresses what is believed to be the more likely RLP scenarios at MIA, runways 9R and 12.

An accurate determination of the risk factors associated with a particular LAHSO scenario requires evaluation of the full range of possible outcomes of the procedure. Since flight-testing or real time simulator testing was not a feasible approach to produce a complete answer, high speed, high fidelity Monte Carlo simulation was used to provide the necessary information. Although still considerable, less data is required to conduct a Monte Carlo simulation to achieve the necessary confidence in the simulation results.

Flight simulator testing involving more than 100 crews (200 pilots) and eight flight simulators generated over 1,200 landings and takeoffs (with emphasis on the rejected landing). During each run, approximately 20 parameters were recorded at 2 Hz or faster for the duration of the run. Scenarios used in the testing included takeoffs, landings, and rejected landings conducted under autopilot, flight director, and manual control. All landings and rejected landings were conducted at maximum landing weight for the specific aircraft.

An agreement was reached among Flight Standards, pilot groups, and airline representatives that during the flight simulator phase, landing aircraft would be at maximum landing weight to reduce their performance on the climb out and departing aircraft would be at a very low weight to reduce their takeoff distance and improve their climb performance. Weather conditions would include a scenario with the worst allowable ceiling and visibility limits for the RLP. The rejected landing procedure would be initiated at no higher than 50 feet above the runway. There would be no equipment failures such as engine out, etc. Vertical guidance would be available. For evaluation purposes, ASAT would be used to translate the RLP data to show the climb out beginning at the end of the touchdown zone (3,000 feet from threshold or a third of the runway length, whichever is shorter). No significant winds would be applied for the flight simulation testing but the ASAT would be used to explore the effects of various wind components.

The requirements are:

a. Data be translated to show the climb out at the end of the touchdown zone.

b. Landing aircraft would be at maximum landing weight with departing aircraft at a very low weight.

c. RLPs initiated no higher than 50 feet above the runway result in a "worst case" scenario.

Therefore, AFS-420 also designed several other more realistic scenarios for inclusion in the ASAT study. All other scenarios designed by AFS-420 started the climb out at random points along the approach. Some scenarios were designed with turns of 20 degrees. Scenarios were designed where the RLP was initiated at altitudes up to 550 feet above the landing surface. More realistic weights for the two aircraft were also incorporated into some scenarios. Thus, the use of ASAT permits a much more varied study than would be feasible in a flight simulator study.

The results of a land and hold short operation can fall into one of three scenarios:

a. In scenario 1 the aircraft executes a rejected landing procedure and must clear another aircraft still on the ground on the crossing runway.

b. In scenario 2 the aircraft executes a rejected landing and must avoid the other aircraft, which is also airborne.

c. In scenario 3 the aircraft lands and must stop before the intersection. The first scenario is not applicable to MIA because the length of runway 9R prior to its intersection with runway 12 insures the aircraft departing runway 9R is airborne upon reaching runway 12. Likewise, the third scenario is not applicable to MIA, but is being investigated by the National Resource Specialist for Flight Simulators using aircraft performance and certification data and flight simulator data for application at other airports. Therefore, scenario 2 is the subject of this report.

The pilot representatives from the Airline Pilot's Association and Allied Pilot's Association had suggested a target level of safety of 10^{-7} be applied to all runs executed under these "worst case" conditions and any separation distances less than 500 feet be considered a test criterion violation (TCV). FAA representatives agreed with the TCV definition, but felt the TLS was not realistic since it did not bring into account the already small percentages of rejected landings that occur during a LAHSO. AFS-420 recommends a TLS of 10^{-8} be required for the entire operation, including the chance of an RLP and more realistic assumptions for certain parameters, such as the point at which the rejected landing begins.

The second scenario involves a complicated situation with both airplanes airborne and requires very large sample sizes for an adequate study. The TCV for this scenario was defined as having a separation distance of less than 500 feet between the centers of gravity of the two aircraft. The total risk for this scenario must also factor in the probability of a rejected landing. The simulation developed for this scenario is a full dual aircraft model with all relevant parameters driven by the distributions derived from the flight simulator data or user settings. The geometry of the airport under consideration was loaded from the appropriate FAA databases. The fleet mix per runway was determined by data provided by the airport under evaluation. Additional aircraft maneuvers such as turns during the RLP or the take-off may be evaluated. The simulation allowed the generation of many thousands of LAHSO RLPs, using the realistic parameter ranges determined from the simulator testing. Sixteen million simulations were performed while preparing this report to insure all possible combinations of factors were evaluated.

Aircraft types were randomly paired for the LAHSO and departure aircraft. It was found TCVs only occur when the LAHSO aircraft is within a fairly narrow window along the glide path. This window starts about 1½ miles outside the LAHSO runway threshold for most aircraft types and ends at the LAHSO threshold. It was determined there is no worst case aircraft or aircraft pair. Nearly all pairings achieve some number of 3-d TCVs. All aircraft pairs achieved 2-d TCVs.

The following conclusions are based on the AFS-420 analysis of the flight simulator test data and the ASAT simulation results for MIA RLP for runways 12 and 9R:

a. The minimum ceiling should be raised from the 1,000-foot allowed in the LAHSO order. Additional testing has indicated that a 2,000-foot ceiling is achievable. This affects all LAHSO operation.

b. The scenario 2 studies indicate the target level of safety is not met without making questionable assumptions about the percentage of RLPs. If the RLP rate is assumed (conservatively) to be 1 per 10,000, then the overall risk of the operation is approximately 1×10^{-6}. Achieving the desired level of safety of 1×10^{-8} with totally independent operations requires an RLP rate of no more than one per million. Additional operational corrections such as incorporating a turn in the RLP to compensate for a higher RLP rate do not reduce the overall risk enough to achieve the desired TLS. Therefore, AFS-420 recommends consideration be given to the establishment of operational guidelines for LAHSO that would not allow the initiation of departures while the approaching (LAHSO) aircraft is between the threshold and a point 1½ NM from the threshold of runway 12.

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1.0 INTRODUCTION

Land and hold short operations (LAHSO) allows simultaneous independent operations to intersecting runways with the special requirement the pilot landing on the LAHSO runway accepts responsibility for either stopping the aircraft prior to the intersection or safely missing the aircraft on the other runway if a rejected landing becomes necessary. The rejected landing procedure (RLP) is intended to safely transition the aircraft on the LAHSO runway from a very low-altitude pilot initiated aborted landing that may involve ground contact back into terminal airspace. The maneuver is complicated by the probable presence of another aircraft taking off or landing on the crossing runway. Since the magnitude of the risk inherent with LAHSO was unknown, the Flight Procedure Standards Branch (AFS-420), of the Flight Standards Service (AFS-1), was directed to develop an evaluation and risk analysis methodology for rejected landings occurring during land and hold short operations. Chicago O'Hare International (ORD) was selected as the first site for application of this analysis tool and a report of the results of the ORD analysis has been published. The subject of this report is the analysis of LAHSO operations at Miami International Airport (MIA). At MIA, departures may be conducted from runway 9R while simultaneous LAHSO operations are conducted to runway 12.

AFS-420 conducted flight simulator tests using eight category C flight simulators to acquire input data for extensive Monte Carlo simulations of LAHSO. For the MIA simulation, AFS-420 designed sixteen different scenarios, each involving forty-nine pairings of approach and departure aircraft, to estimate the risk associated with LAHSO. One million runs of each scenario were performed for sixteen million runs. Unless specifically identified as being more general, all findings in this report should be regarded as applying **only** to this airport/runway combination.

2.0 BACKGROUND

LAHSO has been used as a capacity enhancement tool at various airports in the United States for over 30 years. The operation was introduced at ORD in 1968 as Simultaneous Operations on Intersecting Runways. According to an Air Traffic Operations Program survey, performed in the fall of 1998 by the Federal Aviation Administration (FAA), Office of the Assistant Administrator for System Safety (ASY-1), entitled "Land and Hold Short Operations Risk Assessment, September, 1999", eighty-one airports reported using LAHSO for approximately 2.6 million operations in 1998.

In recent years, various pilot groups have become increasingly concerned over the safety of LAHSO. Although no accidents have occurred during actual LAHSOs, there have been a number of close encounters causing one or both aircraft to take evasive action. The runway lengths and conditions allowed by the LAHSO Order 7110.199 for bringing the airplane to a stop have always been a major topic of concern, but the ability to safely perform a go-around from low altitude has been the critical issue for the pilots. Under LAHSO, the pilot has the responsibility for seeing and avoiding other aircraft that may be present when conducting a rejected landing. During the rejected landing procedure, the aircraft may be at a very low altitude and in the process of being reconfigured for the climb back to altitude. Pilot workload is increased, the visual field is limited, and the aircraft is not in a suitable configuration to maneuver. Because of these concerns, pilot groups have recommended that their members refuse to accept a LAHSO clearance. This action has significant capacity impacts at some airports conducting LAHSO, resulting in delays and causing problems across the National Airspace System (NAS).

As part of FAA's agreement with pilot groups to facilitate pilot acceptance of LAHSO, RLP risk evaluations are being performed case-by-case for each runway pair being considered for the operation. AFS-420 was selected to develop the appropriate system for these studies because of its demonstrated expertise in simulation and risk analysis centered on the Airspace Simulation and Analysis for TERPS (ASAT) system. A report of the simulation and analysis of LAHSO operations at ORD was published in October of 2000. This report will address what is believed to be the more likely RLP scenarios at MIA, runways 12 and 9R. Figure 2.1 is a diagram of MIA and indicates runways 12 and 9R in blue.

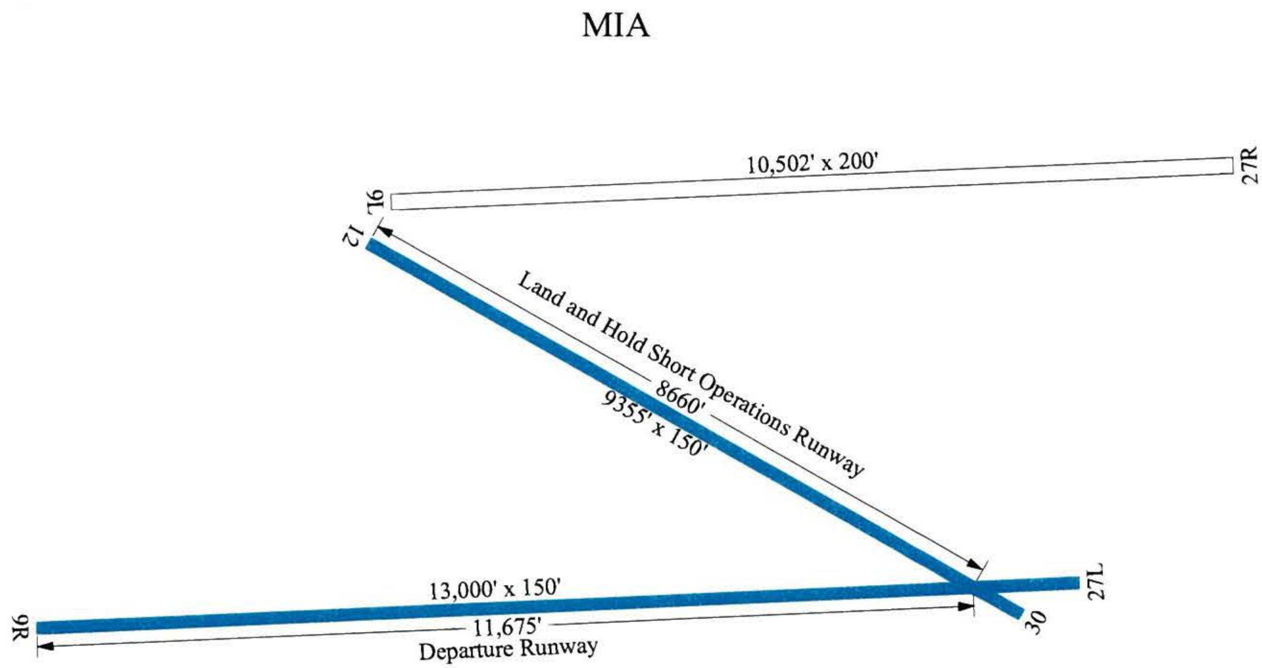

Figure 2.1: MIAMI INTERNATIONAL RUNWAY DIAGRAM

3.0 DISCUSSION

An accurate determination of the risk factors associated with a particular LAHSO scenario requires evaluation of the full range of possible outcomes of the procedure. Given the number of parameters associated with such an operation and the cost and time involved, flight-testing or real-time-simulator testing was not a feasible approach to produce a complete answer. High speed, high fidelity Monte Carlo simulation can provide the necessary information and would require less data to achieve the necessary confidence. An essential part of any computer simulation process is the determination of realistic values for the many parameters that go into modeling a scenario and the development of probability distributions to describe the variation of those values. These parameters are usually found from data collected during preliminary flight-testing or flight simulator testing. While actual flight-testing would be the ideal way to measure these values, it is usually more practical to use FAA-qualified flight simulators and current and qualified line pilots. Therefore, the first phase of the study involved flight simulator testing of LASHO rejected landing procedures to obtain input parameters for the ASAT computer simulation. The second phase of the study involved the ASAT simulation of the LAHSO rejected landing maneuver.

The results of a land and hold short operation can fall into one of three scenarios:

a. In scenario 1 the aircraft executes a rejected landing procedure and must clear another aircraft still on the ground on the crossing runway.

b. In scenario 2 the aircraft executes a rejected landing and must avoid the other aircraft, which is also airborne.

c. In scenario 3 the aircraft lands and must stop before the intersection.

The first scenario is not applicable to MIA because the length of runway 9R prior to its intersection with runway 12 insures the aircraft departing runway 9R is airborne upon reaching runway 12. Likewise, the third scenario is not applicable to MIA, but is being investigated by the National Resource Specialist for Flight Simulators (AFS-408), using aircraft performance and certification data and flight simulator data for application at other airports. Therefore, scenario 2 is the subject of this report.

Discussions prior to the initiation of the study among AFS-1, pilot groups, and airline representatives helped develop a set of conditions for the flight simulator testing and ASAT simulation that essentially defined a "worst case" scenario. Landing aircraft would be at maximum landing weight to reduce their performance on the climb out and departing aircraft would be at a very low weight to reduce their takeoff distance and improve their climb performance. Aircraft would be configured appropriately (flap settings, gear, etc.) for the stage of flight. Weather conditions would include a scenario with the worst allowable ceiling and visibility limits for the RLP. The rejected landing procedure would be initiated at no higher than 50 feet above the runway. (During the flight simulator tests, the rejected landings were usually initiated at 10 to 20 feet AGL.) There would be no equipment failures such as engine out, etc. Vertical guidance for the approach would be available. For evaluation purposes, these data would be translated to show the climb out beginning at the end of the touchdown zone (3,000 feet from threshold or a third of the runway length, whichever is shorter). No significant winds would be applied for the flight simulation testing but the ASAT would be used to explore the effects of various wind components.

The requirements are:

a. Data be translated to show the climb out at the end of the touchdown zone.

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Therefore, AFS-420 also designed several other more realistic scenarios for inclusion in the ASAT study. All other scenarios designed by AFS-420 started the climb out at random points along the approach. Some scenarios were designed with turns of 20 degrees. Scenarios were designed where the RLP was initiated at altitudes up to 550 feet above the landing surface. More realistic weights for the two aircraft were also incorporated into some scenarios. Thus, the use of ASAT permits a much more varied study than would be feasible in a flight simulator study.

The pilot representatives from the Airline Pilot's Association (ALPA) and Allied Pilot's Association (APA) suggested a target level of safety of 10^{-7} be applied to all runs executed under these "worst case" conditions. Any separation distances less than 500 feet be considered a TCV. FAA representatives agreed with the TCV definition, but felt the TLS was not realistic given the small rate of rejected landings that occur during a LAHSO. For example, if rejected landings occur at the rate of one-in-a-hundred approaches (a value commonly used for missed approaches), then the actual TLS would become 10^{-9} before considering the likelihood of the worst case conditions occurring. Therefore, AFS-420 adopted a TLS of 10^{-8} for the entire operation, using assumptions that are more realistic for certain parameters, such as the point at which the rejected landing begins, and considering the actual likelihood of conducting an RLP.

To insure the fidelity of the ASAT simulation, data from as many aircraft types as possible were needed to represent the performance of all aircraft involved in land and hold short operations. Branch personnel prepared test plans and made contacts with various flight simulator sites, coordinating with AFS-408 and headquarters personnel. On June 14, 2000 the simulator testing phase began at the United Airlines Flight Center in Denver, Colorado, in level C or better flight simulators for an Airbus A-320, a Boeing 777, and a Boeing 737-300. Testing was continued at the American Airlines Flight Center in Irving, Texas, with an Embraer Regional Jet, an ATR-42, and a Fokker 100, and at Delta Airlines in Atlanta, Georgia, with a McDonnell-Douglas MD-88. Then the testing went back to United for a Boeing 757 and back to Delta for a Boeing 737-800. Then testing of a Saab 340 was conducted at American Airlines Flight Center and testing of a Boeing 727 was conducted at the Mike Monroney Aeronautical Center, Oklahoma City, Oklahoma.

The flight simulator testing involved more than 100 crews (200 pilots) and has generated over 1,200 landings and takeoffs (with emphasis on the rejected landing). During each run, approximately 20 parameters were recorded at 2 Hz or faster for the duration of the run. Scenarios used in the testing included takeoffs, landings, and rejected landings conducted under autopilot, flight director, and manual control. All landings and rejected landings were conducted at maximum landing weight for the specific aircraft. All takeoffs were conducted with a light load. All runs were performed at a high temperature of 95°F to account for the effect of density altitude and engine performance. A detailed description of the simulator data collection and processing effort is included as appendix A.

Since each airport has a unique traffic mix, the simulation of the LAHSO operation at that airport may not require data from all the tested flight simulators. Data from only seven of the flight simulators were required for the simulation of LAHSO operations at MIA. Table 3.1 summarizes the flight simulators and the aircraft weights that were used for the MIA simulation.

LAHSO TESTED AIRCRAFT WEIGHTS		
AIRCRAFT	**HEAVY WEIGHT, LBS (LANDING)**	**LIGHT WEIGHT, LBS (TAKEOFF)**
Airbus A320	142,000	130,000
ATR - 42	36,160	33,850
Boeing 777	460,000	520,000
Boeing 757	198,000	160,000
Boeing 737-300	114,000	90,000
ERJ-145	42,500	30,500
MD-88	130,000	120,000

Table 3.1: AIRCRAFT WEIGHTS FOR LANDING AND TAKEOFF

Simultaneous with the flight simulator testing, computer software was developed to analyze the data generated from the flight simulator tests and to determine the probability distribution functions (PDFs) necessary for driving the ASAT system. Appendix c contains a description of the operation of the software. ASAT is a computer simulation facility developed in-house by AFS-420. The system uses high-fidelity models of physical systems combined with empirical data for human factors to perform a wide range of aviation related high-speed Monte Carlo simulations. (See appendix B). In this case, the distributions of significance were for various pilot controlled and operational parameters such as rate of climb, speed, etc., which needed to be determined for each aircraft type. Once the data were reduced and the PDFs were determined, an ASAT simulation of the LAHSO rejected landing maneuver was developed. Appendix D contains a segment of a data file generated by the United Airlines B777 simulator.

The second scenario involves a complicated situation with both airplanes airborne and requires very large sample sizes for an adequate study. The TCV for this scenario was defined as having a separation distance of less than 500 feet between the centers of gravity of the two aircraft. The total risk for this scenario must also factor in the probability of a rejected landing. The simulation developed for this scenario is a full dual aircraft model with all relevant parameters driven by the distributions derived from the flight simulator data or user settings. The geometry of the airport under consideration was loaded from the appropriate FAA databases. The fleet mix per runway was determined by data provided by the airport under evaluation. Additional aircraft maneuvers such as turns during the RLP or the take-off may be evaluated. A detailed description of the simulation is included in appendix B. The simulation allowed the generation of many thousands of LAHSO RLPs, using the realistic parameter ranges determined from the simulator testing. Sixteen million simulations were performed while preparing this report to insure that all possible combinations of factors were evaluated.

The likelihood of a rejected landing procedure is an essential component of any conclusion that may be drawn from this analysis. The ALPA and APA representatives that met with AFS-420 during the study indicated the one-percent value that is commonly used for missed approaches seemed a good conservative starting point. A study published by ASY-1, "Land and Hold Short Operations Risk Assessment", showed that reported rejected landings during LAHSO only amounted to about 1.1 per million in 1998 with similar numbers in the preceding four years. The accuracy of this value is unsubstantiated. There are four orders of magnitude difference between the two positions. Both the pilot representatives and the ASY-1 report believe that because of new approach safety requirements, such as the stabilized approach concept, and increasing traffic density, the percentage of rejected landings will increase in the future.

One facet of the stabilized approach concept is the rule that the landing aircraft must touch down within the first 3,000 feet or first third of the runway, whichever is shorter, or a rejected landing must be initiated. During the flight simulator tests, landings were performed to provide data for an estimation of the expected rejected landing rate if the 3,000 feet or first third of the runway-landing rule is strictly observed. For that purpose there were 215 valid landings involving seven simulators. The range of the simulator from threshold where the aircraft touched down could be determined from the recorded variable "weight on wheels".

Because of the small number of landings, the data were analyzed to determine whether the range samples for the various aircraft were similar enough to allow the grouping or combining of data. It was found the data could be grouped as follows:

a. F100, B737, B757, and MD88.

b. B777, ERJ-145.

c. ATR-42.

The groups were determined by testing for homogeneity of variances and means. Table 3.2 indicates the first group is homogeneous in variances. A significance value of less than 0.05 would indicate nonhomogeneity of variances; however, the significance value of table 3.2 is 0.125. Table 3.3 indicates the first group is homogeneous in means. A significance value of less than 0.05 would indicate non-homogeneity of means; however, the significance value of table 3.3 is 0.231.

RANGE

Levene Statistic	df1	df2	Sig.
1.952	3	124	.125

Table 3.2: GROUP 1 LEVENE'S TEST OF HOMOGENEITY OF VARIANCES

RANGE

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1126737	3	375578.898	1.451	.231
Within Groups	32091764	124	258804.545		
Total	33218500	127			

Table 3.3: GROUP 1 ANOVA TEST OF HOMOGENEITY OF MEANS

Table 3.4 indicates the second group is homogeneous in variances. A significance value of less than 0.05 would indicate non-homogeneity of variances; however, the significance value of table 3.4 is 0.755. Table 3.5 indicates the second group is homogeneous in means. A significance value of less than 0.05 would indicate non-homogeneity of means; however, the significance value of table 3.5 is 0.331.

RANGE

Levene Statistic	df1	df2	Sig.
.098	1	62	.755

Table 3.4: GROUP 2 LEVENE'S TEST OF HOMOGENEITY OF VARIANCES

RANGE

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	98047.266	1	98047.266	.961	.331
Within Groups	6325069	62	102017.249		
Total	6423117	63			

Table 3.5: GROUP 2 ANOVA TEST OF HOMOGENEITY OF MEANS

It was found the landing distances of the ATR-42 were much shorter than any of the other aircraft and could not be grouped with any other aircraft.

After the groups have been established, it is possible to analyze the data further. Standard statistics of the grouped data are presented in tables 3.6 and 3.7. Standard statistics for the ATR-42 are presented in table 3.8. The aircraft types are listed by case numbers in the tables. The case numbers are associated with the aircraft as follows:

a. Case 1: F100

b. Case 2: ATR-42

c. Case 3: ERJ-145

d. Case 4: MD-88

e. Case 5: B777

f. Case 6: B737

g. Case 7: B757

Descriptives

RANGE

	N	Mean	Std. Deviation	Minimum	Maximum
1	29	2303.21	586.02	1195	4284
4	25	2063.68	324.59	1365	2764
6	36	2066.19	464.38	1326	3133
7	38	2163.82	578.91	903	3470
Total	128	2148.38	511.43	903	4284

Table 3.6: STANDARD STATISTICS OF RANGE FOR GROUP 1

Descriptives

RANGE

	N	Mean	Std. Deviation	Minimum	Maximum
3	32	1817.50	313.64	1317	2589
5	32	1739.22	325.06	1194	2389
Total	64	1778.36	319.30	1194	2589

Table 3.7: STANDARD STATISTICS OF RANGE FOR GROUP 2

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
RANGE	23	440	2590	1312.43	433.09
Valid N (listwise)	23				

Table 3.8: STANDARD STATISTICS OF RANGE FOR ATR-42

Histograms of the three groups of data are presented in figures 3.1, 3.2, and 3.3.

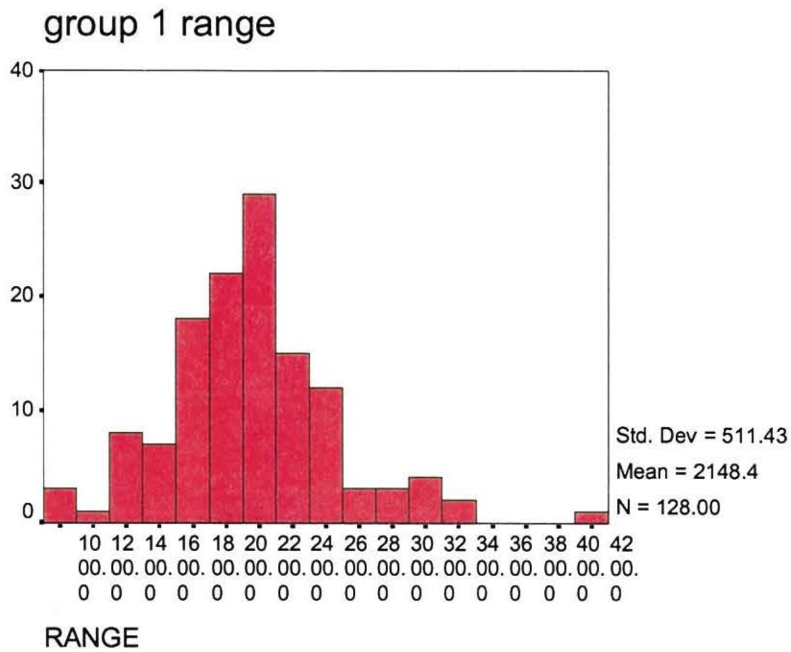

Figure 3.1: HISTOGRAM OF GROUP 1 RANGE DATA

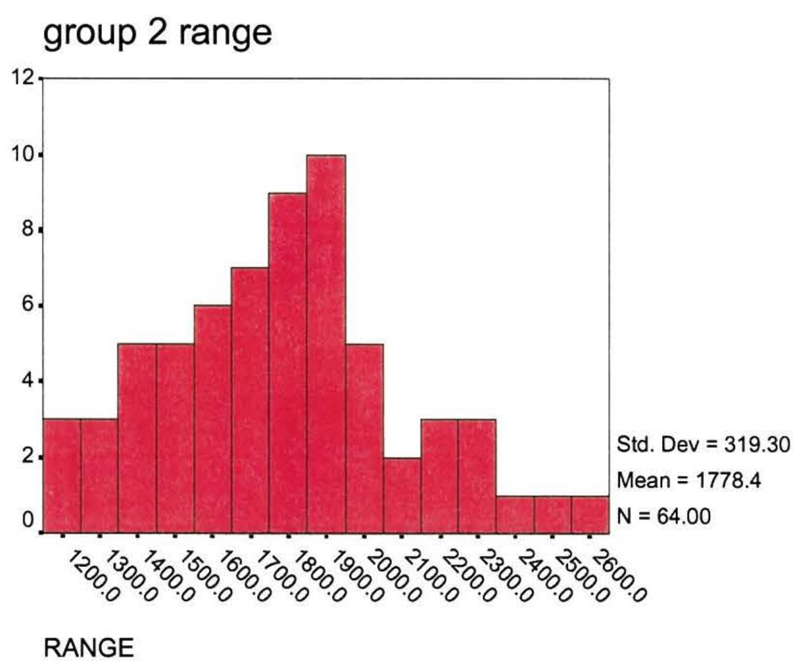

Figure 3.2: HISTOGRAM OF GROUP 2 RANGE DATA

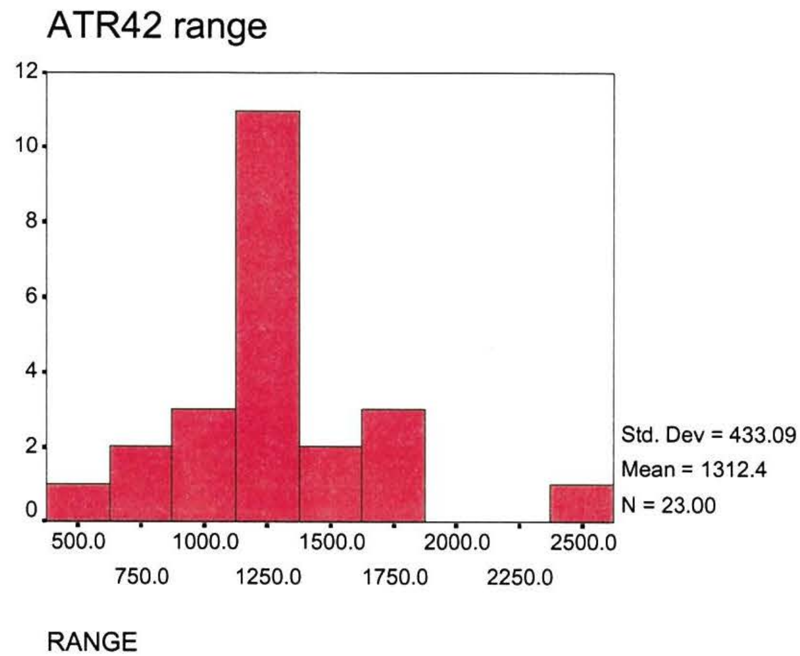

Figure 3.3: HISTOGRAM OF ATR-42 RANGE DATA

From table 3.6, the largest value of range recorded in the group 1 data is 4,284 feet past threshold. Figure 3.1 indicates that nine of the one hundred twenty-eight group 1 landings, or 7 percent, touched down more than 3,000 feet from threshold. From table 3.7, the largest value of range recorded in the group 2 data is 2,589 feet. From Table 3.8, the largest value of range recorded in the ATR-42 data is 2,590 feet. Probability density curves were fitted to each of the three data sets to determine estimates of the probability that touchdown will occur more than three thousand feet from threshold. The results of the curve fit are shown in table 3.9.

GROUP	PROBABILITY THAT RANGE EXCEEDS 3,000 FEET
1	0.047
2	0.0000024
ATR-42	$<10^{-8}$

Table 3.9: PROBABILITY THAT RANGE EXCEEDS 3,000 FEET

From table 3.9 it appears that if the 3,000 feet rule is strictly observed the RLP rate could be as high as 4.7% for the aircraft of group 1. For the aircraft of group 2 the RLP rate is estimated to be 0.00024%. For the ATR-42, the RLP rate is estimated to be less than 10^{-8}. The aircraft of group 1, along with other aircraft of similar performance capabilities, represent about 48 percent of the traffic at MIA.

Another estimate of the RLP rate can be obtained from missed approach and go-around data obtained from ORD. During a 15-day period in August 2000, 60 missed approaches and go-arounds were recorded at ORD. These missed approaches and go-arounds were recorded during

IFR and VFR conditions. To obtain an estimate of the rate during that time-period it is necessary to also estimate the total number of operations. During 1999, there were 909,166 operations at ORD. If half the operations were landings, then about 454,583 landings occurred during 1999. If it is assumed operations occur at a constant rate, then about, 18,681 landings occurred during 15-day periods of 1999. If it is also assumed the number of landings in the year 2000 is about the same as in 1999, then the estimated missed approach, go-around rate is about 60/18,681 = 0.0032 or 0.32% or 3.2×10^{-3}. This rate is almost certainly higher than the actual rejected landing rate since many of the go-arounds were for spacing purposes and may have been initiated at a high altitude. AFS-420 is pursuing actual radar track data from ORD. This data will consist of tracks recorded at ORD possibly as far back as 1997. It is anticipated that analysis of this data will provide a much more accurate estimate of the RLP rate at ORD.

In summary, landing data collected from the flight simulator tests indicate that if the 3,000-foot rule is strictly observed the rate could be as high as 2.4×10^{-6} to 4.7×10^{-2}. Actual missed approach and go-around data supplied by ATP (Air Traffic Operations Program) from ORD suggest the rate from causes other than the 3,000-foot rule could be approximately 3.2×10^{-3}. Since a rate of one in ten thousand (10^{-4}) is within the range of the simulator landing data and smaller than the rate suggested by the ORD data, for the purpose of this report, we will assume a rejected landing probability of one in ten thousand (10^{-4}).

Even given the low probability that an RLP will occur, a pilot must always consider the possibility of not being able to complete a landing, and how to deal with getting the aircraft back in the air. The rejected landing procedure is a workload intensive maneuver. In a LAHSO rejected landing, the pilot must visually identify the other aircraft, determine whether it is a collision risk and, if so, maneuver safely clear of it while being unable to predict what maneuvers it may be making. Given the deck attitude during a rejected landing procedure, the pilot's view is very limited. The maneuvering capabilities of an aircraft transitioning from landing configuration to take-off configuration while very close to the ground are limited. If the rejected landing is initiated near the end of the touchdown zone, the pilot will only have about 20 seconds to handle the situation at MIA. Most other airports will provide even less time.

4.0 RESULTS

One factor that was identified as adversely affecting the safety of the operation, even in the flight simulator testing, was the 1,000-foot ceiling. With modern high-performance aircraft such as the Boeing 777 or the Airbus A320, the requirement to stay visual with such a low ceiling limited the rate of climb and caused a variety of operational problems. Typically, aircraft performing the rejected landing entered the clouds and then had to dive back down into visual conditions. This resulted in several ground proximity warnings and the required maneuvering produced many complaints from the pilots in the simulator tests. Figure 4.1 shows the composite tracks for all the RLPs with the 1000-foot ceiling for the first three aircraft tested. All later testing was done with a 2,000-foot ceiling. AFS-420 recommends the 1,000-foot ceiling option be eliminated and a higher ceiling established. Additional testing and analysis is being conducted to determine a more acceptable value. This finding should be considered applicable to all LAHSO operations, not just ORD and MIA.

The evaluation of scenario 2 involved a large number of simulations and required consideration of several factors. Intuition dictated that there should be a "window" on the final approach course of the LAHSO aircraft so that if an aircraft initiated an RLP while in the window then the probability of a TCV would be high. Intuition also indicated that the window would have varying lengths and positions depending on the LAHSO aircraft and the departing aircraft performance characteristics. Therefore, the ASAT simulation was designed to account for all possible pairs of LAHSO and departing aircraft that would be appropriate for operations at MIA. After consideration of the traffic mix at MIA, seven aircraft were used in the simulation which resulted in $7 \times 7 = 49$ possible pairs. Thus, each aircraft served alternately as the LAHSO aircraft and the departure aircraft with every possible choice of aircraft, including itself.

The simulation was conducted by first choosing a pair of aircraft. If, for example, a B777 was chosen as the LAHSO aircraft and an ATR-42 was chosen as the departing aircraft, then appropriate weights were chosen for each aircraft. Probability distributions of performance parameters derived from the flight simulator phase were used to assign performance capabilities to the two aircraft. Other parameters such as wind speed and direction as well as a turn of the LAHSO aircraft were included. In one simulation, each RLP was initiated at the end of the touch down zone. In all other simulations, the RLP was initiated at random points along the approach and the departure of the other aircraft was initiated at a random time relative to the start of the RLP. Figure 4.2 displays graphical output of an ASAT simulation with the LAHSO aircraft executing a 20° turn. Figure 4.3 shows the results of the ASAT simulation using all the conditions agreed upon by AFS-1, pilot groups, and airline representatives.

To interpret the data displayed in figure 4.3 in a meaningful way, the relative spacing of the two aircraft was selected as a key variable. This spacing represents the range from threshold of the LAHSO aircraft at the time the departing aircraft begins its take-off roll. The simulation recorded all TCVs and made special notice of the outermost and innermost range at which a TCV occurred. TCVs were categorized as either two-dimensional (2-d) or three-dimensional (3-d) with the former indicating there was altitude separation but that one aircraft was essentially passing under the other. The 3-d TCVs were situations where the centers of mass of the two aircraft were within 500 feet of each other. Therefore, the most significant datum on the chart is the first line of the chart giving the total number of 2-d and 3-d TCVs. The percentage of 2-d or 3-d TCVs can be computed by dividing the number of 2-d or 3-d TCVs on the first line by the total number of runs shown in the title bar. The total number of runs was 1,000,000. Along the bottom of the chart is the relative spacing as discussed previously. Along the left side are the possible combinations of aircraft involved in the operation.

Of the eleven simulators tested so far, only seven were representative of types flying into MIA. All other types of aircraft that were not specifically tested were assigned to one of the seven types available. As more data is collected from different simulators, this classification scheme will become increasingly accurate. Beside each aircraft combination is the number of TCVs for that pairing. The blue bar represents the range extremes where 2-d TCVs occurred and the red bar (generally inside the blue) indicates where 3-d TCVs happened.

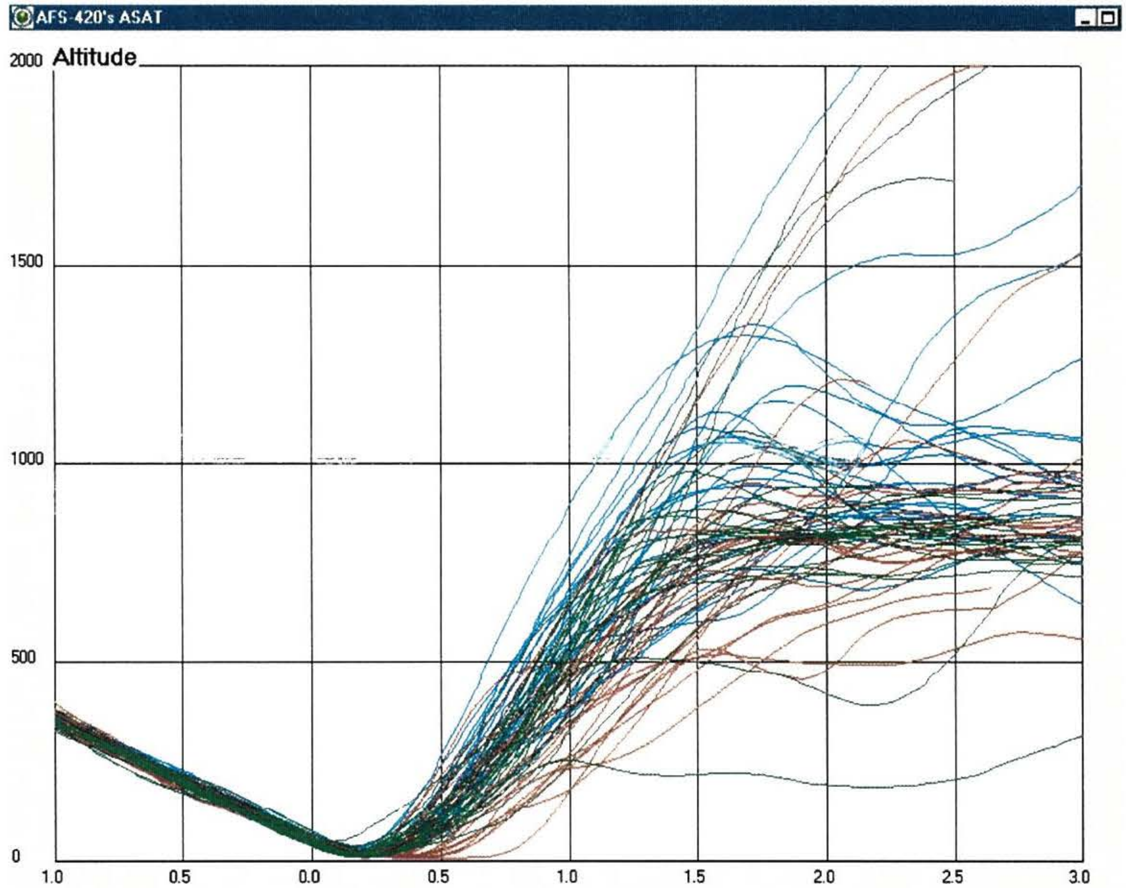

Figure 4.1: REJECTED LANDINGS WITH 1,000-FOOT CEILING

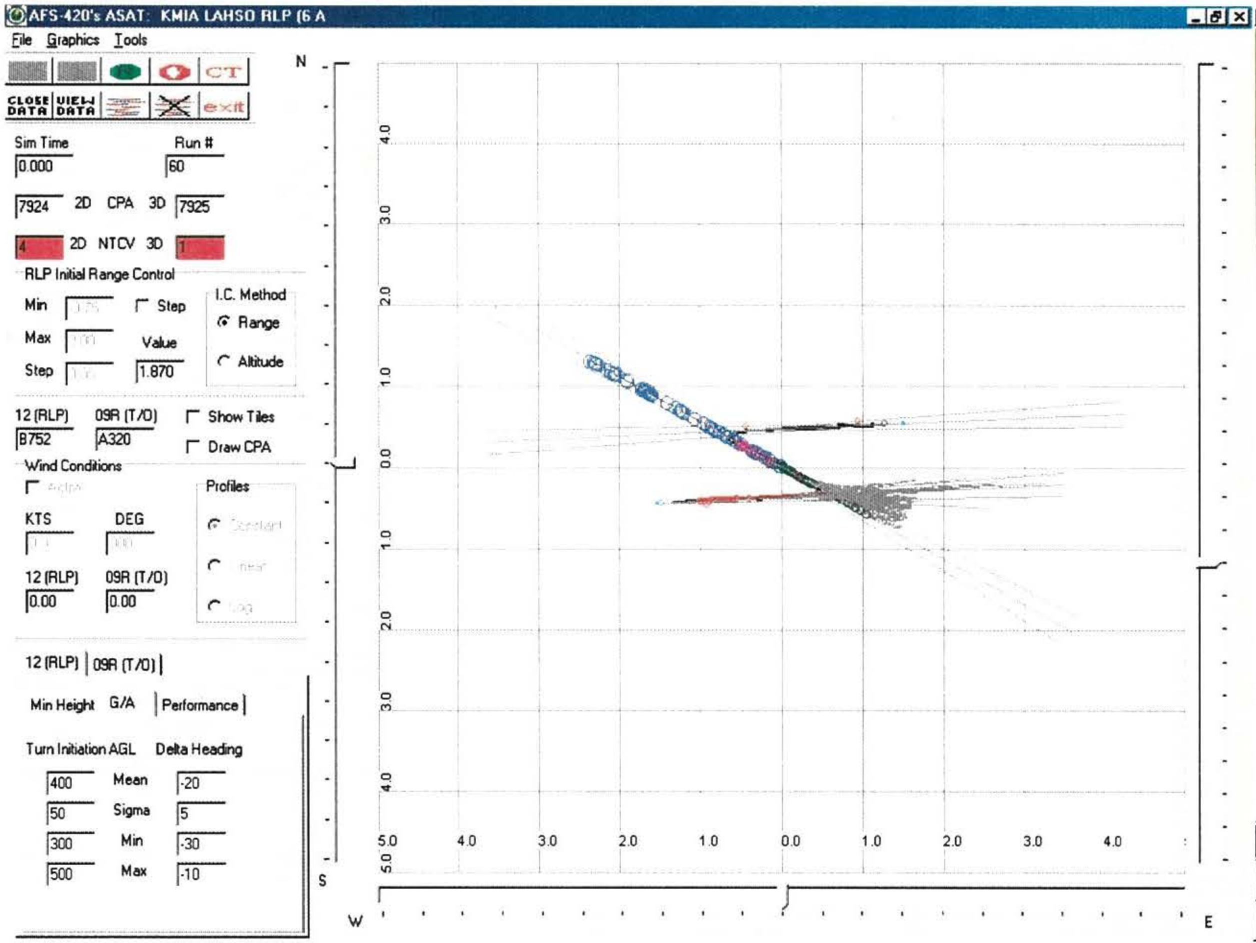

Figure 4.2: ASAT SIMULATION WITH 20° LAHSO TURN

The number of 3-d TCVs indicated by figure 4.3 is 33,149. This results in a TCV rate of 0.033 or 3.3%. To determine the estimated risk of a TCV, multiply 0.033 by 10^{-4}, the estimated RLP rate, to obtain 3.3×10^{-6}. Since the target level of safety is 1×10^{-8}, the target level of safety was not met by the simulation using the agreed upon conditions. Since this simulation was conducted by translating the lowest point of the RLP to 3,000 feet from threshold, it was decided to investigate the effect of randomizing the location of the lowest point of the RLP based on observed touchdown distributions from the flight simulator study.

The charts attached as figures 4.4 through 4.12 were obtained by randomizing the lowest point of the RLP. As in figure 4.3, the most significant datum is on the first line of the chart giving the total number of 2-d and 3-d TCVs. It is clear from the charts that TCVs only occur when the LAHSO aircraft is within a fairly narrow window. This window starts at somewhere between 1.25 and 1.75 miles outside the LAHSO runway threshold for most aircraft types and ends at about the LAHSO threshold. The charts also show that while there is a worst case pairing and there is an aircraft that has a higher percentage of TCVs than any of the other tested types, the differences between pairings and types are not of great consequence. Removal of any single type or avoidance of particular pairings (even if operationally feasible) would not significantly impact the TCV rate.

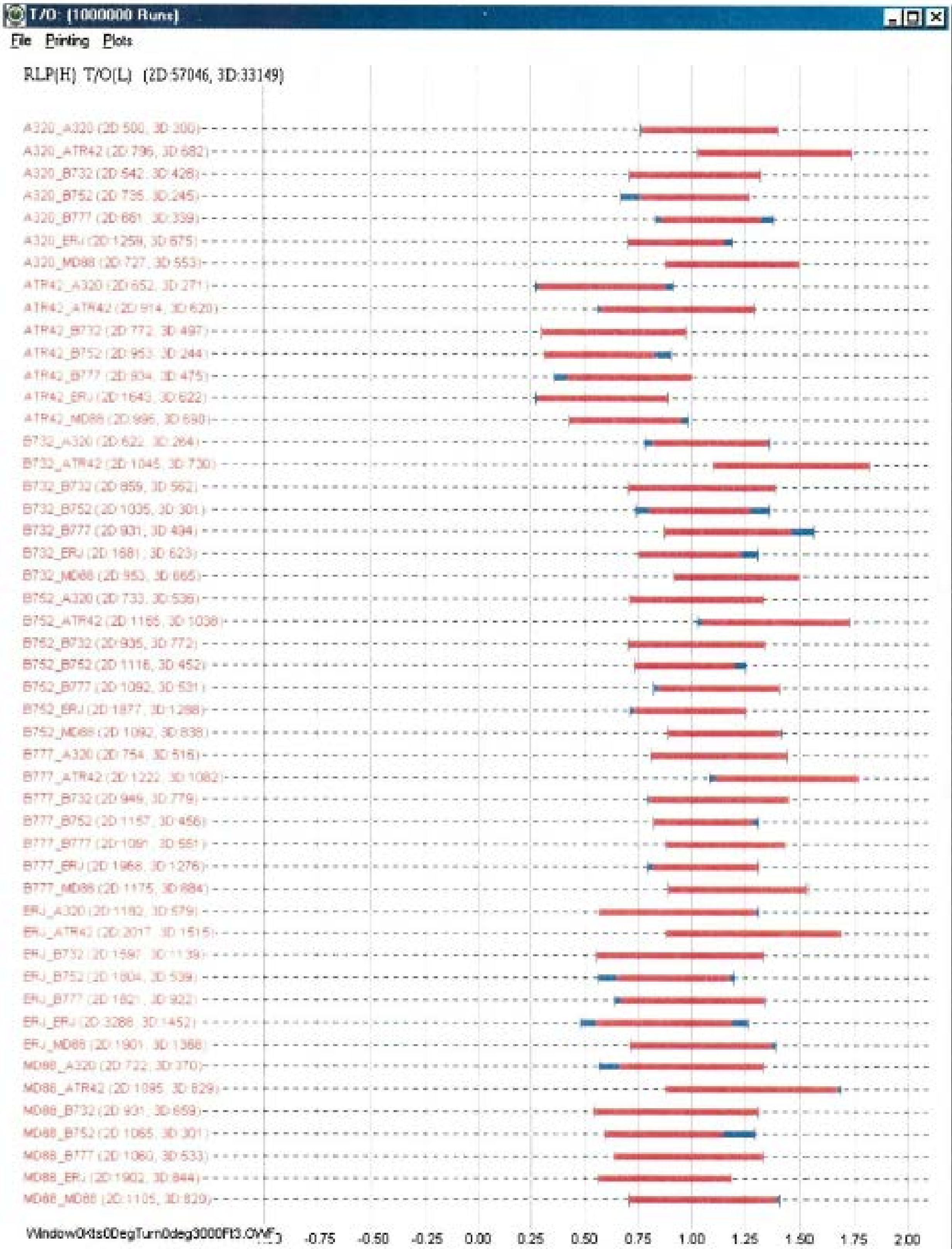

Figure 4.3: NO TURN, DEF AULT WEIGHTS, NO WIND, DAT A TRANSLATED

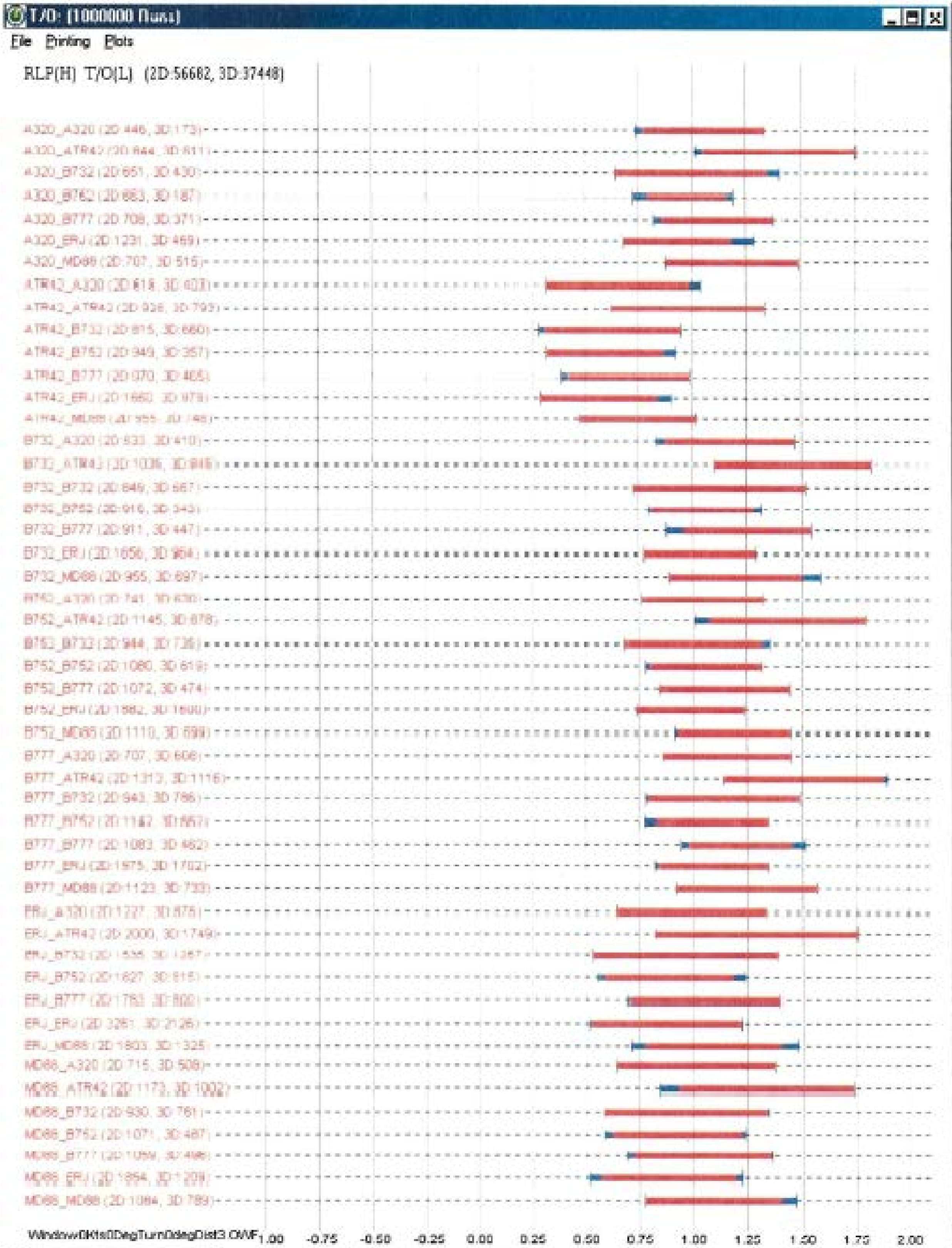

Figure 4.4: NO TURN, DEFAULT WEIGHTS, NO WIND

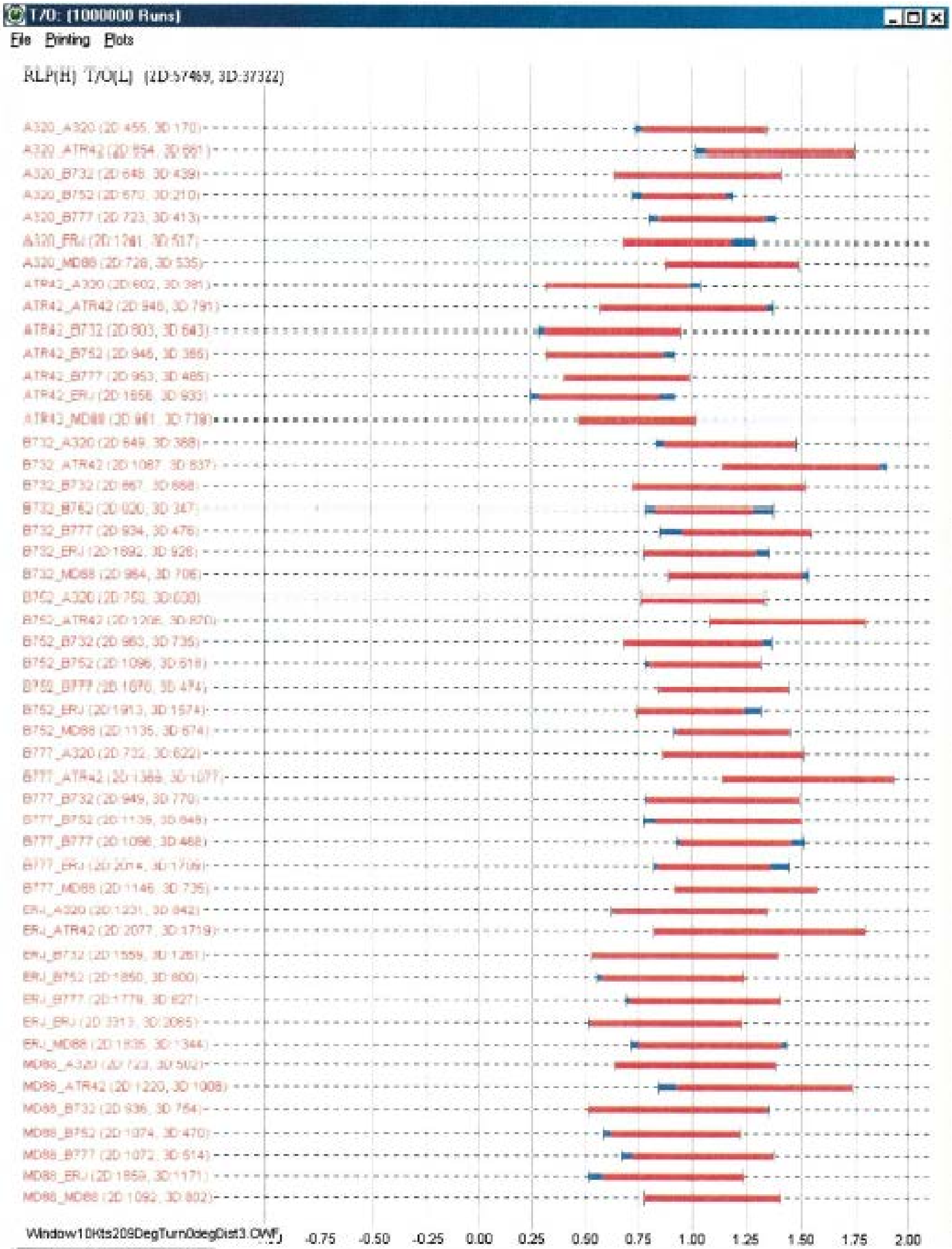

Figure 4.5: NO TURN, DEFAULT WEIGHTS, WIND 10 KT@ 210°

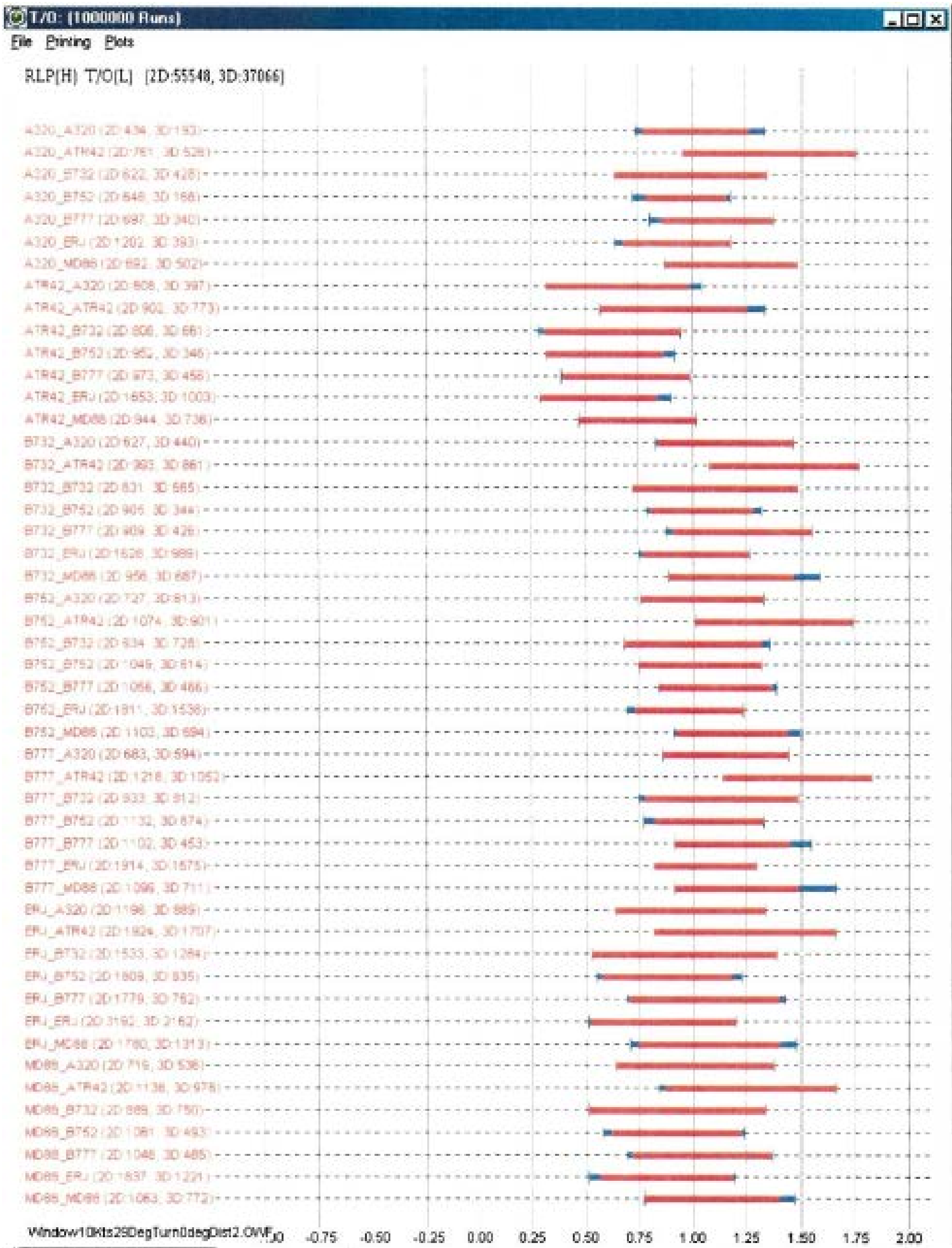

Figure 4.6: NO TURN, DEFAULT WEIGHTS, WIND 10 KT@ 030°

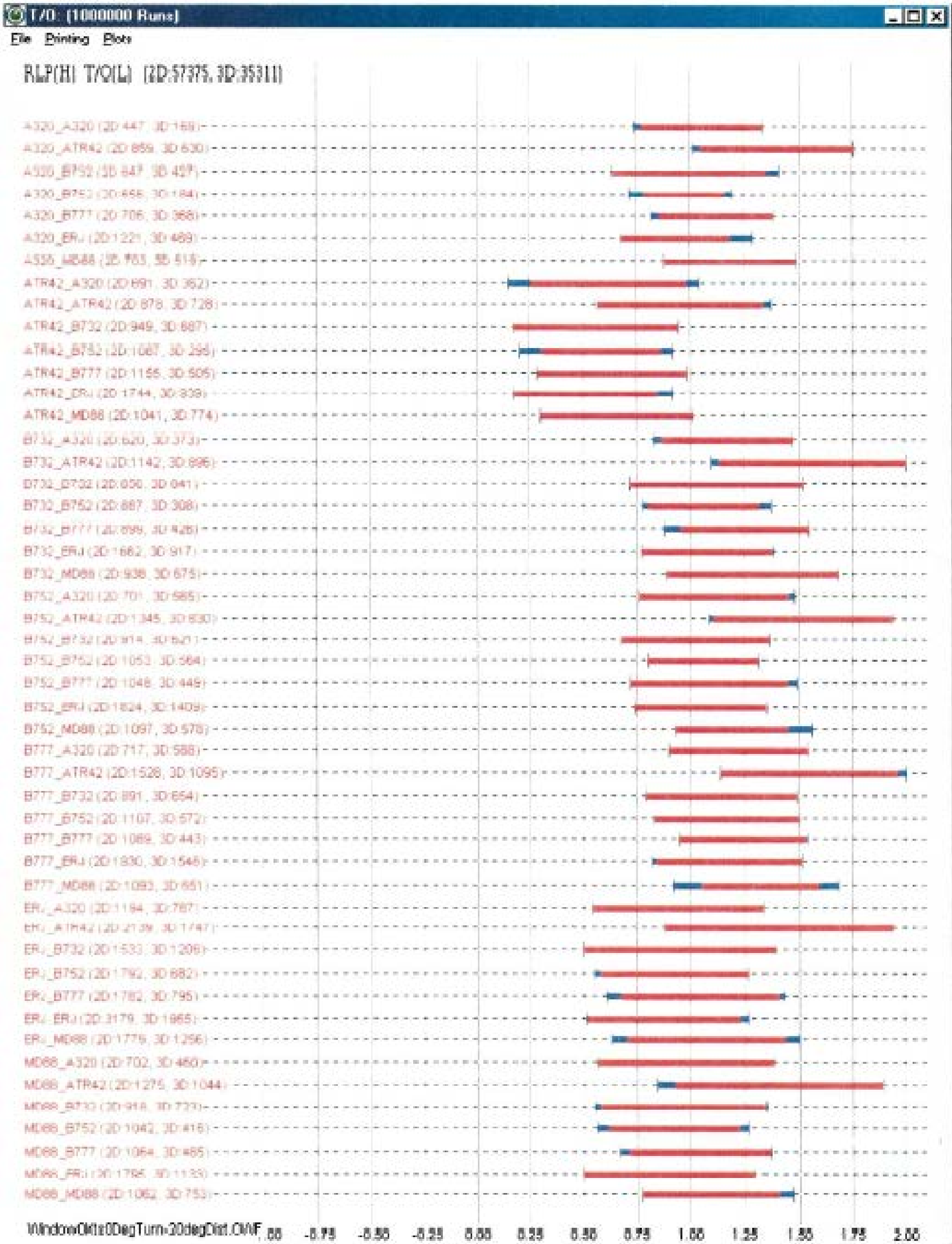

Figure 4.7: 20° LEFT TURN, DEFAULT WEIGHTS, NO WIND

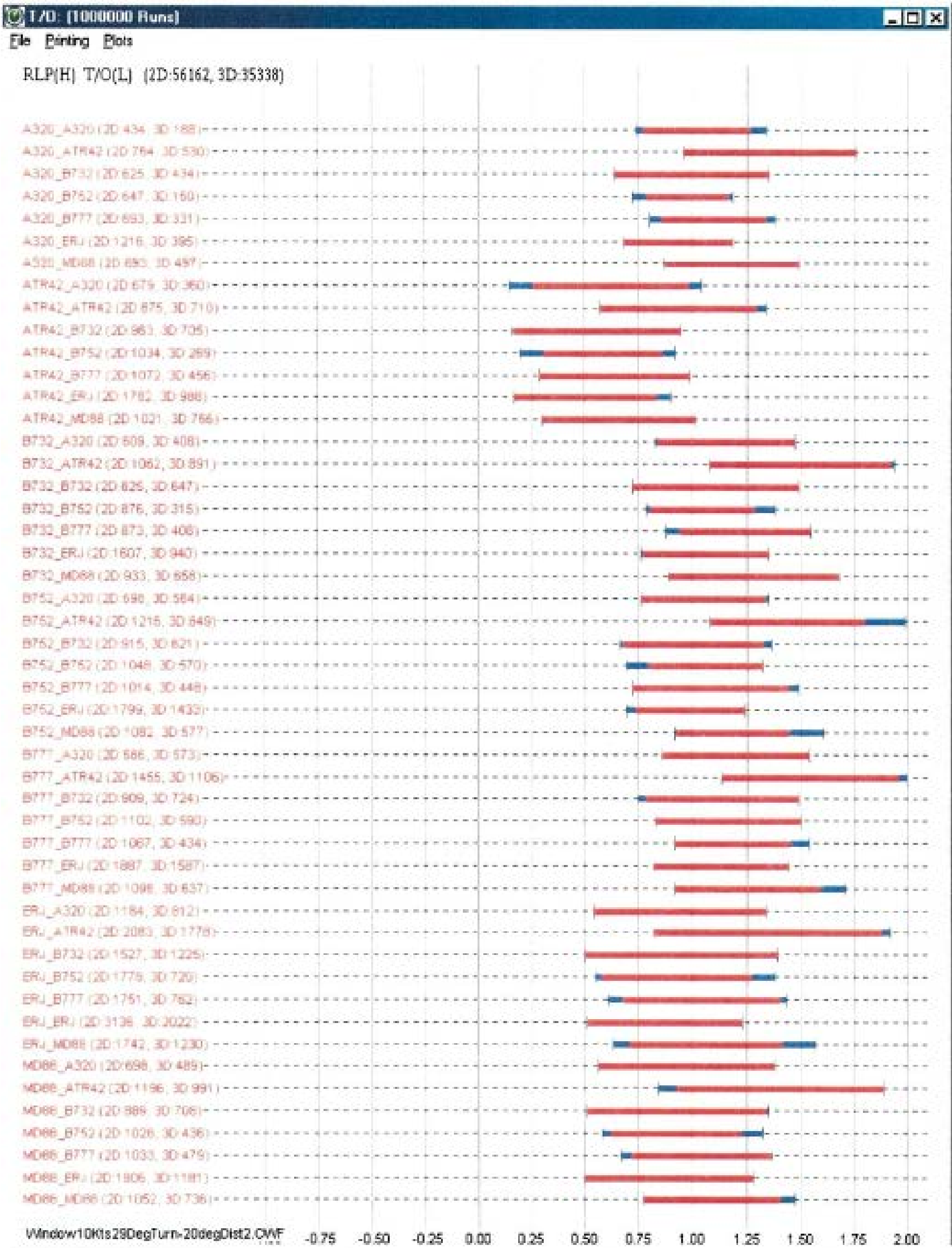

Figure 4.8: 20° LEFT TURN, DEFAULT WEIGHTS, WIND 10 KT@030°

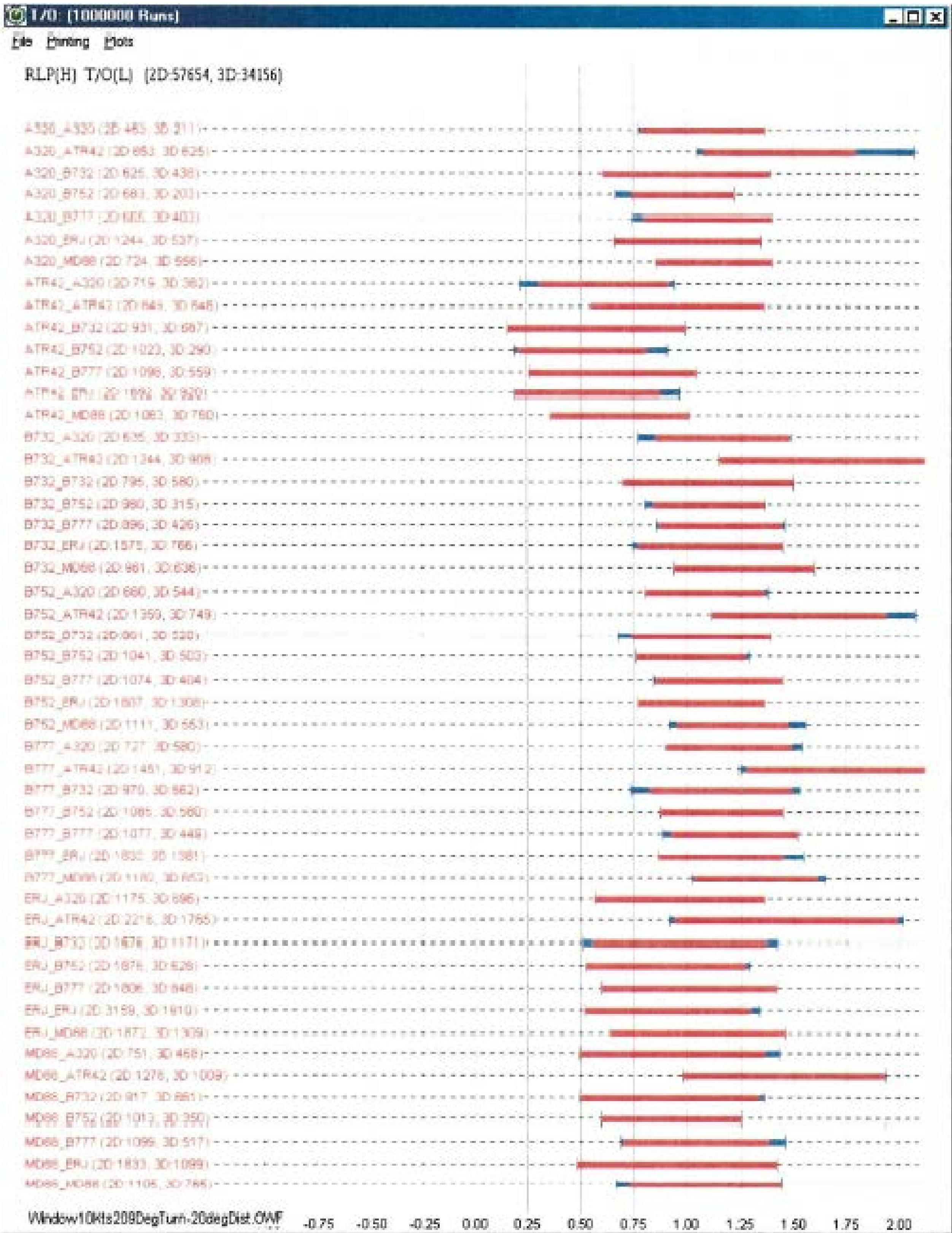

Figure 4.9: 20° LEFT TURN, DEFAULT WEIGHTS, WIND 10 KT@210°

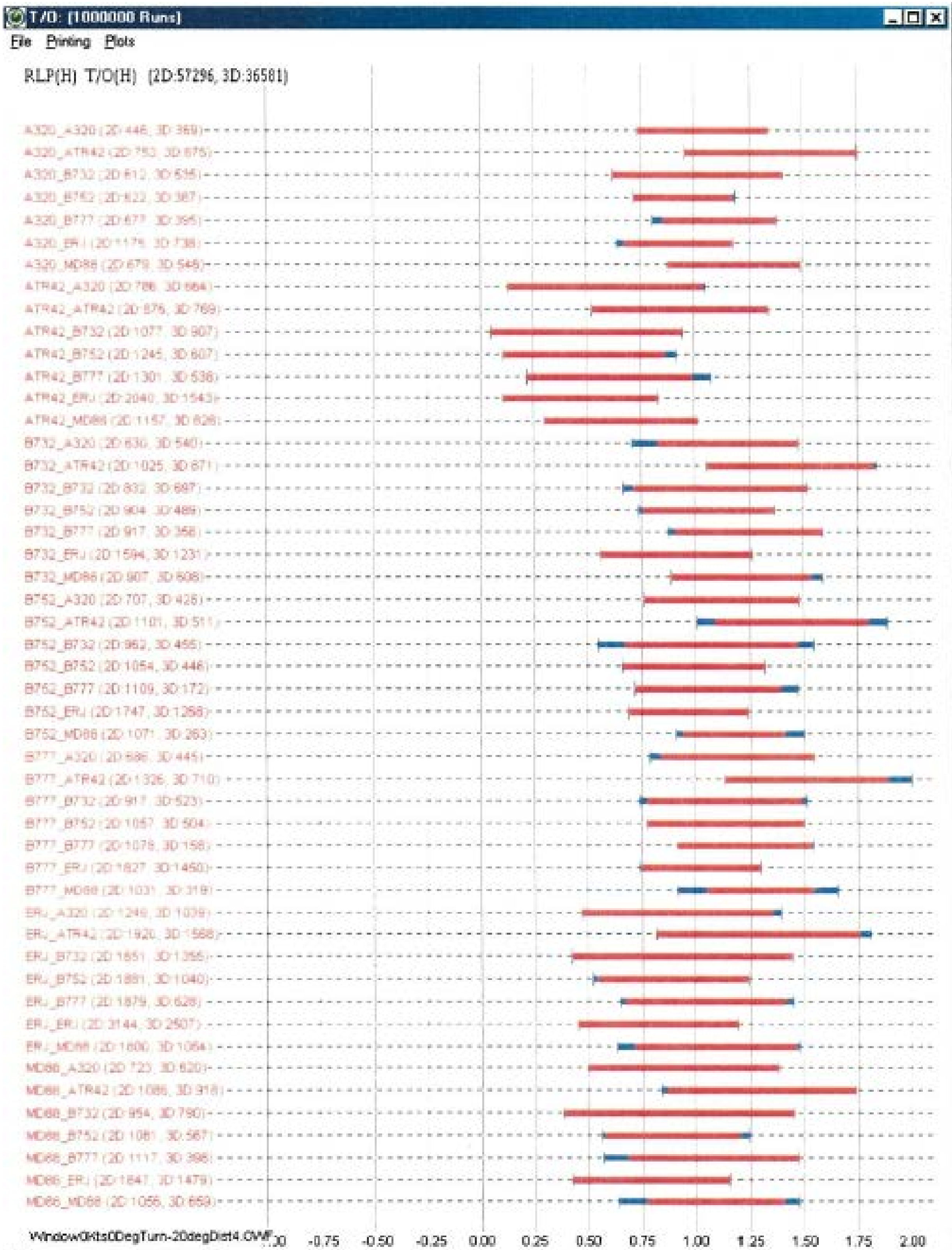

Figure 4.10: 20° LEFT TURN, HEAVY DEPARTURE, NO WIND

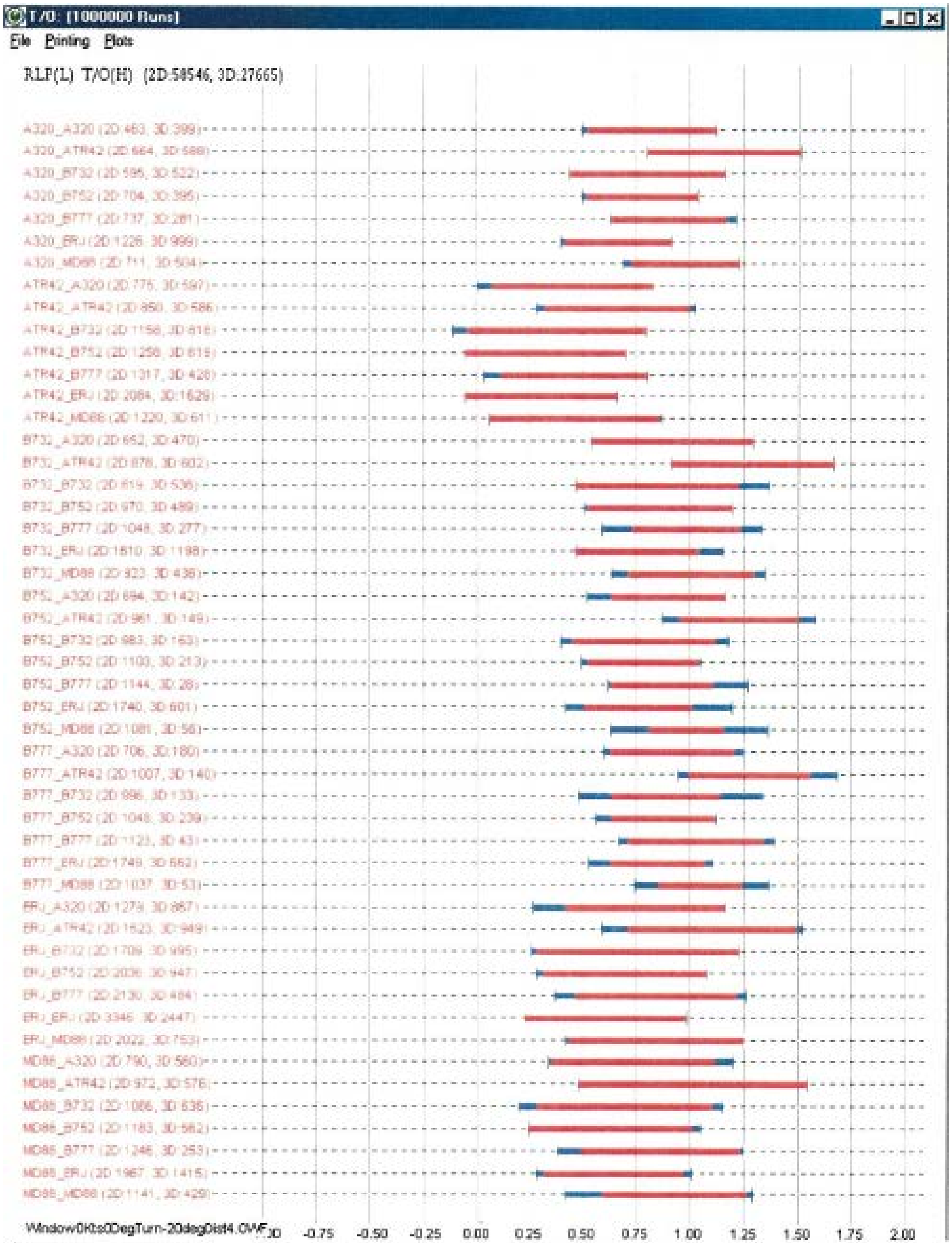

Figure 4.11: 20° LEFT TURN, HEAVY TAKEOFF, LIGHT ARRIVAL, NO WIND

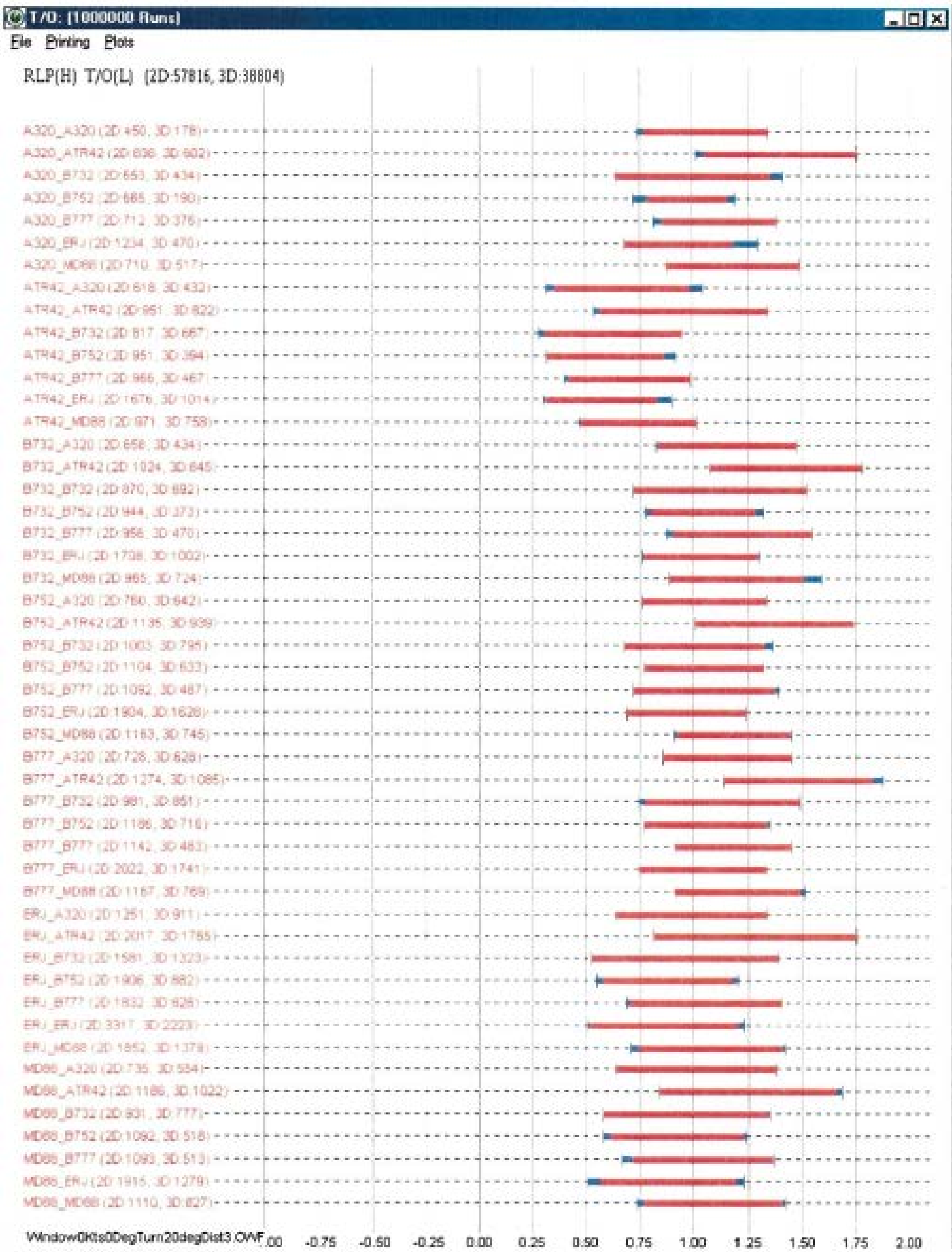

Figure 4.12. 20° RIGHT TURN, DEFAULT WEIGHTS, NO WIND

Figures 4.4 through 4.6 show the results for a straight-ahead LAHSO with no wind, 10 knots right crosswind, and 10 knots left crosswind, respectively. Figures 4.7 through 4.9 show the results for a LAHSO RLP with a 20-degree turn away from the traffic on 9R with the same set of winds. This does not reduce the occurrence of 3-d TCVs, and in one case, the probability is increased. Figure 4.12 shows the results for a LAHSO RLP with a 20-degree turn toward the traffic on 9R. The turn slightly increases the risk of a TCV. In figures 4.3 through 4.8 and figure 4.12, the weights of the aircraft are maximum landing weight for the LAHSO aircraft, and a light take off weight for the departing aircraft. These are referred to as default weights in the caption of each figure.

Figure 4.11 was generated to see what effect a more normal takeoff weight would have. One of the ALPA stipulations was that the departing aircraft in the flight simulator testing be very light to insure a minimum takeoff distance. Most actual takeoffs occur with aircraft near maximum load, lengthening their takeoff roll and slowing their climb rate. This scenario also included the 20-degree turn and had no wind. Figure 4.11 shows the same situation with the LAHSO aircraft at a lighter weight to be more representative of fuel burned on a flight. Figure 4.12 examines the default weights with a 20-degree turn to the right. Table 4.1 summarizes the estimated risk of a TCV for each scenario. The risk is obtained by multiplying the TCV rate by the RLP rate of 10^{-4}. Table 4.1 indicates the target level of safety was not met by any of the scenarios.

Weight		**Turn Direction**	**Wind**		**Data Translated 3,000 Feet**	**Estimated 3-D TCV Rate**
LAHSO	**Take Off**		**Direction**	**Speed**		
Heavy	Light	None	None	None	Yes	3.3×10^{-6}
Heavy	Light	None	None	None	No	3.7×10^{-6}
Heavy	Light	None	210°	10 KT	No	3.7×10^{-6}
Heavy	Light	None	030°	10 KT	No	3.7×10^{-6}
Heavy	Light	20° Left	None	None	No	3.1×10^{-6}
Heavy	Light	20° Left	030°	10 KT	No	3.5×10^{-6}
Heavy	Light	20° Left	210°	10 KT	No	3.4×10^{-6}
Heavy	Heavy	20° Left	None	None	No	3.7×10^{-6}
Light	Heavy	20° Left	None	None	No	2.8×10^{-6}
Heavy	Light	20° Right	None	None	No	3.9×10^{-6}

Table 4.1: SUMMARY OF SCENARIO PARAMETERS WITH TCV RATES

Figures 4.3 through 4.12 indicate the range of starting distances for the RLP relative to the threshold of runway 12 that generate TCVs is bounded and extends from about 1¾ NM prior to threshold to about the threshold. It is of interest to analyze the range of starting distances further, to determine the probability a TCV will occur when an RLP is initiated farther than a given distance from threshold. This analysis, which will establish the boundaries of the risk window, was done for three cases. In the first case, all the TCV data from the runs that generated figure 4.4 were combined into one file. In the second case, all the TCV data from the runs that generated figure 4.7 were combined into a second file. The runs that generated figure 4.12 were combined to produce the third file. Probability density curves were fitted to each of the three combined data sets and probabilities were determined from the three curves. The curves represent the probability density of distance (plus or minus) from threshold given that a TCV and, necessarily, an RLP have occurred. The probability that an RLP initiated more than a given distance D from threshold and a TCV occurred can be written in equation form as follows:

$$P((\text{Dist} > D) \cap \text{TCV} \cap \text{RLP}) = P(\text{Dist} > D \mid \text{TCV} \cap \text{RLP}) \times P(\text{TCV} \cap \text{RLP})$$
$$= P(\text{Dist} > D \mid \text{TCV} \cap \text{RLP}) \times P(\text{TCV} \mid \text{RLP}) \times P(\text{RLP})$$

where the symbol "$\cap$" is read "and".

The first factor in the equation, $P(\text{Dist} > D \mid \text{TCV} \cap \text{RLP})$, may be found from the curves fitted to the combined data. According to probability theory, the probability that a random variable X is larger than a fixed number D is the area between the curve and the x-axis to the right of the number D. This is illustrated in figure 4.13. In figure 4.13 the area of the shaded region represents the probability that the RLP initiated at a distance greater than or equal to ½ NM, i.e., $P(\text{Dist} > D \mid \text{TCV} \cap \text{RLP})$.

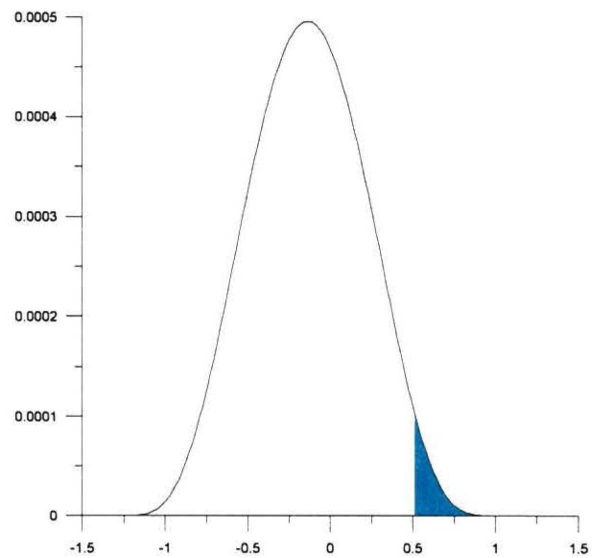

Figure 4.13. P(DIST > D | TCV ∩ RLP), NO WIND, NO TURN, DEFAULT WEIGHTS

The probabilities found from analysis of the three curves are summarized in tables 4.2 through 4.7. In tables 4.2, 4.4, and 4.6, the columns represent distance in NM prior to threshold. In tables 4.3, 4.5, and 4.7, the columns represent distance in feet after threshold. In each table, the first row of data represents the probability that an RLP initiated at a distance greater than or equal to the distance indicated by the column header, i.e., $P(\text{Dist} > D \mid \text{TCV} \cap \text{RLP})$. The second row of data indicates the probability that an RLP occurs and a TCV occurs with the RLP initiated at a distance greater than or equal to the distance indicated by the column header. This row is determined by multiplying the first row entry by $P(\text{TCV} \mid \text{RLP})$. The factor $P(\text{TCV} \mid \text{RLP})$ is the probability that a TCV occurs given that an RLP has occurred. This value is found from figures 4.4, 4.7, and 4.12 by dividing the total number of three-dimensional TCVs by the total number of RLPs. The total number of three-dimensional TCVs is found in the upper left corner of the figures and the total number of simulated RLPs was 1,000,000 for each scenario. From figure 4.4, the total number of three dimensional TCVs is 37,448 so that

$$P(TCV \mid RLP) = 37{,}448/1{,}000{,}000 \approx 3.7 \times 10^{-2},$$

for RLPs performed with no wind, no turn, and default weights. This figure is used to determine the second row of tables 4.2 and 4.3.

From figure 4.7, the total number of three dimensional TCVs is 35,311 so that

$$P(TCV \mid RLP) = 35{,}311/1{,}000{,}000 \approx 3.5 \times 10^{-2},$$

for RLPs performed with no wind, 20° left turn, and default weights. This figure is used to determine the second row of tables 4.4 and 4.5.

From figure 4.12, the total number of three dimensional TCVs is 38,804 so that

$$P(TCV \mid RLP) = 38{,}804/1{,}000{,}000 \approx 3.9 \times 10^{-2},$$

for RLPs performed with no wind, 20° right turn, and default weights. This figure is used to determine the second row of tables 4.6 and 4.7.

In each of the tables, 4.2 through 4.7, the second row is found by multiplying the first row by $P(TCV \mid RLP)$.

The third row of each table is determined by multiplying the second row by P(RLP). In each table, P(RLP), represents the estimated RLP rate, i.e., $P(RLP) = 1 \times 10^{-4}$. The third row represents the total probability that an RLP initiates at a distance greater than the distance in the header row and results in a TCV. In table 4.2 the probability of an RLP initiated at a distance greater than 1½ NM and resulting in a TCV is 1.1×10^{-8}. In table 4.3, the probability of an RLP initiated at threshold or over the runway and resulting in a TCV is 4.4×10^{-8}. Therefore, the window of risk runs from about 1½ NM before threshold to threshold. Thus, the target level of safety is met for RLPs initiated at distances greater than 1½ NM prior to threshold and for those initiated at threshold or over the runway. The addition of a right or left turn has no significant effect on the length or location of the risk window. Tables 4.4 through 4.7 also indicate that the risk window runs from about 1½ NM before threshold to threshold.

PROBABILITIES	**DISTANCE BEFORE THRESHOLD (NM)**		
	1-1/4	1-1/2	1-5/8
$P(RLP>D \mid TCV \cap RLP)$	6.7×10^{-2}	2.9×10^{-3}	2.9×10^{-6}
Row 1 × $P(TCV \mid RLP)$	2.5×10^{-3}	1.1×10^{-4}	1.1×10^{-7}
Row 2 ×P(RLP)	2.5×10^{-7}	1.1×10^{-8}	1.1×10^{-11}

Table 4.2: NO WIND, NO TURN, DEFAULT WEIGHTS, BEFORE THRESHOLD

PROBABILITIES	DISTANCE AFTER THRESHOLD (FEET)		
	0	500	1000
P(RLP>D|TCV∩RLP)	1.2×10^{-2}	2.5×10^{-3}	1.0×10^{-5}
Row 1 × P(TCV|RLP)	4.4×10^{-4}	9.3×10^{-5}	3.7×10^{-7}
Row 2 ×P(RLP)	4.4×10^{-8}	9.3×10^{-9}	3.7×10^{-11}

Table 4.3: NO WIND, NO TURN, DEFAULT WEIGHTS, AFTER THRESHOLD

PROBABILITIES	DISTANCE BEFORE THRESHOLD (NM)		
	1-1/4	1-1/2	1-5/8
P(RLP>D|TCV∩RLP)	6.8×10^{-2}	2.9×10^{-3}	2.9×10^{-6}
Row 1 × P(TCV|RLP)	2.4×10^{-3}	1.0×10^{-4}	1.0×10^{-7}
Row 2 ×P(RLP)	2.4×10^{-7}	1.0×10^{-8}	1.0×10^{-11}

Table 4.4: NO WIND, 20° LEFT TURN, DEFAULT WEIGHTS, BEFORE THRESHOLD

PROBABILITIES	DISTANCE AFTER THRESHOLD (FEET)		
	0	500	1000
P(RLP>D|TCV∩RLP)	1.0×10^{-2}	1.9×10^{-3}	4.0×10^{-5}
Row 1 × P(TCV∩RLP)	3.5×10^{-4}	6.7×10^{-5}	1.4×10^{-6}
Row 2 ×P(RLP)	3.5×10^{-8}	6.7×10^{-9}	1.4×10^{-10}

Table 4.5: NO WIND, 20° LEFT TURN, DEFAULT WEIGHTS, AFTER THRESHOLD

PROBABILITIES	DISTANCE BEFORE THRESHOLD (NM)		
	1-1/4	1-1/2	1-5/8
P(RLP>D|TCV∩RLP)	6.6×10^{-2}	2.9×10^{-3}	3.0×10^{-6}
Row 1 × P(TCV|RLP)	2.6×10^{-3}	1.1×10^{-4}	1.2×10^{-7}
Row 2 ×P(RLP)	2.6×10^{-7}	1.1×10^{-8}	1.2×10^{-11}

Table 4.6: NO WIND, 20°RIGHT TURN, DEFAULT WEIGHTS, BEFORE THRESHOLD

PROBABILITIES	DISTANCE AFTER THRESHOLD (FEET)		
	0	500	1000
P(RLP>D|TCV∩RLP)	1.1×10^{-2}	2.0×10^{-3}	3.0×10^{-5}
Row 1 × P(TCV|RLP)	4.3×10^{-4}	7.8×10^{-5}	1.2×10^{-6}
Row 2 ×P(RLP)	4.3×10^{-8}	7.8×10^{-9}	1.2×10^{-10}

Table 4.7: NO WIND, 20°RIGHT TURN, DEFAULT WEIGHTS, AFTER THRESHOLD

Since another agreed upon condition was that the low points of all RLPs would be no higher than 50 feet, it was thought that this condition could significantly increase the TCV rate. Therefore, additional simulations were conducted to determine the effect of RLP initiation altitude upon the TCV rate. The results of those simulations are presented in table 4.8. In these simulations, the lowest point altitude was fixed at the altitudes indicated in the first column. There is no data translation to 3,000 feet in any of the simulations. Departures are random relative to landings. The fifth column indicates that TCVs are detected as high as 550 feet above the runway threshold. The sixth column displays the risk associated with the corresponding altitude if the RLP rate is 1×10^{-4}. The distribution of lowest point altitudes of RLPs is not known, but column 6 indicates the target level of safety is not met unless all RLPS are initiated above 550 feet. Since this does not seem likely, we must conclude the target level of safety is not met if random departures are permitted. The percentages of column 5 are presented in graphical form in figure 4.14.

LAHSO RLP ALTITUDE DEPENDENCE ONE MILLION RUNS AT EACH ALTITUDE					
RLP Start Alt.	**#2-d TCVs**	**%2-d TCVs**	**#3-d TCVs**	**%3-d TCVs**	**3-d TCV Risk**
50	48071	4.8071	32105	3.2105	3.2×10^{-6}
150	65803	6.5803	31553	3.1553	3.2×10^{-6}
250	68447	6.8447	16246	1.6246	1.6×10^{-6}
350	68621	6.8621	6089	0.6089	6.1×10^{-7}
450	68215	6.8215	2214	0.2214	2.2×10^{-7}
550	67595	6.7595	743	0.0743	7.4×10^{-8}

Table 4.8: LAHSO-RLP ALTITUDE DEPENDENCE

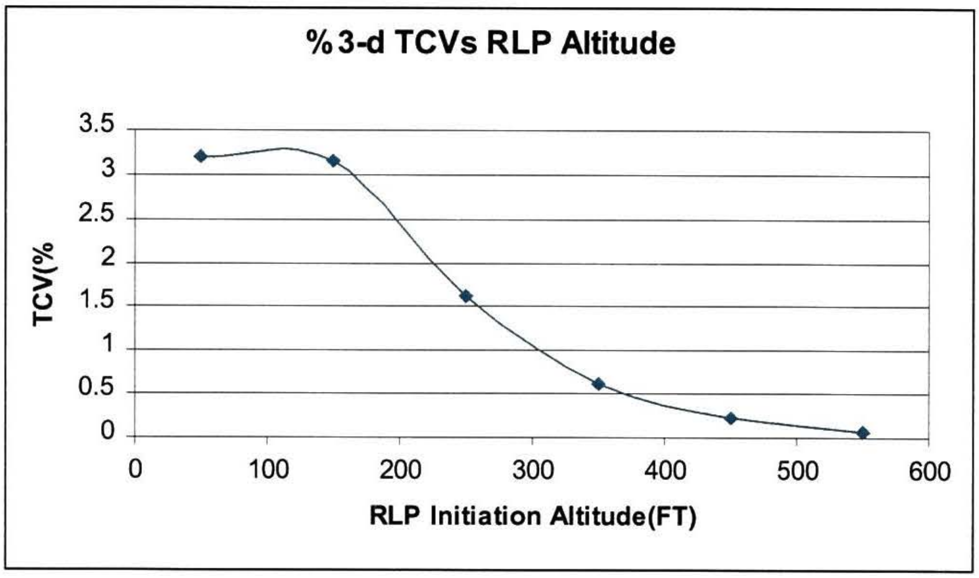

Figure 4.14: 3-D TCV RATE vs RLP ALTITUDE

5.0 CONCLUSIONS

The following conclusions are based on the AFS-420 analysis of the flight simulator test data and the ASAT simulation results for MIA RLP for runways 12 and 9R:

a. The minimum ceiling should be raised from the 1,000-foot allowed in the LAHSO order. Additional testing has indicated that a 2,000-foot ceiling is achievable. This affects all LAHSO operation.

b. Because of the distance from threshold to the intersection of runways 9R and 12, both aircraft will be airborne should an RLP occur. Therefore, scenarios 1 and 3 are not applicable at Miami for LAHSO operations on either runway 9R or 12.

c. Scenario 2 studies indicate the target level of safety is not met without making questionable assumptions about the percentage of RLPs. If the RLP rate is assumed to be 1 per 10,000, then the overall risk of the operation is approximately 1×10^{-6}. Achieving the desired level of safety of 1×10^{-8} with totally independent operations requires an RLP rate of no more than one per million. Additional operational corrections such as incorporating a turn in the RLP to compensate for a higher RLP rate do not appear significant enough to achieve the desired TLS. To significantly impact the overall risk level, some operational steps should be taken to reduce the probability of both aircraft being at the intersection at the same time. The results of the simulation shown in figures 4.3 through 4.12 indicate there is a long segment of the approach that the LAHSO aircraft can be in and the departing aircraft can begin its take-off with essentially zero probability of a TCV. Conversely, there is a short segment of the approach that the LAHSO aircraft can be in where the risk of a TCV with a departing aircraft may not meet the target level of safety. Therefore, AFS-420 recommends consideration be given to the establishment of operational guidelines for LAHSO that would not allow the initiation of departures while the approaching (LAHSO) aircraft is in the interval beginning at 1½ NM from the threshold of runway 12 and extending to the threshold of runway 12. This concept is illustrated in figures 5.1, 5.2, and 5.3.

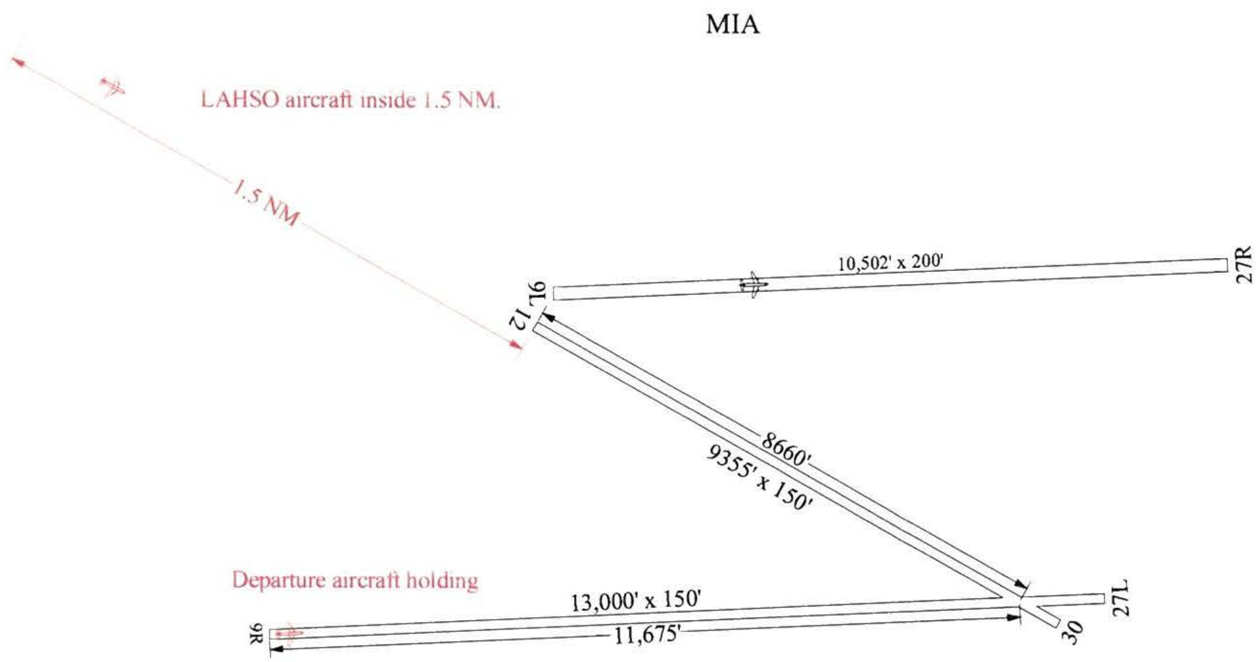

Figure 5.1: LAHSO AIRCRAFT WITHIN 1½ NM, DEPARTURE AIRCRAFT HOLDING

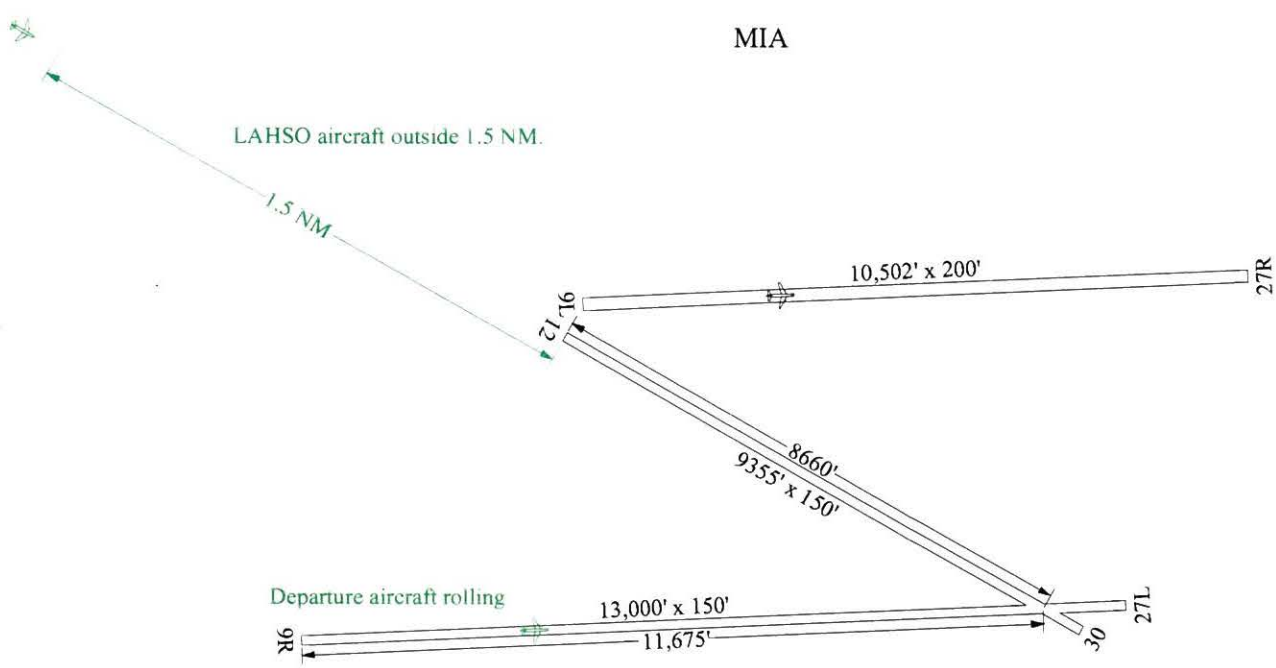

Figure 5.2: LAHSO AIRCRAFT OUTSIDE 1½ NM, DEPARTURE AIRCRAFT ROLLING

MIA

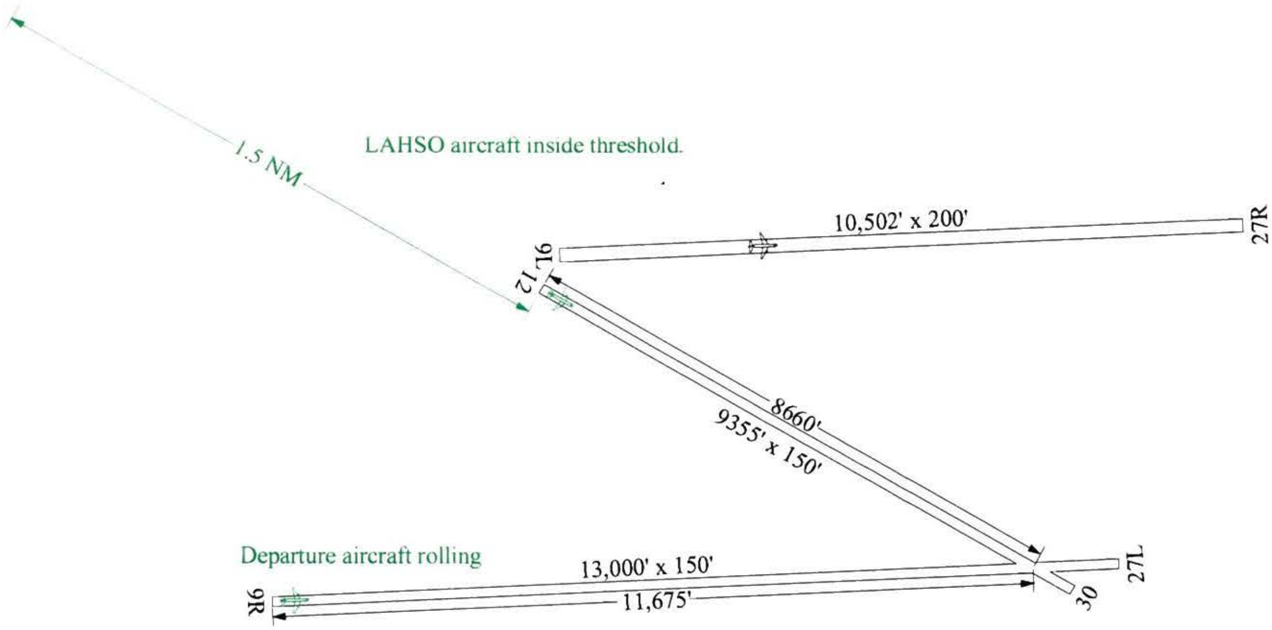

Figure 5.3: LAHSO AIRCRAFT INSIDE THRESHOLD, DEPARTURE AIRCRAFT ROLLING

APPENDIX A. COLLECTION AND PROCESSING OF FLIGHT SIMULATOR DATA

APPENDIX A. COLLECTION AND PROCESSING OF FLIGHT SIMULATOR DATA

A.1 STATUS OF DATA COLLECTION

Data has been collected from eleven flight simulators for use in the LAHSO simulations. Table A1 summarizes the current status of the data collection process.

Number	Owner/Location	Aircraft	Status
1	UAL/Denver	A320	Completed
2	UAL/Denver	B737-300	Completed
3	UAL/Denver	B757-200	Completed
4	UAL/Denver	B777	Completed
5	AA/DFW	ATR-42	Completed
6	AA/DFW	ERJ-145	Completed
7	AA/DFW	F-100	Completed
8	DAL/Atlanta	B737-800	Completed
9	DAL/Atlanta	MD-88	Completed
10	AA/DFW	SAAB-340B	Completed
11	FAA/OKC	B727-200	Completed

Table A1: FLIGHT SIMULATORS

A.2 DATA COLLECTION PROCESS

Before the beginning of each data acquisition session, a communication channel was established between the simulator test site and AFS-420. The communication channels used were an FTP site and e-mail. Prior to the execution of the planned tests a few pre-test runs were performed and sent via the electronic link in order to confirm that the link was functional and that all required variables were being recorded.

During the flight simulator tests, several parameters were recorded. Although there was some variation between simulators, the list of recorded variables consisted of at least the following time stamped parameters:

a. Distance to active runway threshold along runway centerline,

b. Cross track distance to runway centerline,

c. Height above terrain,

d. Pressure altitude,

e. Calibrated air speed,

f. Bank Angle,

g. Magnetic heading,

h. Rate of climb,

i. Engine throttle angle,

j. Auto-pilot switch,

k. TOGA switch,

l. Gear position,

m. Weight on wheels (WOW),[1]and

n. Flap position.[2]

As the flight simulator session progressed, the variables listed above and other variables specific to each flight simulator were recorded in files that were saved for data analysis. At the end of each session the files were sent by the flight simulator personnel via the electronic link to AFS-420 to be processed. Appendix C contains a section of a data file that was generated by the United Airlines B777 flight simulator.

A.3 DATA PROCESSING PROCEDURE

The ASAT data processing suite of programs was customized to handle the data formats of each simulator and data analysis requirements associated with the new data. Once a data set was received at AFS-420, each track was individually plotted, identified with a specific run from the test plan and processed. There were three types of tracks, take-off tracks, landing tracks and rejected landing tracks. The track data processing sorted the results for each individual track, according to the track type as detailed in table 2.

The ASAT data handling section was extensively used to view and process the data. The system allows for qualitative as well as quantitative inspection and analysis of the data. As an example, figure 1 shows the differences in the way that two aircraft (in this case an ERJ-145 in green and an ATR-42 in red) perform a rejected landing procedure. Figure 2 shows the dispersion of the location of the minimum altitude point during the RLP. The figure illustrates in planar view the TDZ area and beyond. The horizontal axis represents distance from threshold to 4,000-foot past the threshold. The vertical axis represents the lateral dispersion around runway centerline on a scale of ±100 feet. Data points associated with the ERJ are drawn in green and those associated with the ATR-42 are drawn in red.

A total of 931 tracks were used to establish the statistical data bases used by ASAT in the MIA simulation. The tracks consisted of 7 different aircraft detailed in table 3. Figures A3, A4, and

[1] Except for the A320 tests
[2] Except for the A320 where Configuration Angle was used

A5 depict altitude, rate of climb and airspeed for a single B777 track vs distance from threshold. The plots use data contained in 777P309.DAT flight simulator test data file.

Data Item	**Track Type**		
	Take Off	**Landing**	**Rejected Landing**
Approach IAS		√	
Touch down point along runway centerline		√	
Touch down point across runway centerline		√	
Lowest altitude point along runway centerline			√
Lowest altitude point across runway centerline			√
Rate of climb	√		√
Rate of change of rate of climb @ take off	√		√
Climb IAS	√		√
Rate of change of IAS	√		√
Bank angle @ turn			√
Bank rate @ turn			√
Change of heading @ turn			√
Turn altitude			√
Take off distance	√		
Take off IAS	√		

Table A2: DATA ITEMS DERIVED FROM FLIGHT SIMULATOR TRACKS

Aircraft	**Track Type**			**Total**
	Take off	**Landing**	**Rejected Landing**	
1. A320	25	45	86	156
2. B737-300	23	36	85	144
3. B757-200	26	39	95	160
4. B777	21	32	84	137
5. ATR-42	13	24	49	86
6. ERJ-145	22	32	76	130
7. MD-88	21	27	70	118
Totals	151	235	545	931

Table A3: BREAKDOWN OF TEST RUNS

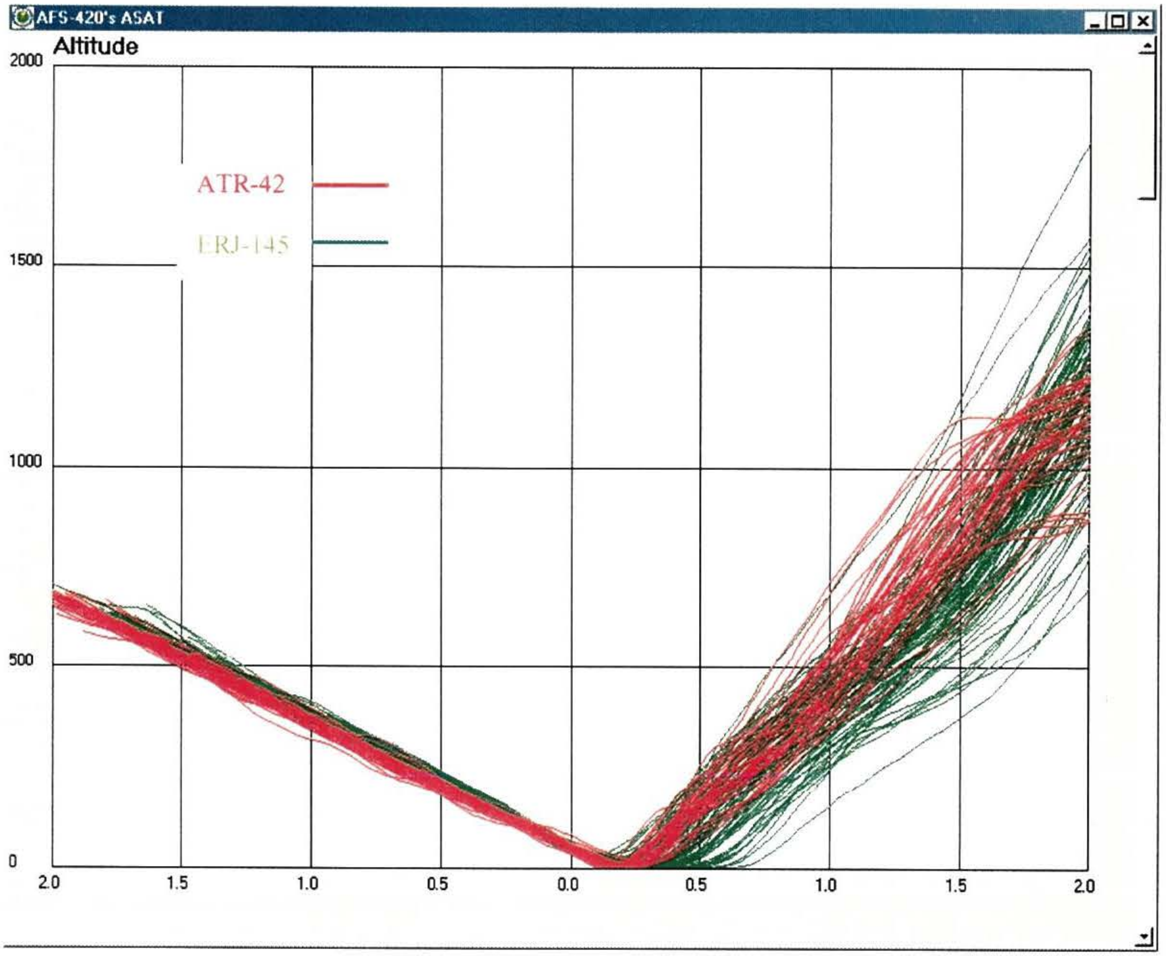

Figure A1: COMPOSITE CHART OF HEIGHT ABOVE TERRAIN IN FT vs DISTANCE FROM THRESHOLD IN NM FOR ERJ (GREEN) AND ATR-42 (RED) TRACKS EXECUTING A RLP

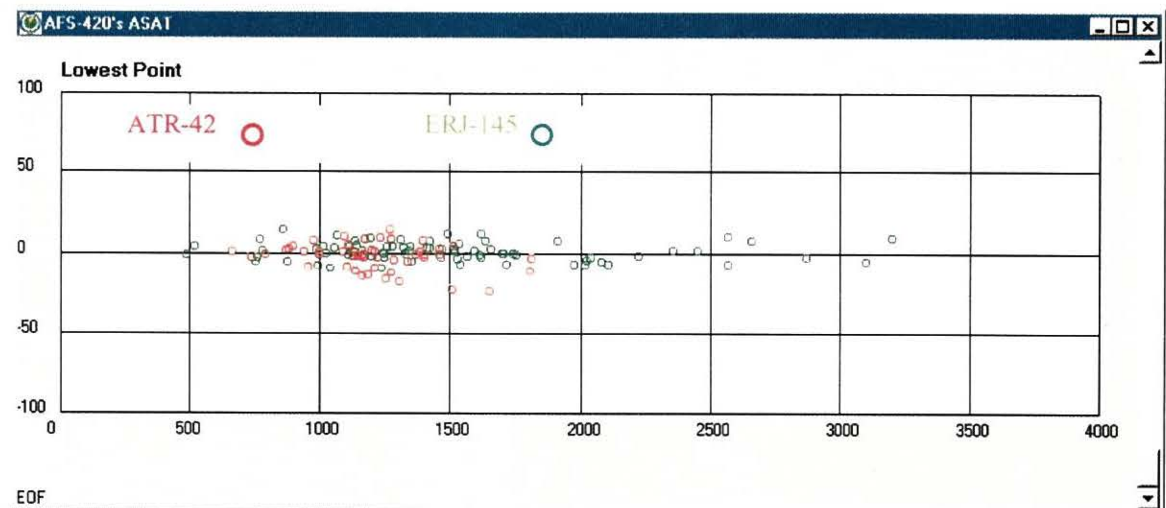

Figure A2: COMPOSITE CHART OF MINIMUM HEIGHT ABOVE TERRAIN POINT FOR RLPS

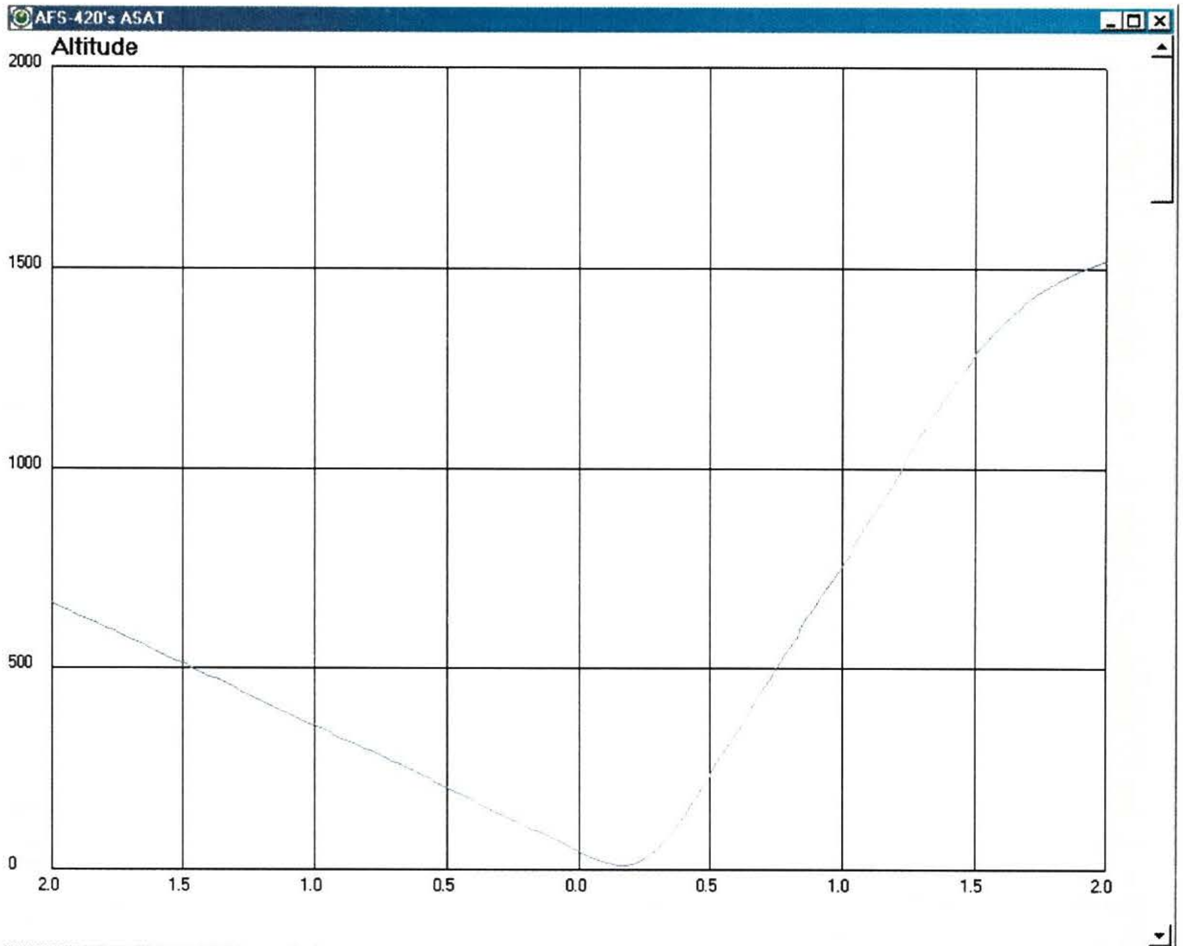

Figure A3: HEIGHT ABOVE TERRAIN (FT) vs DISTANCE FROM THRESHOLD (NM) FOR A SINGLE B777 RUN

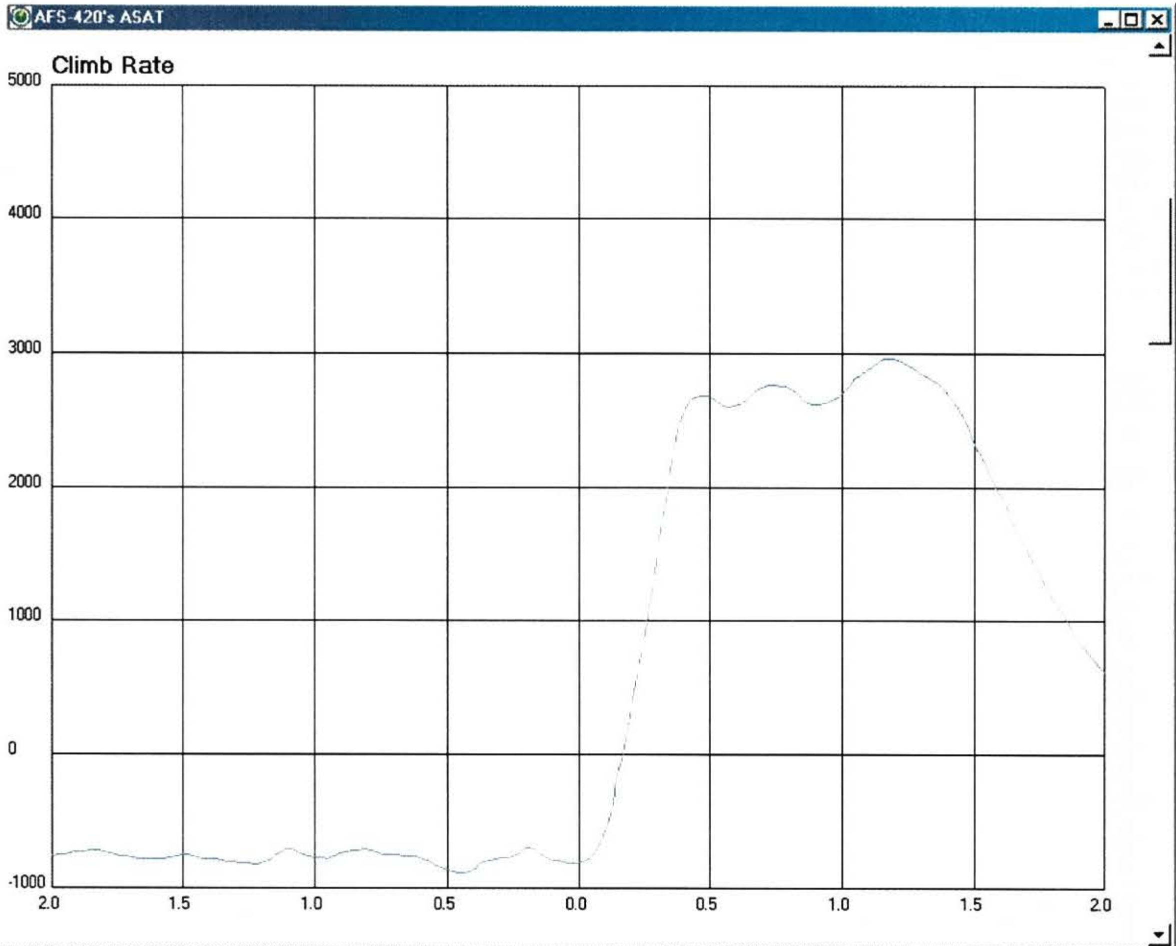

Figure A4: RATE OF CLIMB [FPM] vs DISTANCE FROM THRESHOLD [NM] FOR A SINGLE B777 RUN

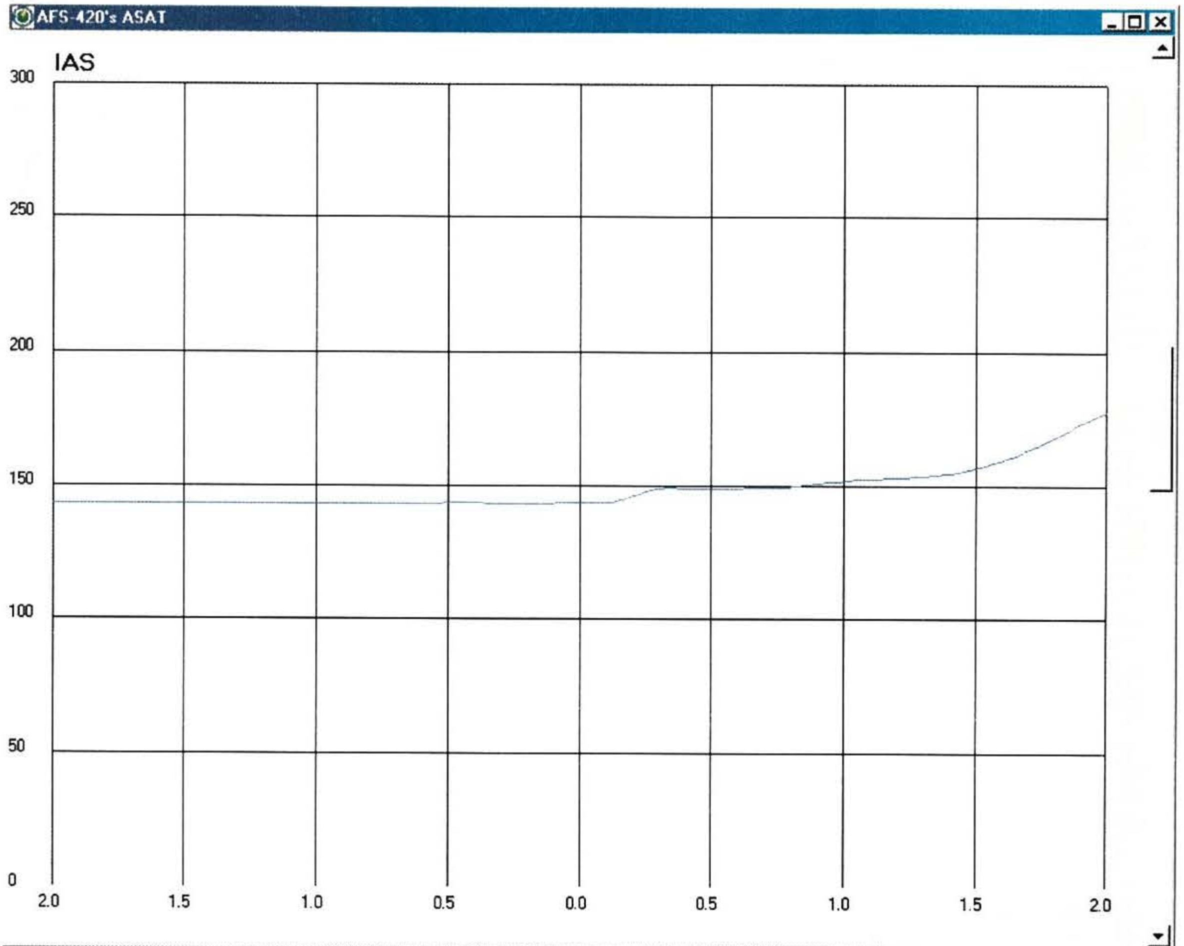

Figure A5: IAS (KT) vs DISTANCE FROM THRESHOLD (NM) FOR A SINGLE B777 RUN

APPENDIX B. ASAT MONTE CARLO SIMULATION RUNS

APPENDIX B. ASAT MONTE CARLO SIMULATION RUNS

B.1 FITTING CURVES TO AIRCRAFT DATA

In order to use the aircraft performance data, such as the distance from the departure end of the runway that a departing aircraft leaves the ground, continuous probability curves must be fitted to the data. The Johnson family of curves, developed by N. L. Johnson in 1949, is used to fit probability curves to the data sets. The Johnson family includes three types of curves, the Johnson S_L family, the Johnson S_B family, and the Johnson S_U family. The curves of the S_L family are bounded at one end with an infinite tail at the other end. The curves of the S_B family are bounded at both ends. The curves of the S_U family are unbounded, i.e., have infinite tails at both ends. Each family of curves is based on a transformation of the observed data into a set of data that could be generated by a normal N(0,1) distribution. A test based on the standard statistics of the data determines which type of curve will best fit the data. Aircraft performance data are generally best fit with S_B curves and sometimes with S_U curves. Rarely is aircraft performance data best fit with an S_L curve. Statistical tests are used to determine the "goodness of fit" of the curves to the data sets.

B.2 CLASSIFICATION OF AIRCRAFT

During the year 2001, twenty-two different types of aircraft are projected to contribute a significant number of operations at Miami International Airport. It was determined that these twenty-two aircraft could be represented by seven of the eleven flight simulators available. The aircraft projected to operate from MIA were assigned to the aircraft represented by the flight simulators according to type (turboprop, regional jet, heavy, etc.) and performance. Some aircraft such as the Cessna 150 could not be assigned, but the number of operations of the unassigned aircraft relative to the total number of operations was considered insignificant. The assignment of aircraft means that, for example, Boeing B747 aircraft models were not used in the simulation, but they were represented or replaced by Boeing B777 aircraft. Tables B1 and B2 present the assignment of aircraft to the aircraft used in the flight simulator data collection exercise.

Flight Simulator Aircraft				
	B777	B757	B737-300	MD-88
Assigned Aircraft	A340	B767		DC-9
	B747			MD-80
	L1011			

Table B1: AIRCRAFT ASSIGNED TO FLIGHT SIMULATOR AIRCRAFT

Flight Simulator Aircraft			
	A320	ATR-42	ERJ-145
Assigned Aircraft	A300	ATR-72	B727
	A306		DC-8
	A310		
	A330		
	A319		
	A321		

Table B2: AIRCRAFT ASSIGNED TO FLIGHT SIMULATOR AIRCRAFT

In order to determine the projected aircraft mix, i.e., the percentage of operations each aircraft model is projected to contribute, the projected number of operations of each type was found. For example, for the aircraft represented by the Boeing B777, the projected number of operations of all series of B777, A340, B747, and L1011 were added together to obtain a total number of operations that will be represented in the simulation by the Boeing B777. Then the numbers of operations obtained for the seven flight simulator aircraft were added together to obtain a grand total of annual operations. Then by dividing each of the seven subtotals by the grand total, projected percentages of operations were obtained. Table B3 presents the projected number of operations and the percentage of each of the eight flight simulator aircraft.

Aircraft Model	Percentage
B777	6.0
B757	22.0
B737-300	12.0
MD-88	14.0
A320	9.0
ATR-42	13.0
ERJ	24.0
Totals	100

Table B3: AIRCRAFT TRAFFIC PERCENTAGES AT MIA

The percentages presented in the table are used to randomly select pairs of aircraft in the LAHSO simulation according to the percentage of operations that the aircraft are projected to produce. A random number generator is a computer program that produces random numbers ranging from 0 to 1. Each of the eight aircraft is assigned a subinterval in the interval ranging from 0 to 1 whose length is proportional to its percentage of operations. For example, the B777 could be assigned the subinterval 0 to 0.06. The ratio of the length of the B777 subinterval to the interval 0 to 1 is 6.0%. The B757 could be assigned to the subinterval 0.06 to 0.28. The length of the subinterval is 0.22 and the ratio of length of the subinterval to the interval 0 to 1 is 22.0%. In a similar fashion, subintervals can be assigned to each of the eight aircraft. In order to determine an aircraft pair, i.e., an arriving and a departing aircraft, the random number generator produces two random numbers. The subintervals that the random numbers fall in determine the two aircraft that are paired for the LAHSO simulation. For example, if the first random number is in the range 0 to 0.06 then the arriving aircraft is chosen to be a B777. If the second random number is in the range 0.06 to 0.22, then the departing aircraft is chosen to be a B757. Because of the assignment of aircraft to the B777 the B777 will be representative of the B777, B747 and L1011. In a similar fashion, the B757 will be representative of the B757 and the B767.

B.3 SIMULATION RUN OUTLINE

The various continuous distributions derived from the flight simulator data are used to drive critical sections of the ASAT track generation section. This section describes the method that is used to execute a single ASAT run.

After the user sets global options, such as wind conditions and the option to execute a turn during the RLP, ASAT starts a set of Monte Carlo runs in the following manner:

a. Based upon the fleet mix, ASAT will randomly select the next pair of aircraft for both runways.

b. ASAT will randomly assign the approaching aircraft the following parameters:

(1) Approach IAS,

(2) Min height above terrain during the RLP,

(3) Along runway location of the min altitude point during the RLP,

(4) Climb rate during RLP,

(5) Rate of change of rate of climb during RLP,

(6) IAS during RLP climb, and

(7) Rate of change of IAS during the RLP.

If the turn option is selected for the approaching aircraft, then the following additional values are also randomly selected:

(1) Altitude at which the turn is initiated,

(2) Bank angle,

(3) Bank rate, and

(4) Heading change.

c. ASAT will randomly assign the departing aircraft the following parameters:

(1) Take off IAS,

(2) Take off distance,

(3) Rate of climb,

(4) Rate of change of rate of climb,

(5) Climb IAS, and

(6) Rate of change of IAS.

If the turn option is selected for the departing aircraft, the following values are also randomly selected:

(1) Altitude at which the turn is initiated,

(2) Bank angle,

(3) Bank rate, and

(4) Heading change.

d. Initial Position of the Aircraft.

(1) ASAT will always start the run when the departing aircraft is at the threshold of the departure runway, runway 27L.

(2) The approaching aircraft will be placed at a random distance between –1.0NM and +2.5NM from the threshold. Therefore, when the departing aircraft starts its takeoff roll the approaching aircraft will begin its flight at a random distance between 2.5NM prior to the threshold to 1.0NM past the threshold.

e. Trajectory Generation of the Approaching Aircraft (RLP).

(1) The approaching aircraft executes the approach and descends to a randomly selected minimum altitude at a randomly selected distance from threshold over the runway.

(2) When the location of the lowest point is reached, the aircraft initiates a climb using a randomly selected rate of climb and a randomly selected rate of change of rate of climb.

(3) While climbing, the aircraft accelerates to the climb speed using a randomly selected acceleration.

(4) If a turn is to be performed, upon reaching the predetermined turn altitude a turn to a predetermined new heading is initiated using a randomly selected bank angle and bank rate.

The program ensures that no rejected landings are ***initiated*** later than 3,000-foot past the threshold.

f. Trajectory Generation of the Departing Aircraft (T/O).

(1) Using a randomly selected IAS and a randomly selected take off distance for the current run, a nominal acceleration is calculated. The aircraft is released at the simulation start and its speed builds up.

(2) The aircraft initiates a climb to a randomly selected rate of climb and at a randomly selected rate of change of rate of climb.

(3) While climbing, the aircraft accelerates to the climb speed at a randomly selected acceleration.

(4) If a turn is to be performed, upon reaching the predetermined turn altitude a turn to a predetermined new heading is initiated using randomly selected bank angle and bank rate.

B.4 ADDITIONAL ASAT FUNCTIONS

During initial discussions regarding the modeling of the RLP, ALPA requested the operation be modeled at what was perceived to be the worst case for ORD. The worst case scenario consisted of a light aircraft taking off while a heavy aircraft is performing a RLP. The reasoning was that a light aircraft would become airborne in a short distance and climb faster while the heavy aircraft would climb slowly. All flight simulator data gathered for this study was generated under these conditions. However, due to the variation in geometry between airports it is possible that this combination will not constitute the worst case for a similar operation at another airport. In order to facilitate the analysis of other cases, such as a heavy aircraft taking off and a light aircraft executing an RLP, ASAT can adjust critical aircraft performance parameters.

The adjustments made to the RLP aircraft performance parameters for a LIGHT RLP are summarized in table B4.

Parameter	Ratio	Comments
Approach IAS	90%	Approach speed is 10% lower than heavy approach speed
Climb IAS	90%	Climb speed is 10% lower than heavy climb speed
Rate of change of IAS	115%	Acceleration is 15% higher than heavy climb speed
Rate of change of ROC	115%	Rate of climb is 15% higher than heavy approach speed

Table B4: VARIATION OF CRITICAL PARAMETERS TO ACCOMMODATE A LIGHT RLP

The adjustments made to the departure aircraft performance parameters for a heavy takeoff are shown in table B5.

Parameter	Ratio	Comments
Take off IAS	110%	Take off speed is 10% higher than light take off
Take off distance	120%	Take off distance is 20% longer than light take off
Climb IAS	110%	Climb speed is 10% higher than light take off
Rate of change of IAS	85%	Acceleration is 15% lower than light take off
Rate of change of ROC	85%	Rate of climb is 15% lower than light take off

Table B5: VARIATION OF CRITICAL PARAMETERS TO ACCOMMODATE A HEAVY TAKEOFF

ASAT constantly measures the 2-dimensional and 3-dimensional distance between the 2 aircraft. At the end of each single run, ASAT stores the minimum values for the 2-dimensional and 3-dimensional minimum distances. The values are stored per aircraft types. In this simulation, using 8 different aircraft results in 64 different combinations.[1]

Using this method allows the definition of the operational window for each possible pair of aircraft type combinations as well as for the entire operation in which no TCVs occurred.

Figures B1 and B2 depict the on-line graphic display of ASAT. Figure B1 depicts a 'NON TURNING" RLP while figure B2 depicts the RLP aircraft executing a 20 degree (nominal) turn.

The blue circle on the extended runway 14R centerline shows where the RLP aircraft was placed when the departure aircraft started its takeoff run from runway 27L.

[1]Aircraft of type "1" taking off and of type "2" executing a RLP is not the same as aircraft of type "2" taking off and aircraft of type "1" executing a RLP

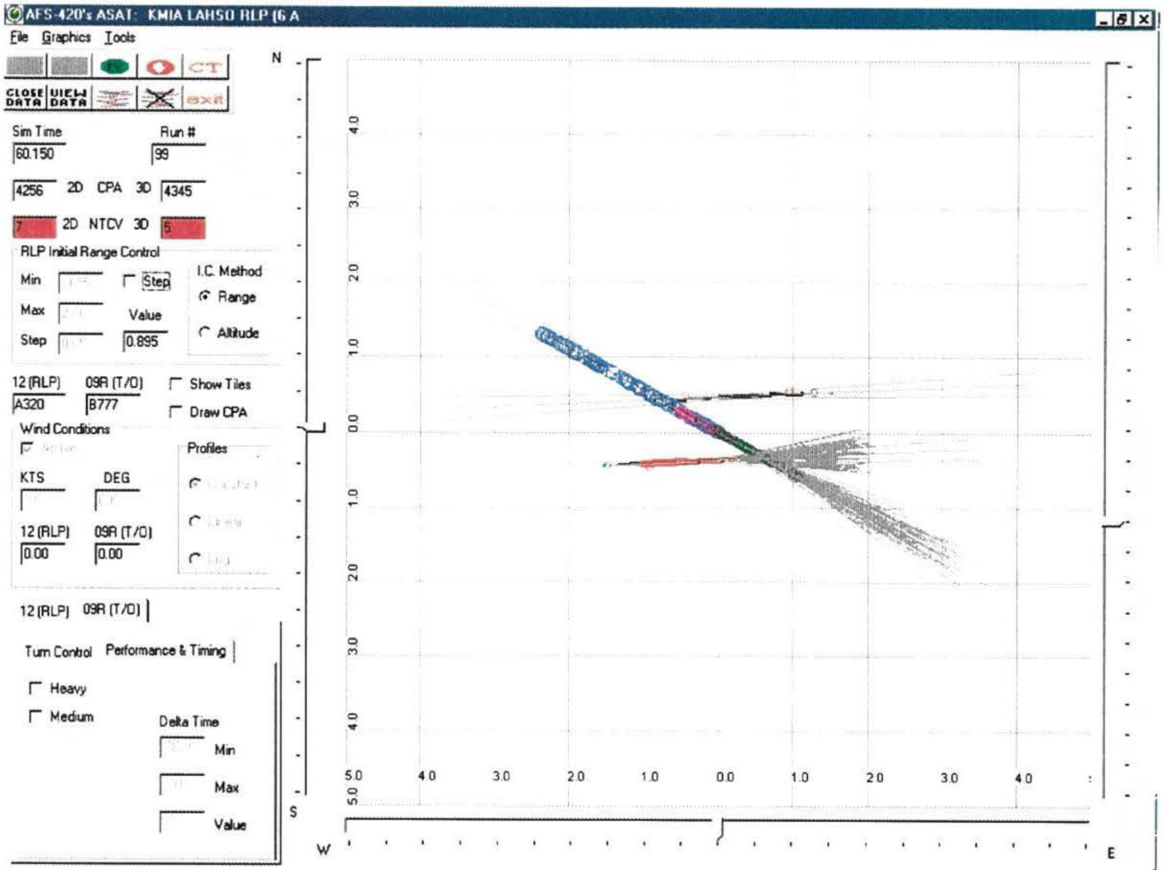

Figure B1: NO TURN RLP EXAMPLE

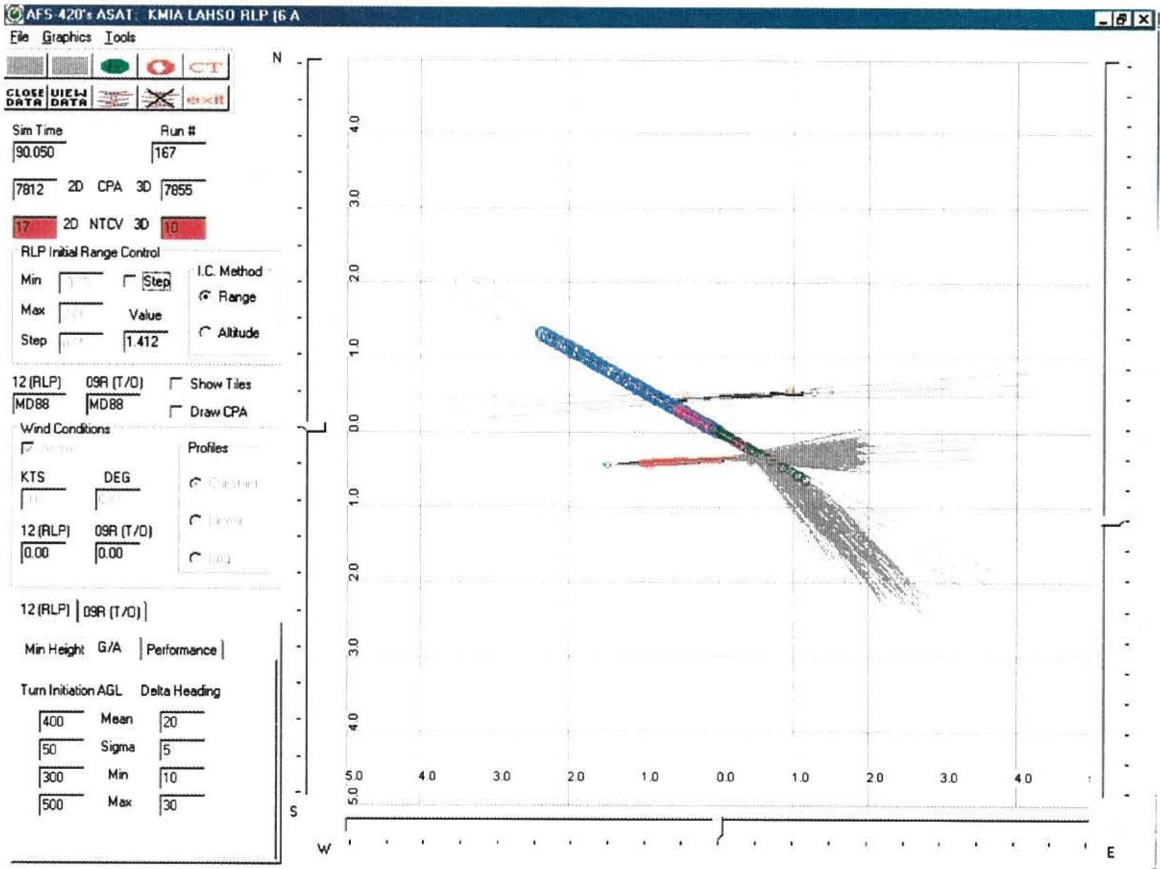

Figure B2: RLP AIRCRAFT TURNING

APPENDIX C. LAHSO FLIGHT SIMULATOR DATA HANDLING PROGRAM

APPENDIX C. LAHSO FLIGHT SIMULATOR DATA HANDLING PROGRAM

C.1: INTRODUCTION

The C program, LAHSO Tracks, was developed to perform several activities:

a. Pre processing of flight simulator data.

b. Display of the data

c. Interactive measurement and data logging for statistical curve fitting.

These activities are discussed in the following sections.

C.2: PRE-PROCESSING OF FLIGHT SIMULATOR DATA

Flight simulator data were received in various formats. The following are some of the essential parameters that are not consistent between the data sets generated by various flight simulators:

a. Number of files per run: Three different cases were encountered and handled under this activity:

(1) A single file containing all data for a single test run.

(2) Two files containing all data for a single test run that had to be handled simultaneously.

(3) A single file containing a set of runs.

b. Data formats: Except for the AA simulators (Data Format #1) and the DAL simulators (Data Format #2) ALL other data sets have different data formats. The data format varied in two ways:

(1) Number of data items logged.

(2) Sequence of the data items logged.

In addition, some of the data files had to be edited to remove irrelevant data that cluttered the display. Such cases were common when the simulator data logging program was not disabled before resetting the simulator. Obviously, these extra data points are not of any significance however they clutter the display.

C.3: PROCESSING OF FLIGHT SIMULATOR DATA

After being pre-processed, the flight simulator data can be displayed, analyzed and logged. The processing of the data consisted of two main types of data analysis. The program automatically processed some of the data. These data items consisted of easy to determine variables, such as:

a. Approach IAS,

b. Minimum altitude,

c. Along track location of the minimum altitude point,

d. Across track location of the minimum altitude point,

e. IAS at minimum altitude point,

f. Maximum bank angle,

g. A/P switch related data,

h. TO/GA related data,

i. Landing gear related data, and

j. Flaps related data.

The data that had to be interactively processed for each individual track consisted of:

a. Climb rate at go around,

b. Rate of change of climb rate at go around,

c. IAS at go around, and

d. IAS rate-of-change at go around.

The data analysis was done on a per aircraft basis to create specific aircraft databases that properly represent the combined response of a given airframe with a pilot in the loop.

C.4: INSTALLING LAHSO TRACKS

The entire directory should be copied from the CD-ROM. After copying the necessary files, the directory structure should look similar to the one described in figure C1.

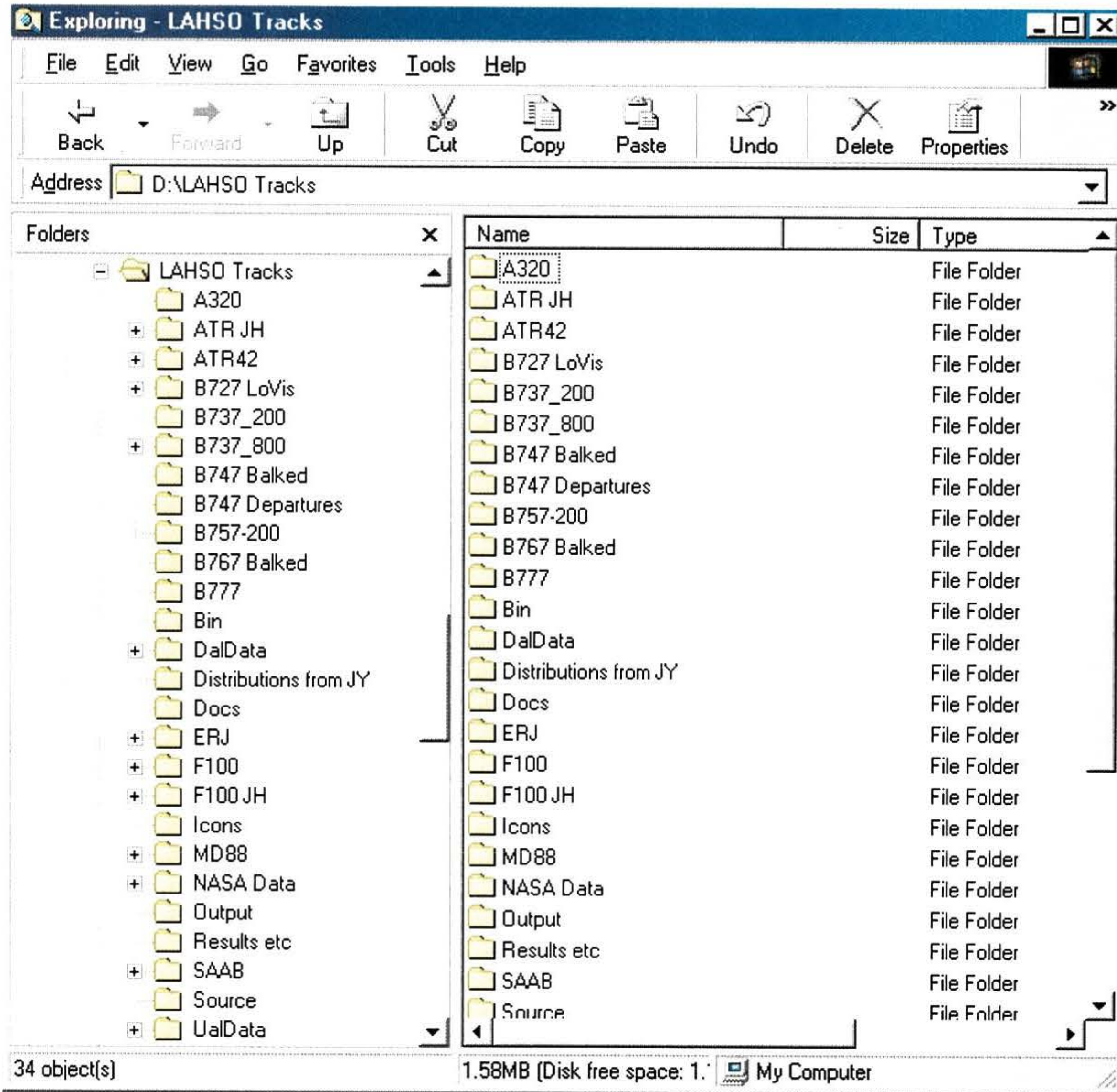

Figure C1: DIRECTORIES STRUCTURE FOR LAHSO TRACKS

C.5: RUNNING LAHSO TRACKS

When executed, LAHSO Tracks comes up with the main control bar, as shown in figure C2. The program is a "point & click" type application and is intuitive.

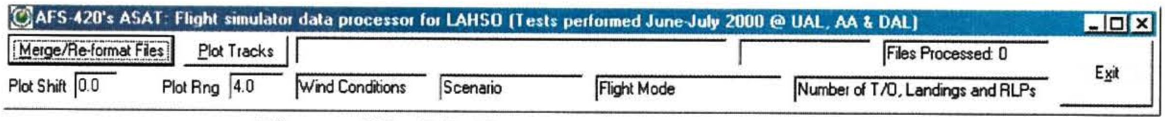

Figure C2: MAIN LAHSO TRACKS CONTROL BAR

The user has 3 options:

a. Merge/Re-format files,

b. Plot Tracks, or

c. Exit.

The main control bar shows various statistics and allows the user some flexibility regarding the scale of some of the charts. These fields will be filled as the program is executed.

NOTE: If ALL data is copied from the CD-ROM, there is no need to run the Merge/Re-format section of the program.

Figure C3 shows the secondary screen for the "Merge/Re-format" option. As can be seen the user can select from 7 different data formats.

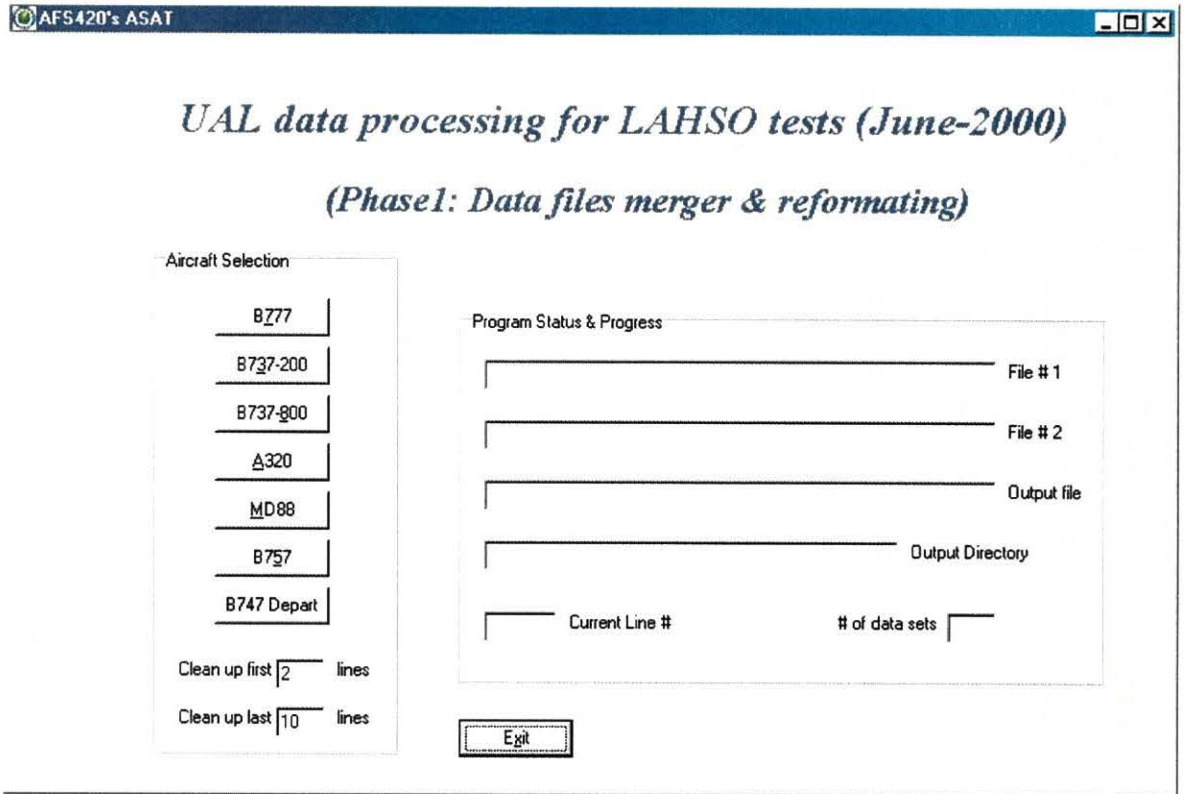

Figure C3: "MERGE/RE-FORMAT" OPTION SECONDARY SCREEN

Figure C4 shows the secondary screens for the "Plot Tracks" option. In this option the user can select data to be displayed based upon aircraft type and/or track type and/or scenario type[1].

[1] Not all data was available in a way that this option is fully functional.

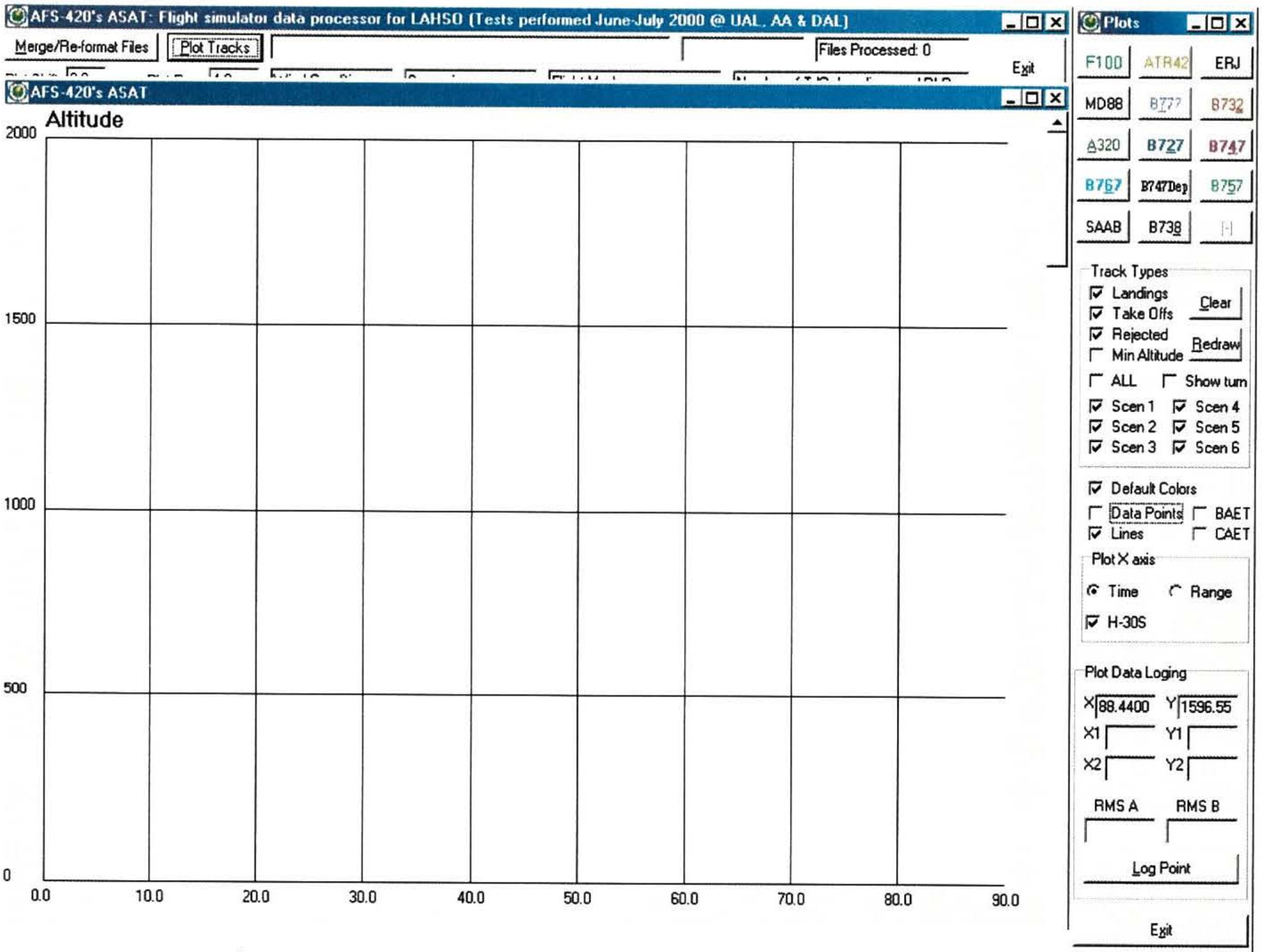

Figure C4: "PLOT TRACKS" OPTION SECONDARY SCREENS

Under the "Plot Tracks" option, the program performs various data evaluation tasks as explained in section 3. In addition, the program displays the following graphic data[2]:

a. Alt: Altitude,

b. ROC: Climb Rate,

c. IAS: Indicated Air Speed,

[2] User Selectable: Variable 1 to 11 can be plotted Vs Range from threshold or vs Time. Graph number 12 is ALWAYS plotted on the same scale as described.

d. Propulsion[3]: Throttle lever angle or any other relevant indicator,

e. Gear: Gear position,

f. Flaps: Flaps position[4],

g. TO/GA: Take-Off/Go-Around switch,

h. A/P: Auto-pilot switch,

i. Bank: Bank angle,

j. Top View: A top view of the track, in Across Track vs Along track coordinates,

k. Acceleration: Rate of change of IAS[5], and

l. Lowest Point: A top view of the first 4,000 feet of the runway showing the location of the minimum altitude point.

C.5.1 DRAWING TRACKS

To draw tracks, the user must select a specific aircraft from the group of aircraft on the top section of the "Plots" control form (see figure C5).

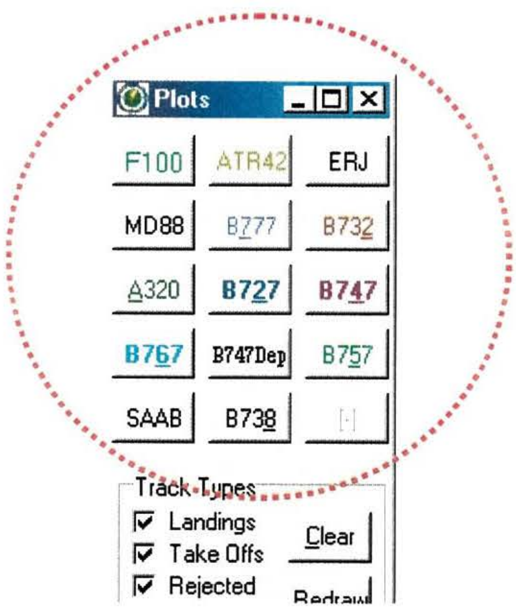

Figure C5: AIRCRAFT SELECTION

[3] The term "Propulsion" was used to accommodate turbo jets and turbo prop aircraft types.
[4] Configuration angle for A320.
[5] The flight simulator does not log this value. This value is calculated from the data.

Upon a selection of an aircraft, a files open dialog will open. The program allows for multiple files selection. Figure C6 shows a multiple files selection for the B777 aircraft.

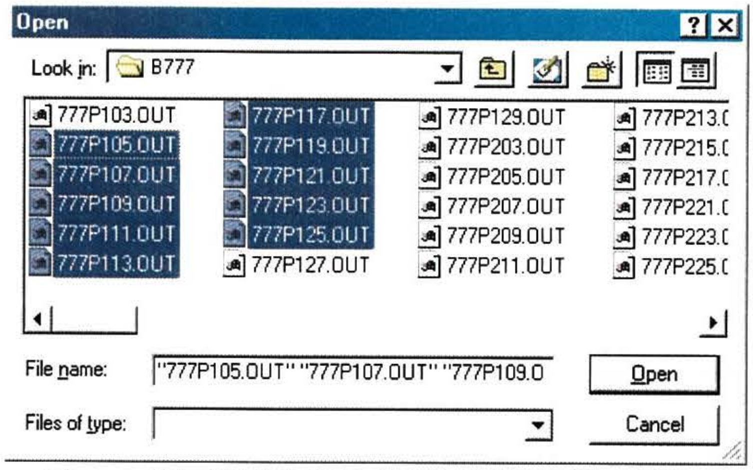

Figure C6: MULTIPLE FILES SELECTION

Figures C7-C12 show the plots generated by the program for the files selected.

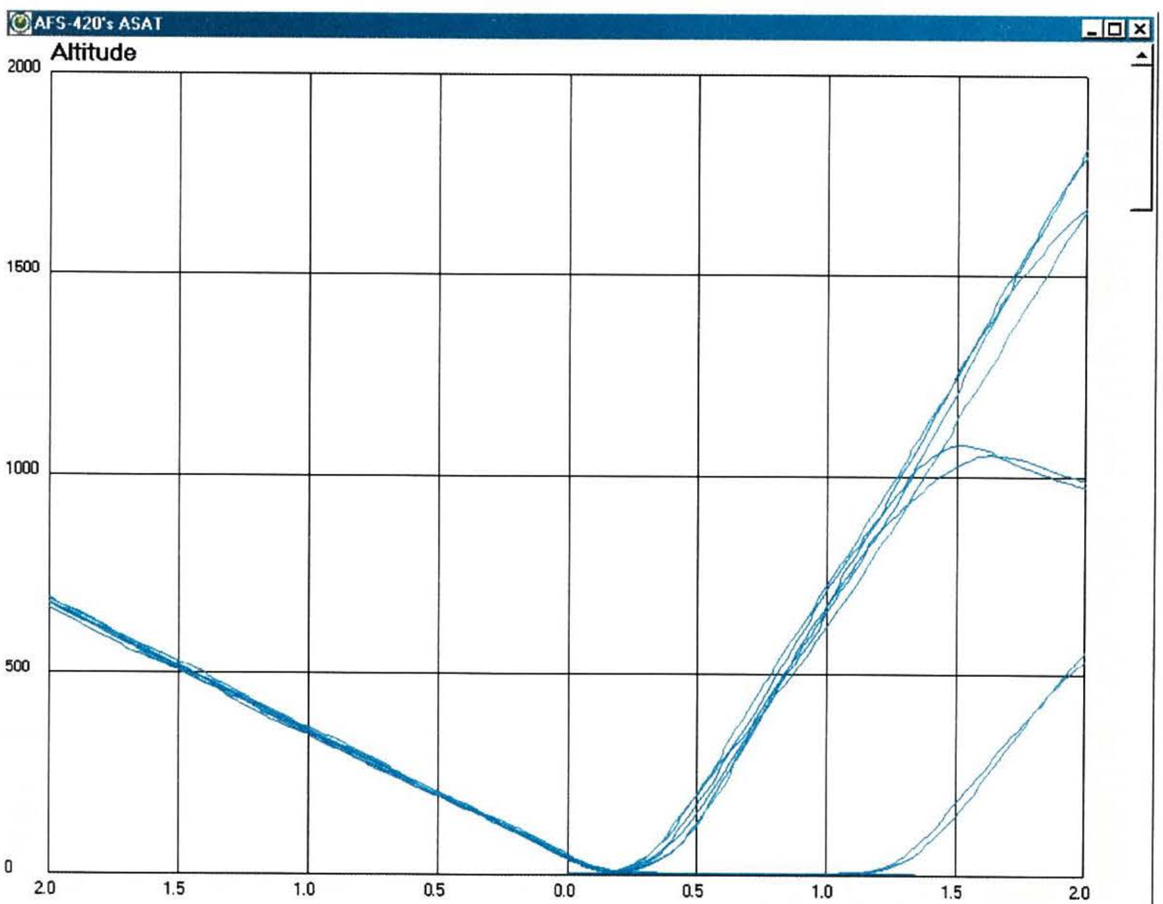

Figure C7: ALTITUDE vs RANGE FROM THRESHOLD

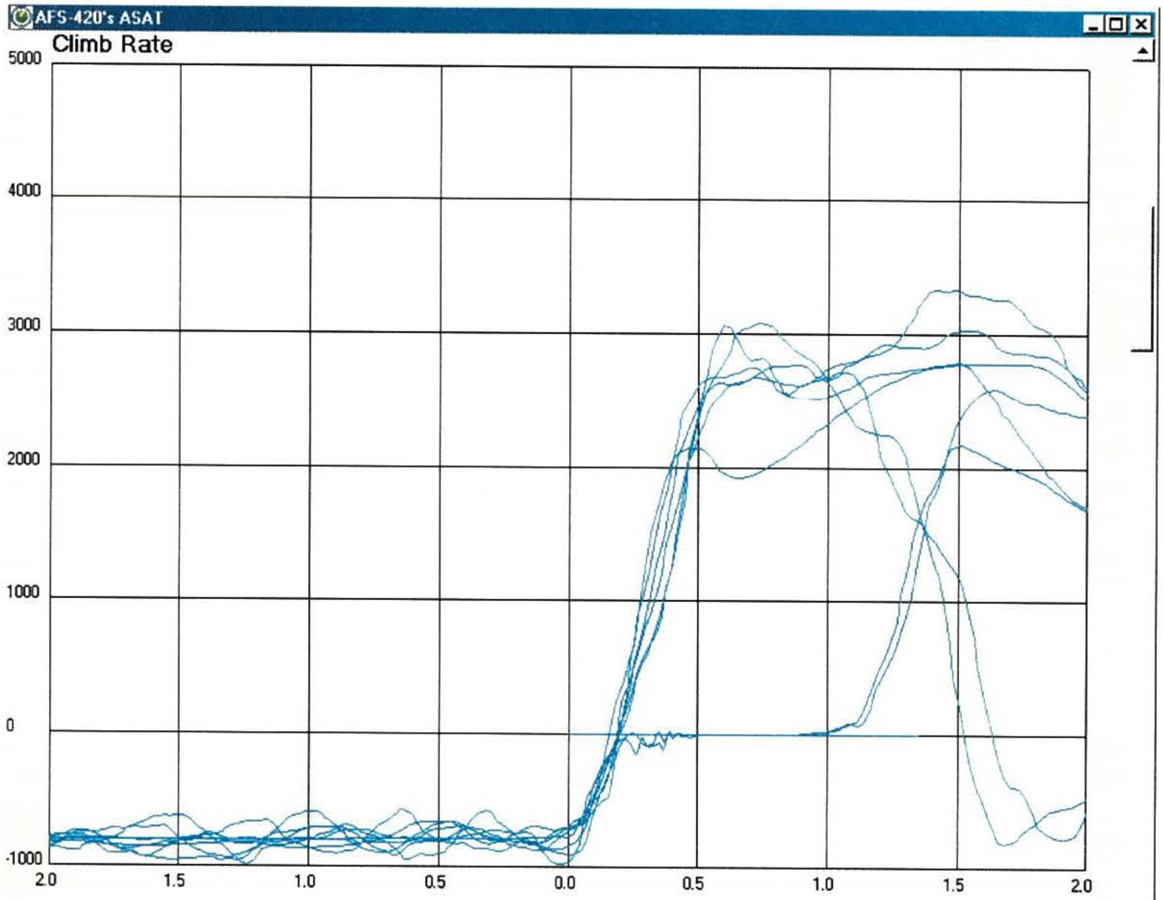

Figure C8: CLIMB RATE vs RANGE FROM THRESHOLD

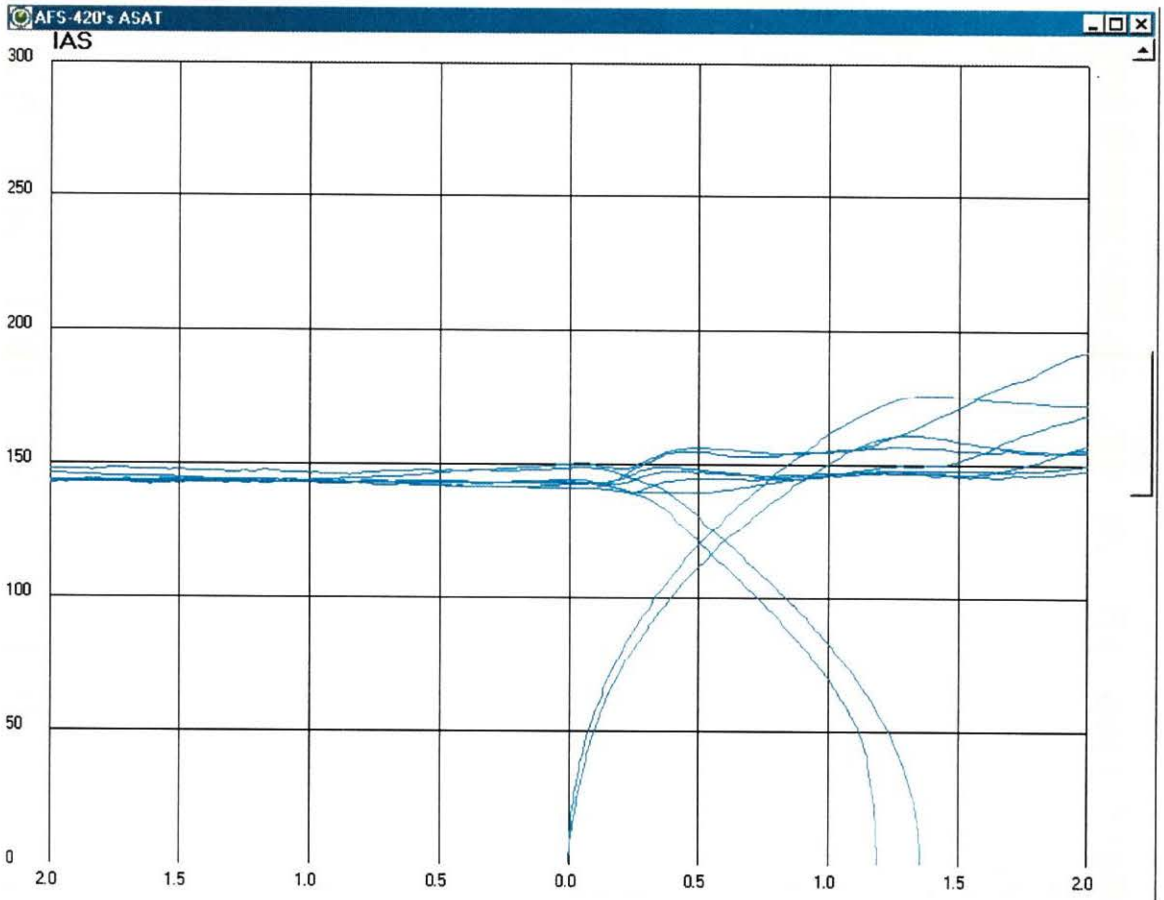

Figure C9: IAS vs RANGE FROM THRESHOLD

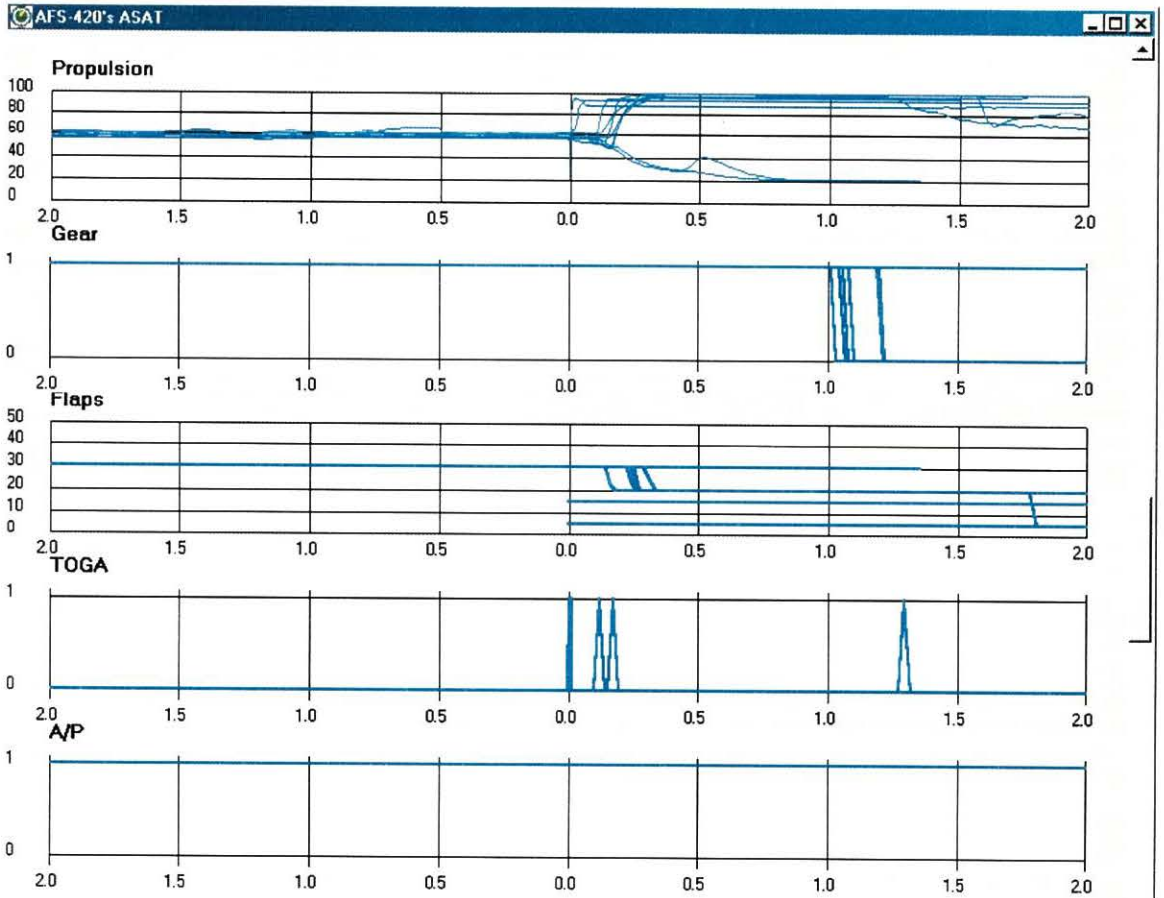

Figure C10: PROPULSION, GEAR, FLAPS, TOGA AND A/P vs RANGE FROM THRESHOLD

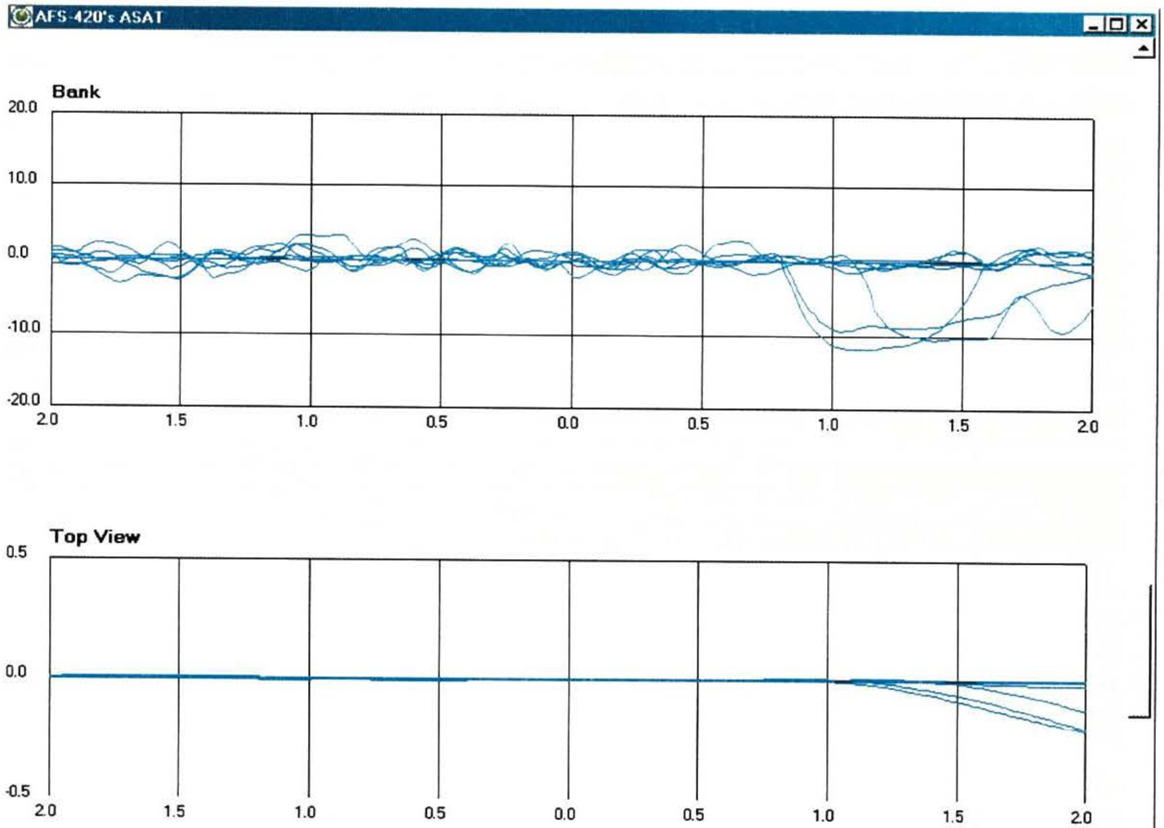

Figure C11: BANK AND DISTANCE FROM RUNWAY CENTERLINE vs RANGE FROM THRESHOLD

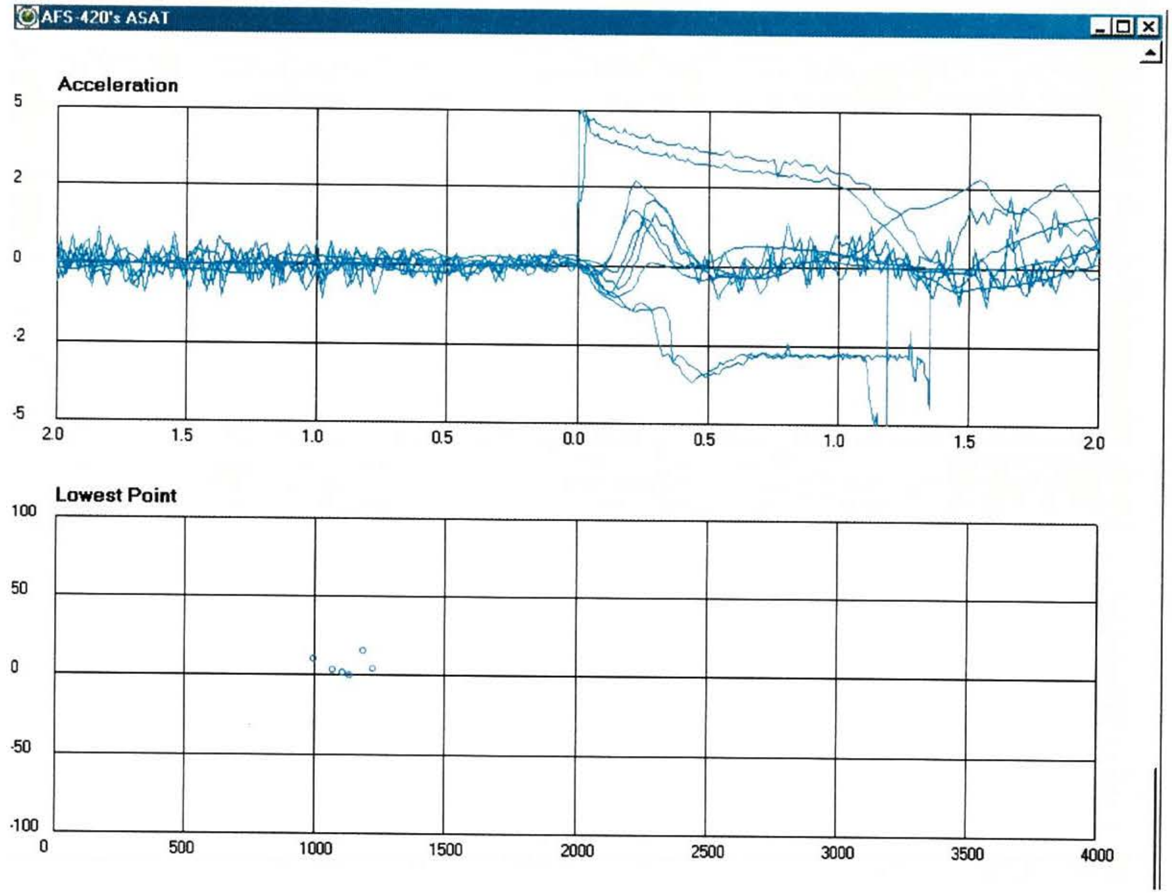

Figure C12: ACCELERATION AND LOCATION OF LOWEST POINT vs RANGE FROM THRESHOLD

C.5.2 MEASURING AND LOGGING DATA

Data can be measured and logged using one of the first 3 charts:

a. Altitude,

b. Climb Rate, and

c. Air Speed.

To measure, just place the mouse inside the drawing area, where the mouse cursor turns into a cross hair. The X and Y values will be displayed on the bottom of the Plots form in the "Plot Data Logging" area, as shown in figure C13.

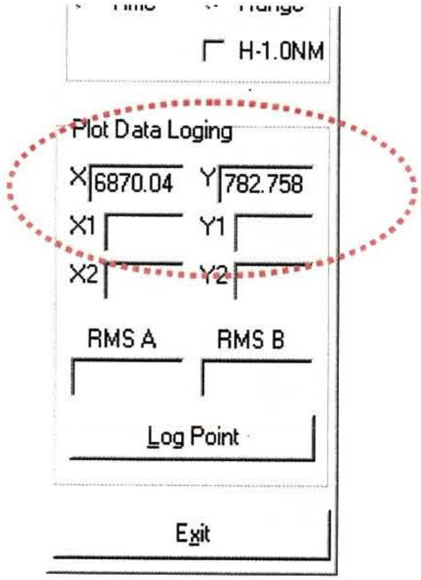

Figure C13: MEASURING DATA FROM THE GRAPHS

To calculate the slope of a set of data, move the cursor to the desired initial position and click the RIGHT mouse button. A point will appear on the chart. Use the same technique to select the last point. When the right mouse is pressed for the second time, 2 lines will appear on the chart as well as additional data on the "Plot Data Logging" area. The lines represent the direct slope connecting the two selected and the resulting line out of a RMS fit to the data within the range selected. In addition, X and Y values, as well as the line coefficients (a and b coefficients, Y = aX + b) for the FITTED line are displayed (RMS A and RMS B). The data is logged by using the "Log Data" button, as shown in figure C14.

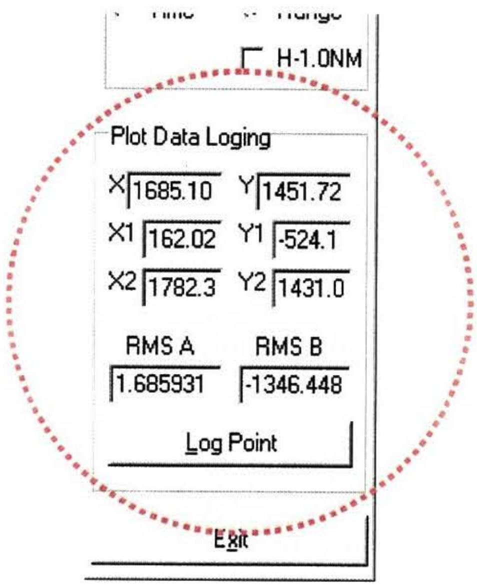

Figure C14: X, Y, AND RMS VALUES FOR SELECTED POINTS

C.5.3 OUTPUT

LahsoTracks generates the following output files. Each file contains a header detailing the data items being logged into a specific file.

a. **LAHSODATA.OUT:**	Main output file
b. **LAHSOSHORT.OUT:**	A shorter version of the above
c. **ALTMIN.OUT:**	File containing data related to the minimum altitude point.
d. **LANDING.OUT:**	File containing data related to landings
e. **TAKEOFF.OUT:**	File containing data related to take-off
f. **TURN.OUT:**	File containing data related to the RLP climbing turn.

NOTE: Files 1 and 2 are created in the main directory. All other files are created in the Output directory.

C.6 ADDITIONAL FUNCTIONALITY

The "Plots" Control Panel offers additional functionality to the user, as shown in figure C15.

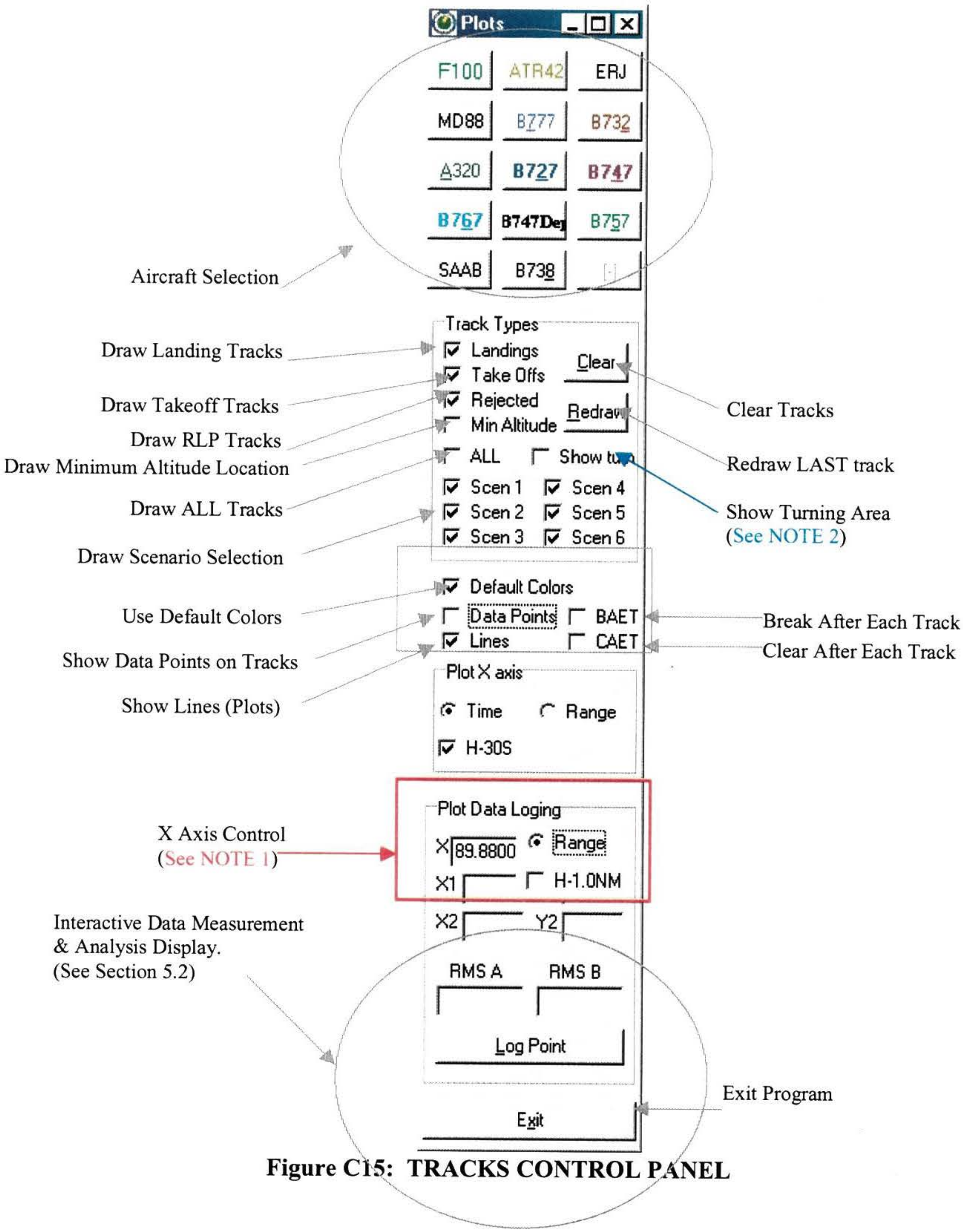

Figure C15: TRACKS CONTROL PANEL

NOTE 1: X axis can be selected as time **OR** distance from threshold. If Time is selected, the "H-30S" check box will appear under the "Time" radio button. If "H-30S" is checked, the program will draw ALL the minimum altitude points at a time value of 0.00 seconds and the tracks will be shown from 30 seconds prior to the lowest point to 90 seconds past the lowest point (120 seconds total). If the "Range" radio button is selected, the "H-1.0NM" check box will appear. If "H-1.0NM" is checked, the program will draw ALL the minimum altitude points at a value of 0.00 NM and the tracks will be shown from –1.0NM to +3.0NM (unless the user, changes "Plot Shift and/or Plot Range). **FOR ILLUSTRATION PURPOSES ONLY figure C15 shows both check boxes, "H-30S" & "H-1.0NM" at the same time. This can not occur when the program is running.**

NOTE 2: When "Show Turn" check box is checked, the Altitude plot tracks will change color when the change in ground track from the approach track will be equal or greater than 10 degrees.

APPENDIX D. B777 FLIGHT SIMULATOR DATA FILE EXAMPLE

D2

DAXLAT	A/C LATITUDE
DAXLONG	A/C LONGITUDE
RUXGSECS	GPS UTC : SECONDS
RRXRTHD	DISTANCE TO ACT RWY THRESHOLD ALONG C/L
RRXDTCL	A/C DISTANCE TO RUNWAY CENTRE LINE
RAXHGCG	A/C HEIGHT ABOVE TERRAIN
RAXVC	A/C CALIBRATED AIRSPEED
RRXTROLL	TCAS-ROLL ATT SRCE +/-180
RAXHDGM	A/C MAGNETIC HEADING
RRXVRATE	A/C VERTICAL RATE FPM
RAXSURWS	SURFACE WIND SPEED
RAXSURWD	SURFACE WIND DIRECTION
RLXFLEV	FLAP LEVER POSITION
RAXHP	A/C ALTITUDE
DAXLAT	A/C LATITUDE
REXTRA	# ENG THROTTLE RESOLVER ANGLE
REXPN1CD	@ ENG N1 COMMAND
RRXTPTCH	TCAS-PITCH ATT SRCE +/-90
RAXQNH	QNH / SEA LEVEL PRESSURE
KR97O016	TCAS MODE/SENS
LAXONGND	A/C ON GROUND
LQWH00	L A/P SERVO ARM
LGWL04	A/T TO/GA SW (NOT)
LRXGEAR	TCAS-GEAR POSITION (1=DOWN)

DAXLAT	DAXLONG	RUXGSECS	RRXRTHD	RRXDTCL	RAXHGCG	RAXVC	RRXTROLL	RAXHDGM	RRXVRATE	RAXSURWS	RAXSURWD	RLXFLEV	RAXHP	DAXLAT	REXTRA	REXPN1CD	RRXTPTCH	RAXQNH	KR97O016	LAXONGND	LQWH00	LGWL04	LRXGEAR
DEG	DEG	SEC	FT	FT	FT	KTS	DEG	DEG	FPM	KTS	DEG	[-]	FT	DEG	DEG	RPM	DEG	INHG					
0.73349	-1.53542	34.66	16865.95	0.37	927.65	147.07	-0.0	141.4	-1166.0	0.00	130.0	30.0	1592.65	0.73350	45.1	57.6	1.98	29.92	973652000	0	1	1	1
0.73348	-1.53541	35.16	16732.11	0.78	917.62	145.96	-0.1	141.3	-1162.0	0.00	130.0	30.0	1582.62	0.73349	45.5	58.5	1.89	29.92	973652000	0	1	1	1
0.73348	-1.53541	35.66	16598.74	1.31	908.40	145.16	-0.2	141.2	-1082.0	0.00	130.0	30.0	1573.40	0.73349	47.2	60.5	2.81	29.92	973652000	0	1	1	1
0.73347	-1.53540	36.26	16465.79	1.92	900.01	144.36	-0.3	141.0	-994.0	0.00	130.0	30.0	1565.01	0.73348	49.0	63.3	4.02	29.92	973652000	0	1	1	1
0.73347	-1.53540	36.76	16333.21	2.56	892.65	143.64	-0.4	140.8	-860.0	0.00	130.0	30.0	1557.65	0.73348	51.7	67.9	5.10	29.92	973652000	0	1	1	1
0.73346	-1.53539	37.26	16200.83	3.18	886.39	142.83	-0.4	140.7	-724.0	0.00	130.0	30.0	1551.39	0.73347	54.9	71.3	5.62	29.92	973652000	0	1	1	1
0.73346	-1.53539	37.66	16134.68	3.48	881.05	142.72	-0.5	140.5	-610.0	0.00	130.0	30.0	1546.05	0.73347	57.3	74.6	6.02	29.92	973652000	0	1	1	1
0.73345	-1.53538	38.16	16002.35	4.01	876.42	142.55	-0.5	140.4	-544.0	0.00	130.0	30.0	1541.42	0.73346	59.5	77.6	6.04	29.92	973652000	0	1	1	1
0.73345	-1.53538	38.76	15869.84	4.47	872.18	142.37	-0.4	140.3	-484.0	0.00	130.0	30.0	1537.18	0.73346	60.2	79.0	5.67	29.92	973652000	0	1	1	1
0.73344	-1.53537	39.26	15737.02	4.82	868.33	142.58	-0.4	140.2	-458.0	0.00	130.0	30.0	1533.33	0.73345	59.9	80.3	5.27	29.92	973652000	0	1	1	1

D3

0.73344	-1.53537	39.76	15603.83	5.08	864.51	142.74	-0.2	140.2	-462.0	0.00	130.0	30.0	1529.51	0.73345	58.8	81.2	4.68	29.92	973652000	0	1	1	1
0.73344	-1.53536	40.26	15466.07	5.24	860.53	142.74	-0.1	140.1	-490.0	0.00	130.0	30.0	1525.53	0.73344	56.6	81.0	3.98	29.92	973652000	0	1	1	1
0.73343	-1.53535	40.76	15332.09	5.30	856.10	143.02	-0.0	140.2	-524.0	0.00	130.0	30.0	1521.10	0.73344	54.4	79.3	3.21	29.92	973652000	0	1	1	1
0.73343	-1.53535	41.26	15197.76	5.27	851.40	143.55	0.1	140.2	-576.0	0.00	130.0	30.0	1516.40	0.73344	52.2	77.0	2.50	29.92	973652000	0	1	1	1
0.73342	-1.53534	41.76	15063.08	5.19	846.32	143.69	0.4	140.3	-624.0	0.00	130.0	30.0	1511.32	0.73343	50.9	75.0	2.04	29.92	973652000	0	1	1	1
0.73342	-1.53534	42.26	14995.62	5.14	840.84	143.62	0.5	140.3	-678.0	0.00	130.0	30.0	1505.84	0.73343	49.7	73.7	1.49	29.92	973652000	0	1	1	1
0.73341	-1.53533	42.76	14860.46	5.07	834.95	144.19	0.7	140.4	-716.0	0.00	130.0	30.0	1499.94	0.73342	48.9	72.1	1.05	29.92	973652000	0	1	1	1
0.73341	-1.53533	43.26	14724.97	5.02	828.65	143.96	0.7	140.5	-768.0	0.00	130.0	30.0	1493.65	0.73342	48.0	70.6	0.68	29.92	973652000	0	1	1	1
0.73340	-1.53532	43.76	14589.19	5.03	821.93	144.14	0.6	140.6	-824.0	0.00	130.0	30.0	1486.93	0.73341	47.2	68.7	0.42	29.92	973652000	0	1	1	1
0.73340	-1.53532	44.26	14453.15	5.07	814.86	144.46	0.6	140.7	-866.0	0.00	130.0	30.0	1479.86	0.73341	45.9	66.5	0.18	29.92	973652000	0	1	1	1
0.73339	-1.53531	44.76	14316.89	5.15	807.52	144.64	0.6	140.8	-888.0	0.00	130.0	30.0	1472.52	0.73340	45.0	63.8	0.00	29.92	973652000	0	1	1	1
0.73339	-1.53531	45.26	14180.45	5.28	799.75	144.69	0.5	140.9	-908.0	0.00	130.0	30.0	1464.75	0.73340	44.1	61.8	-0.02	29.92	973652000	0	1	1	1
0.73338	-1.53530	45.76	14039.60	5.48	792.11	144.95	0.5	141.1	-924.0	0.00	130.0	30.0	1457.11	0.73339	43.7	60.4	-0.04	29.92	973652000	0	1	1	1
0.73338	-1.53530	46.26	13971.27	5.59	784.36	144.98	0.4	141.1	-936.0	0.00	130.0	30.0	1449.36	0.73339	43.5	59.8	-0.02	29.92	973652000	0	1	1	1
0.73337	-1.53529	46.76	13834.56	5.84	776.54	144.64	0.3	141.2	-942.0	0.00	130.0	30.0	1441.54	0.73338	43.7	59.9	0.00	29.92	973652000	0	1	1	1
0.73337	-1.53529	47.26	13697.78	6.12	768.46	144.96	0.2	141.3	-940.0	0.00	130.0	30.0	1433.46	0.73338	44.2	59.1	0.07	29.92	973652000	0	1	1	1
0.73336	-1.53528	47.76	13560.92	6.43	760.74	145.03	0.1	141.4	-926.0	0.00	130.0	30.0	1425.74	0.73337	44.7	58.8	0.18	29.92	973652000	0	1	1	1
0.73336	-1.53527	48.26	13423.99	6.74	753.16	145.05	-0.0	141.4	-906.0	0.00	130.0	30.0	1418.16	0.73337	45.2	59.1	0.31	29.92	973652000	0	1	1	1
0.73336	-1.53527	48.76	13286.97	7.04	745.73	144.83	-0.2	141.5	-894.0	0.00	130.0	30.0	1410.73	0.73336	45.7	59.5	0.44	29.92	973652000	0	1	1	1
0.73335	-1.53526	49.26	13149.87	7.31	738.43	144.82	-0.2	141.5	-874.0	0.00	130.0	30.0	1403.43	0.73336	45.9	60.1	0.53	29.92	973652000	0	1	1	1
0.73335	-1.53526	49.76	13012.65	7.56	731.03	144.97	-0.3	141.5	-858.0	0.00	130.0	30.0	1396.03	0.73336	46.4	60.7	0.55	29.92	973652000	0	1	1	1
0.73334	-1.53525	50.26	12944.00	7.67	724.19	145.19	-0.4	141.5	-850.0	0.00	130.0	30.0	1389.19	0.73335	46.4	61.5	0.59	29.92	973652000	0	1	1	1
0.73334	-1.53525	50.76	12806.64	7.86	716.94	145.25	-0.4	141.5	-842.0	0.00	130.0	30.0	1381.94	0.73335	46.1	61.9	0.64	29.92	973652000	0	1	1	1
0.73333	-1.53524	51.26	12664.90	8.01	710.02	145.39	-0.4	141.5	-832.0	0.00	130.0	30.0	1375.02	0.73334	46.1	61.8	0.64	29.92	973652000	0	1	1	1
0.73333	-1.53524	51.76	12527.37	8.10	703.19	145.54	-0.4	141.5	-818.0	0.00	130.0	30.0	1368.19	0.73334	46.6	61.8	0.68	29.92	973652000	0	1	1	1

0.73332	-1.53523	52.26	12389.74	8.13	696.52	145.92	-0.5	141.5	-798.0	0.00	130.0	30.0	1361.52	0.73333	47.1	62.3	0.73	29.92	973652000	0	1	1	1
0.73332	-1.53523	52.76	12252.02	8.09	689.94	145.79	-0.5	141.5	-792.0	0.00	130.0	30.0	1354.94	0.73333	47.4	63.0	0.75	29.92	973652000	0	1	1	1
0.73331	-1.53522	53.26	12114.20	8.00	683.34	145.95	-0.4	141.5	-794.0	0.00	130.0	30.0	1348.34	0.73332	47.3	63.7	0.77	29.92	973652000	0	1	1	1
0.73331	-1.53522	53.76	11976.29	7.87	676.78	146.07	-0.3	141.5	-784.0	0.00	130.0	30.0	1341.78	0.73332	47.0	64.0	0.75	29.92	973652000	0	1	1	1
0.73330	-1.53521	54.26	11907.30	7.79	670.13	145.86	-0.3	141.5	-770.0	0.00	130.0	30.0	1335.13	0.73331	46.6	63.9	0.70	29.92	973652000	0	1	1	1
0.73330	-1.53521	54.76	11769.24	7.61	663.78	146.49	-0.3	141.5	-762.0	0.00	130.0	30.0	1328.78	0.73331	46.0	63.7	0.73	29.92	973652000	0	1	1	1
0.73329	-1.53520	55.26	11631.13	7.40	657.45	146.83	-0.3	141.5	-762.0	0.00	130.0	30.0	1322.45	0.73330	45.4	63.0	0.73	29.92	973652000	0	1	1	1
0.73329	-1.53519	55.76	11493.00	7.18	651.14	146.75	-0.3	141.5	-758.0	0.00	130.0	30.0	1316.14	0.73330	44.8	62.1	0.64	29.92	973652000	0	1	1	1
0.73328	-1.53519	56.26	11354.85	6.95	644.86	146.60	-0.3	141.4	-756.0	0.00	130.0	30.0	1309.86	0.73329	44.5	61.1	0.57	29.92	973652000	0	1	1	1
0.73328	-1.53518	56.76	11212.42	6.70	638.51	145.96	-0.3	141.4	-766.0	0.00	130.0	30.0	1303.51	0.73329	44.3	60.1	0.53	29.92	973652000	0	1	1	1
0.73327	-1.53518	57.26	11074.36	6.42	632.00	146.22	-0.3	141.4	-788.0	0.00	130.0	30.0	1297.00	0.73328	44.0	59.3	0.46	29.92	973652000	0	1	1	1
0.73327	-1.53517	57.76	10936.36	6.12	625.11	146.15	-0.3	141.3	-808.0	0.00	130.0	30.0	1290.11	0.73328	43.7	58.5	0.40	29.92	973652000	0	1	1	1
0.73327	-1.53517	58.26	10867.40	5.95	618.55	146.08	-0.2	141.3	-818.0	0.00	130.0	30.0	1283.55	0.73327	43.2	57.5	0.37	29.92	973652000	0	1	1	1
0.73326	-1.53516	58.76	10729.55	5.60	611.49	145.97	-0.2	141.3	-824.0	0.00	130.0	30.0	1276.49	0.73327	42.9	56.5	0.40	29.92	973652000	0	1	1	1
0.73326	-1.53516	59.26	10591.83	5.23	604.65	145.55	-0.1	141.3	-822.0	0.00	130.0	30.0	1269.65	0.73327	43.0	55.6	0.48	29.92	973652000	0	1	1	1
0.73325	-1.53515	59.76	10454.22	4.86	597.83	145.71	-0.1	141.3	-820.0	0.00	130.0	30.0	1262.83	0.73326	43.5	55.2	0.59	29.92	973652000	0	1	1	1
0.73325	-1.53515	0.26	10316.72	4.49	591.06	145.58	-0.1	141.3	-812.0	0.00	130.0	30.0	1256.06	0.73326	44.1	55.2	0.66	29.92	973652000	0	1	1	1
0.73324	-1.53514	0.76	10179.30	4.10	584.39	145.90	-0.1	141.3	-802.0	0.00	130.0	30.0	1249.39	0.73325	44.8	56.0	0.73	29.92	973652000	0	1	1	1
0.73324	-1.53514	1.26	10041.96	3.72	577.78	145.81	-0.1	141.3	-794.0	0.00	130.0	30.0	1242.78	0.73325	45.4	56.9	0.79	29.92	973652000	0	1	1	1
0.73323	-1.53513	1.76	9904.66	3.32	571.23	145.95	-0.0	141.3	-786.0	0.00	130.0	30.0	1236.23	0.73324	45.7	57.8	0.81	29.92	973652000	0	1	1	1
0.73323	-1.53512	2.26	9836.03	3.12	564.77	145.92	0.0	141.3	-772.0	0.00	130.0	30.0	1229.77	0.73324	46.0	58.8	0.83	29.92	973652000	0	1	1	1
0.73322	-1.53512	2.76	9694.45	2.73	558.42	145.64	0.1	141.3	-762.0	0.00	130.0	30.0	1223.42	0.73323	46.1	59.7	0.81	29.92	973652000	0	1	1	1
0.73322	-1.53511	3.26	9557.14	2.39	551.87	145.39	0.1	141.3	-762.0	0.00	130.0	30.0	1216.87	0.73323	45.8	60.7	0.79	29.92	973652000	0	1	1	1
0.73321	-1.53511	3.76	9419.80	2.09	545.52	145.15	0.1	141.3	-764.0	0.00	130.0	30.0	1210.52	0.73322	45.2	61.1	0.75	29.92	973652000	0	1	1	1
0.73321	-1.53510	4.26	9282.44	1.83	539.10	145.50	0.1	141.3	-776.0	0.00	130.0	30.0	1204.10	0.73322	44.7	60.7	0.66	29.92	973652000	0	1	1	1

0.73320	-1.53510	4.76	9145.09	1.60	532.60	145.76	0.2	141.3	-788.0	0.00	130.0	30.0	1197.60	0.73321	44.2	60.0	0.57	29.92	973652000	0	1	1	1
0.73320	-1.53509	5.26	9007.79	1.41	525.75	145.73	0.2	141.3	-800.0	0.00	130.0	30.0	1190.75	0.73321	44.1	58.9	0.51	29.92	973652000	0	1	1	1
0.73319	-1.53509	5.76	8870.54	1.27	519.01	145.78	0.2	141.3	-812.0	0.00	130.0	30.0	1184.01	0.73320	44.3	58.2	0.51	29.92	973652000	0	1	1	1
0.73319	-1.53508	6.26	8733.33	1.16	512.28	145.43	0.1	141.3	-808.0	0.00	130.0	30.0	1177.28	0.73320	45.0	57.8	0.51	29.92	973652000	0	1	1	1
0.73318	-1.53508	6.76	8664.73	1.12	505.61	145.62	0.1	141.4	-800.0	0.00	130.0	30.0	1170.61	0.73319	45.5	58.3	0.55	29.92	973652000	0	1	1	1
0.73318	-1.53507	7.26	8527.51	1.04	498.97	145.83	0.1	141.4	-798.0	0.00	130.0	30.0	1163.97	0.73319	45.5	59.2	0.62	29.92	973652000	0	1	1	1
0.73317	-1.53507	7.76	8386.00	0.99	492.14	145.98	-0.0	141.4	-796.0	0.00	130.0	30.0	1157.13	0.73318	45.2	59.5	0.64	29.92	973652000	0	1	1	1
0.73317	-1.53506	8.26	8248.78	0.93	485.57	145.86	-0.1	141.3	-788.0	0.00	130.0	30.0	1150.57	0.73318	44.7	59.6	0.62	29.92	973652000	0	1	1	1
0.73317	-1.53505	8.76	8111.57	0.87	479.04	145.72	-0.3	141.3	-784.0	0.00	130.0	30.0	1144.04	0.73317	44.5	59.2	0.57	29.92	973652000	0	1	1	1
0.73316	-1.53505	9.26	7974.38	0.77	472.54	145.46	-0.4	141.2	-780.0	0.00	130.0	30.0	1137.54	0.73317	44.3	58.7	0.55	29.92	973652000	0	1	1	1
0.73316	-1.53504	9.76	7837.23	0.63	465.76	145.16	-0.4	141.2	-792.0	0.00	130.0	30.0	1130.76	0.73317	44.1	58.1	0.53	29.92	973652000	0	1	1	1
0.73315	-1.53504	10.26	7700.16	0.44	459.07	144.92	-0.4	141.1	-808.0	0.00	130.0	30.0	1124.07	0.73316	43.7	57.5	0.51	29.92	973652000	0	1	1	1
0.73315	-1.53503	10.76	7631.65	0.32	452.21	145.16	-0.3	141.0	-832.0	0.00	130.0	30.0	1117.21	0.73316	43.5	56.9	0.48	29.92	973652000	0	1	1	1
0.73314	-1.53503	11.26	7494.70	0.04	445.21	145.50	-0.3	140.9	-844.0	0.00	130.0	30.0	1110.21	0.73315	43.5	56.3	0.46	29.92	973652000	0	1	1	1
0.73314	-1.53502	11.76	7357.84	-0.31	438.12	145.37	-0.4	140.9	-856.0	0.00	130.0	30.0	1103.12	0.73315	43.5	55.9	0.46	29.92	973652000	0	1	1	1
0.73313	-1.53502	12.26	7221.07	-0.75	430.96	144.93	-0.7	140.8	-864.0	0.00	130.0	30.0	1095.96	0.73314	44.2	55.7	0.46	29.92	973652000	0	1	1	1
0.73313	-1.53501	12.76	7084.34	-1.33	423.72	144.96	-0.8	140.8	-874.0	0.00	130.0	30.0	1088.72	0.73314	45.0	56.2	0.46	29.92	973652000	0	1	1	1
0.73312	-1.53501	13.26	6943.35	-2.08	416.45	145.24	-0.7	140.8	-874.0	0.00	130.0	30.0	1081.45	0.73313	45.3	57.3	0.48	29.92	973652000	0	1	1	1
0.73312	-1.53500	13.76	6806.63	-2.92	408.98	145.13	-0.4	140.8	-870.0	0.00	130.0	30.0	1073.98	0.73313	45.1	58.2	0.51	29.92	973652000	0	1	1	1
0.73311	-1.53500	14.26	6669.91	-3.81	401.77	145.05	0.1	140.8	-866.0	0.00	130.0	30.0	1066.77	0.73312	44.7	58.5	0.51	29.92	973652000	0	1	1	1
0.73311	-1.53499	14.76	6601.55	-4.26	394.58	145.06	0.5	140.9	-864.0	0.00	130.0	30.0	1059.58	0.73312	44.5	58.3	0.55	29.92	973652000	0	1	1	1
0.73310	-1.53498	15.26	6464.84	-5.10	387.42	145.45	0.9	140.9	-860.0	0.00	130.0	30.0	1052.42	0.73311	44.4	58.0	0.53	29.92	973652000	0	1	1	1
0.73310	-1.53498	15.76	6328.14	-5.83	380.28	145.63	0.9	141.0	-860.0	0.00	130.0	30.0	1045.28	0.73311	44.3	57.8	0.51	29.92	973652000	0	1	1	1
0.73309	-1.53497	16.26	6191.47	-6.43	373.05	145.18	0.7	141.0	-872.0	0.00	130.0	30.0	1038.05	0.73310	44.1	57.6	0.48	29.92	973652000	0	1	1	1
0.73309	-1.53497	16.76	6054.85	-6.90	365.78	144.92	0.6	141.1	-876.0	0.00	130.0	30.0	1030.78	0.73310	44.0	57.2	0.46	29.92	973652000	0	1	1	1

0.73309	-1.53496	17.26	5918.25	-7.27	358.48	145.14	0.4	141.1	-880.0	0.00	130.0	30.0	1023.48	0.73309	44.2	57.0	0.44	29.92	973652000	0	1	1	1
0.73308	-1.53496	17.76	5781.68	-7.57	351.16	145.09	0.3	141.1	-880.0	0.00	130.0	30.0	1016.16	0.73309	44.2	56.9	0.42	29.92	973652000	0	1	1	1
0.73308	-1.53495	18.26	5645.13	-7.83	343.85	145.18	0.2	141.1	-880.0	0.00	130.0	30.0	1008.85	0.73309	43.8	57.0	0.44	29.92	973652000	0	1	1	1
0.73307	-1.53495	18.76	5508.61	-8.05	336.31	144.99	0.4	141.1	-878.0	0.00	130.0	30.0	1001.30	0.73308	43.5	56.5	0.42	29.92	973652000	0	1	1	1
0.73307	-1.53494	19.26	5436.10	-8.15	328.98	145.09	0.7	141.1	-882.0	0.00	130.0	30.0	993.98	0.73308	43.4	56.0	0.40	29.92	973652000	0	1	1	1
0.73306	-1.53494	19.76	5299.64	-8.29	321.65	144.98	1.1	141.2	-882.0	0.00	130.0	30.0	986.65	0.73307	43.4	55.6	0.37	29.92	973652000	0	1	1	1
0.73306	-1.53493	20.26	5163.23	-8.29	314.33	145.02	1.7	141.3	-880.0	0.00	130.0	30.0	979.33	0.73307	43.4	55.5	0.37	29.92	973652000	0	1	1	1
0.73305	-1.53493	20.76	5026.88	-8.04	307.07	145.10	1.8	141.5	-870.0	0.00	130.0	30.0	972.07	0.73306	43.4	55.3	0.42	29.92	973652000	0	1	1	1
0.73305	-1.53492	21.26	4890.60	-7.50	299.91	144.86	1.7	141.6	-860.0	0.00	130.0	30.0	964.91	0.73306	43.4	55.2	0.55	29.92	973652000	0	1	1	1
0.73304	-1.53492	21.76	4754.41	-6.69	292.56	145.02	1.6	141.6	-854.0	0.00	130.0	30.0	957.56	0.73305	43.6	55.1	0.66	29.92	973652000	0	1	1	1
0.73304	-1.53491	22.26	4618.28	-5.64	285.74	145.09	1.3	141.7	-848.0	0.00	130.0	30.0	950.74	0.73305	43.9	55.1	0.70	29.92	973652000	0	1	1	1
0.73303	-1.53491	22.76	4482.23	-4.39	278.77	145.00	1.0	141.7	-836.0	0.00	130.0	30.0	943.77	0.73304	44.1	55.5	0.70	29.92	973652000	0	1	1	1
0.73303	-1.53490	23.26	4414.23	-3.71	271.74	144.90	0.8	141.7	-810.0	0.00	130.0	30.0	936.74	0.73304	44.1	55.9	0.75	29.92	973652000	0	1	1	1
0.73302	-1.53489	23.76	4278.30	-2.25	265.15	145.11	0.7	141.7	-790.0	0.00	130.0	30.0	930.15	0.73303	44.0	56.0	0.94	29.92	973652000	0	1	1	1
0.73302	-1.53489	24.26	4142.47	-0.70	258.82	144.96	0.3	141.7	-754.0	0.00	130.0	30.0	923.82	0.73303	43.9	56.1	1.16	29.92	973652000	0	1	1	1
0.73301	-1.53488	24.76	4002.51	0.94	252.59	144.58	-0.2	141.6	-718.0	0.00	130.0	30.0	917.59	0.73302	43.9	56.0	1.30	29.92	973652000	0	1	1	1
0.73301	-1.53488	25.26	3866.95	2.46	246.77	144.12	-0.9	141.5	-694.0	0.00	130.0	30.0	911.77	0.73302	44.3	56.0	1.49	29.92	973652000	0	1	1	1
0.73301	-1.53487	25.76	3731.54	3.83	241.09	144.00	-1.3	141.4	-680.0	0.00	130.0	30.0	906.09	0.73301	44.8	56.4	1.65	29.92	973652000	0	1	1	1
0.73300	-1.53487	26.26	3596.26	4.97	235.57	143.74	-1.6	141.3	-662.0	0.00	130.0	30.0	900.57	0.73301	45.4	57.1	1.71	29.92	973652000	0	1	1	1
0.73300	-1.53486	26.76	3461.07	5.82	230.19	143.57	-1.5	141.3	-642.0	0.00	130.0	30.0	895.19	0.73301	45.9	58.0	1.78	29.92	973652000	0	1	1	1
0.73299	-1.53486	27.26	3393.50	6.15	224.95	143.54	-1.1	141.2	-626.0	0.00	130.0	30.0	889.95	0.73300	46.0	59.2	1.85	29.92	973652000	0	1	1	1
0.73299	-1.53485	27.76	3258.43	6.66	219.83	143.72	-1.0	141.2	-614.0	0.00	130.0	30.0	884.83	0.73300	46.0	60.0	1.89	29.92	973652000	0	1	1	1
0.73298	-1.53485	28.26	3123.42	7.00	214.61	143.65	-1.1	141.1	-608.0	0.00	130.0	30.0	879.61	0.73299	46.0	60.7	1.91	29.92	973652000	0	1	1	1
0.73298	-1.53484	28.76	2988.48	7.15	209.60	143.64	-1.3	141.0	-600.0	0.00	130.0	30.0	874.60	0.73299	46.3	61.1	1.91	29.92	973652000	0	1	1	1
0.73297	-1.53484	29.26	2853.58	7.08	204.64	143.67	-1.6	140.9	-596.0	0.00	130.0	30.0	869.64	0.73298	46.8	61.5	1.89	29.92	973652000	0	1	1	1

0.73297	-1.53483	29.76	2718.71	6.76	199.63	143.56	-1.5	140.9	-610.0	0.00	130.0	30.0	864.63	0.73298	47.2	62.1	1.85	29.92	973652000	0	1	1	1
0.73296	-1.53483	30.26	2579.61	6.14	194.25	143.73	-1.1	140.8	-630.0	0.00	130.0	30.0	859.25	0.73297	47.2	62.9	1.67	29.92	973652000	0	1	1	1
0.73296	-1.53482	30.76	2444.68	5.35	188.79	143.76	-0.5	140.8	-664.0	0.00	130.0	30.0	853.79	0.73297	46.9	63.3	1.41	29.92	973652000	0	1	1	1
0.73295	-1.53482	31.26	2309.70	4.48	183.09	143.76	0.3	140.9	-694.0	0.00	130.0	30.0	848.09	0.73296	46.5	63.3	1.19	29.92	973652000	0	1	1	1
0.73295	-1.53481	31.76	2242.19	4.05	177.21	143.64	0.9	140.9	-714.0	0.00	130.0	30.0	842.21	0.73296	45.9	63.0	0.99	29.92	973652000	0	1	1	1
0.73294	-1.53481	32.26	2107.14	3.29	171.19	143.60	0.9	141.0	-726.0	0.00	130.0	30.0	836.19	0.73295	45.5	62.4	0.94	29.92	973652000	0	1	1	1
0.73294	-1.53480	32.76	1972.05	2.65	164.98	143.75	0.7	141.0	-756.0	0.00	130.0	30.0	829.98	0.73295	45.2	61.6	0.92	29.92	973652000	0	1	1	1
0.73294	-1.53479	33.26	1836.92	2.13	158.26	143.83	0.4	141.0	-794.0	0.00	130.0	30.0	823.26	0.73294	45.0	60.8	0.81	29.92	973652000	0	1	1	1
0.73293	-1.53479	33.76	1701.75	1.66	151.69	143.91	-0.0	141.0	-834.0	0.00	130.0	30.0	816.69	0.73294	44.9	60.2	0.55	29.92	973652000	0	1	1	1
0.73293	-1.53478	34.26	1566.51	1.18	144.33	144.13	-0.3	140.9	-864.0	0.00	130.0	30.0	809.33	0.73294	44.7	59.7	0.31	29.92	973652000	0	1	1	1
0.73292	-1.53478	35.06	1359.32	0.31	132.60	144.39	-0.6	140.8	-916.0	0.00	130.0	30.0	797.60	0.73293	44.4	59.2	0.11	29.92	973652000	0	1	1	1
0.73291	-1.53477	35.56	1223.94	-0.41	124.58	144.44	-0.4	140.8	-940.0	0.00	130.0	30.0	789.58	0.73293	44.2	58.6	0.02	29.92	973652000	0	1	1	1
0.73291	-1.53476	36.06	1088.53	-1.20	116.68	144.56	-0.0	140.8	-954.0	0.00	130.0	30.0	781.68	0.73292	43.7	57.5	-0.02	29.92	973652000	0	1	1	1
0.73290	-1.53476	36.56	1020.81	-1.61	108.82	144.51	0.5	140.9	-936.0	0.00	130.0	30.0	773.82	0.73291	43.4	56.7	0.04	29.92	973652000	0	1	1	1
0.73290	-1.53475	37.06	885.36	-2.40	101.02	144.42	0.9	140.9	-902.0	0.00	130.0	30.0	766.02	0.73291	43.2	56.0	0.31	29.92	973652000	0	1	1	1
0.73290	-1.53475	37.56	749.94	-3.06	93.83	144.35	0.9	141.0	-858.0	0.00	130.0	30.0	758.83	0.73290	43.1	55.4	0.79	29.92	973652000	0	1	1	1
0.73289	-1.53474	38.06	614.57	-3.58	86.89	144.37	0.7	141.0	-830.0	0.00	130.0	30.0	751.89	0.73290	43.2	54.9	1.05	29.92	973652000	0	1	1	1
0.73289	-1.53474	38.56	479.27	-4.00	80.08	144.39	0.6	141.0	-816.0	0.00	130.0	30.0	745.08	0.73290	43.6	54.7	1.14	29.92	973652000	0	1	1	1
0.73288	-1.53473	39.06	344.01	-4.33	73.13	144.28	0.8	141.1	-804.0	0.00	130.0	30.0	738.13	0.73289	43.9	54.9	1.05	29.92	973652000	0	1	1	1
0.73288	-1.53473	39.56	208.81	-4.55	66.58	144.24	1.1	141.2	-784.0	0.00	130.0	30.0	731.58	0.73289	44.0	55.4	1.01	29.92	973652000	0	1	1	1
0.73287	-1.53472	40.06	73.66	-4.61	60.29	144.10	1.0	141.3	-750.0	0.00	130.0	30.0	725.29	0.73288	43.8	55.6	1.16	29.92	973652000	0	1	1	1
0.73287	-1.53472	40.56	6.12	-4.52	54.25	144.00	0.9	141.3	-720.0	0.00	130.0	30.0	719.25	0.73288	43.6	55.5	1.36	29.92	973652000	0	1	1	1
0.73286	-1.53471	41.06	-133.14	-4.42	48.20	143.93	0.7	141.3	-694.0	0.00	130.0	30.0	713.20	0.73287	43.7	55.3	1.49	29.92	973652000	0	1	1	1
0.73286	-1.53471	41.56	-268.12	-4.15	42.76	143.87	0.5	141.3	-672.0	0.00	130.0	30.0	707.75	0.73287	44.1	55.3	1.54	29.92	973652000	0	1	1	1
0.73285	-1.53470	42.06	-403.03	-3.80	37.20	143.80	0.2	141.3	-638.0	0.00	130.0	30.0	702.20	0.73286	44.1	55.6	1.67	29.92	973652000	0	1	1	1

0.73285	-1.53470	42.56	-537.87	-3.42	32.29	143.69	0.1	141.3	-570.0	0.00	130.0	30.0	697.29	0.73286	44.0	56.0	1.82	29.92	973652000	0	1	1	1
0.73284	-1.53469	43.06	-672.58	-3.02	28.10	143.44	0.2	141.3	-468.0	0.00	130.0	30.0	693.10	0.73285	42.3	55.8	2.26	29.92	973652000	0	1	1	1
0.73284	-1.53469	43.56	-807.06	-2.60	24.85	143.16	0.4	141.4	-370.0	0.00	130.0	30.0	689.85	0.73285	42.7	54.7	3.12	29.92	973652000	0	1	0	1
0.73283	-1.53468	44.06	-941.29	-2.11	22.83	142.91	0.6	141.4	-206.0	0.00	130.0	30.0	687.83	0.73284	59.7	76.5	4.15	29.92	973652000	0	1	1	1
0.73283	-1.53468	44.56	-1075.34	-1.51	22.10	142.80	0.9	141.5	-40.0	0.00	130.0	30.0	687.10	0.73284	69.1	84.3	5.05	29.92	973652000	0	1	1	1
0.73283	-1.53467	45.06	-1142.35	-1.16	22.64	142.84	1.0	141.6	126.0	0.00	130.0	30.0	687.64	0.73283	74.7	88.1	6.02	29.92	973652000	0	1	1	1
0.73282	-1.53466	45.56	-1276.41	-0.34	24.52	143.13	0.9	141.6	246.0	0.00	130.0	20.0	689.52	0.73283	76.7	89.8	6.68	29.92	973652000	0	1	1	1
0.73282	-1.53466	46.06	-1410.75	0.64	27.57	143.68	0.7	141.6	394.0	0.00	130.0	20.0	692.57	0.73283	77.4	91.2	7.21	29.92	973652000	0	1	1	1
0.73281	-1.53465	46.56	-1549.86	1.78	31.80	144.45	0.4	141.6	558.0	0.00	130.0	20.0	696.80	0.73282	77.8	93.3	7.51	29.92	973652000	0	1	1	1
0.73281	-1.53465	47.06	-1685.49	2.95	37.35	145.24	0.0	141.6	734.0	0.00	130.0	20.0	702.35	0.73282	77.9	94.1	7.89	29.92	973652000	0	1	1	1
0.73280	-1.53464	47.56	-1821.77	4.12	44.54	145.92	-0.3	141.5	900.0	0.00	130.0	20.0	709.54	0.73281	77.9	94.1	8.61	29.92	973652000	0	1	1	1
0.73280	-1.53464	48.06	-1958.53	5.20	53.61	146.38	-0.6	141.4	1148.0	0.00	130.0	20.0	718.61	0.73281	77.9	95.4	9.76	29.92	973652000	0	1	1	1
0.73279	-1.53463	48.56	-2095.55	6.14	64.58	146.73	-0.8	141.3	1392.0	0.00	130.0	20.0	729.58	0.73280	77.9	96.1	10.74	29.92	973652000	0	1	1	1
0.73279	-1.53463	49.06	-2164.12	6.54	77.23	146.93	-0.8	141.2	1598.0	0.00	130.0	20.0	742.23	0.73280	77.9	96.4	11.89	29.92	973652000	0	1	1	1
0.73278	-1.53462	49.56	-2301.32	7.20	91.46	147.13	-0.6	141.2	1752.0	0.00	130.0	20.0	756.46	0.73279	77.9	96.4	12.66	29.92	973652000	0	1	1	1
0.73278	-1.53462	50.06	-2438.43	7.70	108.03	147.13	-0.3	141.2	1980.0	0.00	130.0	20.0	773.03	0.73279	77.9	96.4	13.36	29.92	973652000	0	1	1	1
0.73277	-1.53461	50.56	-2575.24	8.11	125.93	147.04	-0.1	141.2	2226.0	0.00	130.0	20.0	790.93	0.73278	77.9	96.2	14.17	29.92	973652000	0	1	1	1
0.73277	-1.53461	51.06	-2711.63	8.48	145.32	146.90	-0.1	141.2	2380.0	0.00	130.0	20.0	810.32	0.73278	77.9	96.2	15.27	29.92	973652000	0	1	1	1