NASA/TM-2002-211639

Flight Test Evaluation of the Airborne Information for Lateral Spacing (AILS) Concept

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April 2002

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Space Administration

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Acknowledgments

The author gratefully acknowledges the significant contributions of the many members of the research and development team, both Government and Industry, that were required to implement this concept and conduct the simulation and flight test. With respect and gratitude I offer tribute to the pioneers of the AILS concept, Leonard Credeur, Charlie Scanlon, Marvin Waller, Gary Lohr, and Bill Capron. Also deserving of credit are the other members of the NASA LaRC AILS development team, R. Brad Perry, Dawn Elliott, Phil Brown, Daniel DiCarlo, Laura Rine, and Donner Grigsby as well as the contractor counterparts, from Lockheed-Martin, Jake Barry, Dan Burdette and Frank McGee; retired United Airline Captains, William Gifford and Dave Simmon; retired American Airline Captain Al Price; and from Adsystech, Inc., Thomas Doyle. Much appreciation is also extended to Honeywell, specifically, Bill Corwin, Dave Maahs, Jarold Weiser, Paul Samanant, Mike Jackson, Scott Snyder, and Christine Haissig for taking an interest in the AILS concept and working to make this research a success. Many other persons whose names are not mentioned here have contributed significantly, and the author expresses his sincerest thanks. The author is only reporting the results of this study, the research, development, and implementation team members are what made this report possible.

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Abstract

The Airborne Information for Lateral Spacing (AILS) concept is designed to support independent parallel approach operations to runways spaced as close as 2,500 ft. This report briefly describes the AILS operational concept and the results of a flight test of one implementation of this concept. The focus of this flight test was to validate a prior simulator study. Both studies evaluated pilot performance, pilot acceptability, and minimum miss-distances for the rare situation in which an aircraft on one approach intrudes into the path of an aircraft on the other approach. Although the flight data set was not meant to be a statistically valid sample, the trends acquired in flight followed those of the simulator and therefore met the intent of validating the findings from the simulator. Results from this study showed that the design-goal mean miss-distance of 1,200 ft to potential collision situations was surpassed with an actual mean miss-distance of 1,859 ft. Pilot reaction times to the alerting system, which was an operational concern, averaged 0.65 sec, were well below the design-goal reaction time of 2.0 sec. From the results of both of these tests, it can be concluded that this operational concept, with supporting technology and procedures, may provide an operationally viable means for conducting simultaneous, independent instrument approaches to runways spaced as close as 2500 ft.

Introduction

In recent years, airport runway construction within the United States has not been able to keep pace with the rise in traffic growth; resulting in an increase in both the number and duration of flight delays. In addition, many U.S. airports depend on parallel runway operations to meet the growing demand for day-to-day operations. In the current airspace system, poor weather conditions reduce the capacity of closely spaced parallel runway operations. These capacity losses can result in landing delays causing inconveniences to the traveling public, interruptions in commerce, and increased operating cost to the airlines. The Federal Aviation Administration (FAA) has addressed this reduced capacity problem for closely spaced parallel runways in its Precision Runway Monitor (PRM) Program (ref. 1). With ground-based radar technology consisting primarily of high update rate, more accurate radar, and higher resolution displays for Air Traffic Control (ATC) controller stations, PRM has certified capabilities to operate independent parallel approaches to runway separations as close as 3400 ft.

To further exploit independent parallel runway operations at airports with runway spacing below 4300 ft, the National Aeronautics and Space Administration has developed a flight deck centered concept that may allow operations below the current PRM runway separation minima. This new concept is called Airborne Information for Lateral Spacing (AILS) and is designed to support independent parallel approach operations to runways spaced as close as 2500 ft. This report will describe the results of a flight test of one implementation of this concept. The focus of this test was to validate the results of a prior ground-based simulator study (ref. 2) in an actual flight environment.

This effort was conducted under the Terminal Area Productivity element of NASA's Aviation Systems Capacity Project. Avionics hardware development and integration to support the AILS concept and a fully instrumented test aircraft were provided by Honeywell under a cooperative agreement. In addition, Honeywell personnel made significant contributions to the operational procedures unique to this flight test.

Nomenclature

ADS-B	Automatic Dependent Surveillance Broadcast
AILS	Airborne Information for Lateral Spacing
ATC	Air Traffic Control
CASPER	Closely Spaced Parallel Approaches
CDI	Course Deviation Indicator
CPA	Closest Point of Approach, minimum slant-range distance
DGPS	differential GPS
EADI	Electronic Attitude Director Indicator
EEM	emergency escape maneuver
evader	properly maneuvering aircraft being threatened by another aircraft with a collision
FAA	Federal Aviation Administration
FAF	final approach fix
FMS	Flight Management System
GPS	Global Positioning System
IFD	Integration Flight Deck
intruder	improperly maneuvering aircraft that produces a collision risk to another aircraft
ILS	Instrument Landing System
NASA	National Aeronautics and Space Administration
ND	navigation display
NMAC	near midair collision, where an aircraft is within 500ft of another aircraft
ownship	From a flight crews' perspective, the aircraft that they are flying
PRM	Precision Runway Monitor

RA	resolution advisory
TA	traffic advisory
TCAS	Traffic Alert and Collision Avoidance System

Concept Overview

The Airborne Information for Lateral Spacing (AILS) concept is an operational, procedures-based technique, along with appropriate supporting technologies, for conducting independent, simultaneous approaches to closely spaced parallel runways. For suitably equipped aircraft with eligible crews, AILS is very similar to today's typical instrument approach operations. AILS only becomes truly obvious to the flight crew when an extremely unusual event occurs: one aircraft flies off-path and threatens the safety of another.

The AILS concept focuses on two aspects of the closely-spaced parallel approach problem. First, approach paths must be designed and flown such that the possibility of one aircraft on one approach interfering with another aircraft on the other approach is remote. Second, if this remote event does occur, a means must be provided that will allow the non-offending aircraft to safely avoid the intruding aircraft. How AILS accommodates both of these operational aspects of the closely-spaced parallel approach problem is described in detail in reference 2.

Emergency Escape Maneuver (EEM)

AILS is fundamentally a procedures-based concept with conventional Instrument Approach Procedures used as a basis for a “normal” operation. In the rare event that a “normal” operation does not occur-- that is, an aircraft flies off its approach and threatens another-- the AILS concept relies on a fixed, documented procedure to minimize the collision risk. Based on previous analytical efforts and industry studies (refs. 3 to 9), it was determined that a maneuver in which an aircraft climbed, accelerated, and turned 45° away from the approach path of the other aircraft would provide a simple yet effective means for dealing with a potential collision situation. This maneuver would be part of the published Instrument Approach Procedures (see figure 1 for an example) and would be performed whenever an AILS collision alert warning is activated. This climb-turn procedure is defined as an emergency escape maneuver (EEM). Also, note that reference 4 describes the advantages that a climb-turn maneuver has relative to a climb-only maneuver.

Because the occurrence of an EEM is considered very infrequent, the cost of implementing autopilot or flight guidance information for the EEM was considered prohibitive relative to the benefit. The EEM is procedural and is performed without unique autopilot or flight director guidance.

General Operational and Pilot Procedures

As stated previously, an AILS approach would be very similar to today's typical ILS approach operation. Like today, flight crews would conduct an approach briefing using an instrument approach chart (fig. 1), although this chart would now include the EEM required for this procedure. Aircraft would either be radar vectored or use a charted route to become established on the final approach course with the flight crews selecting the relevant approach either through the Flight Management System (FMS) or a dedicated navigation radio control panel. Until the aircraft were on the final approach course, they would be separated vertically by a minimum of 1000 ft for the two approach streams. During this time, the airborne components of the AILS system would perform the required electronic handshakes, via data link, between aircraft and annunciate the availability of the system to perform AILS to the flight crew. (The equipment is described in a later section.) The flight crew would then be cleared for the AILS approach procedure, with a subsequent reduction of vertical separation between the approach streams. Under normal conditions, no other AILS specific actions would be required of the flight crew.

Reducing the Intrusion Risk

The primary means for safely conducting simultaneous, independent instrument approaches to closely spaced parallel runways is through approach design and flight operations that would reduce the possibility of one aircraft intruding into the approach path of another. To accomplish this, the AILS concept requires a highly accurate navigation source, an approach path design that minimizes the potential for intrusions, and pilot alerting for situations that would generate a collision risk.

Navigation Source

From a navigation sensor standpoint, the AILS concept assumes the use of differential global positioning system (DGPS) or a navigation source with an equivalent level of accuracy and precision. The use of a standard instrument landing system (ILS) was not considered adequate due to course "bends" and other navigation anomalies that are not unusual to a typical ILS installation.

Lateral Path Boundary Design

From the approach design standpoint, straight-in, parallel approaches using standard ILS design were considered to be unacceptable for an AILS operation due to lateral path boundary overlap. One alternative that would allow for the use of DGPS ILS-lookalike approaches (current production DGPS-based approach systems mimic, from an approach design standpoint, conventional ILS approaches) is an offset approach path. In this alternative, one or both of the lateral paths to the parallel runways would be angularly offset or slewed such that the inner path boundaries between the two approach paths would be parallel. For this study, it was determined that the more challenging option of this alternative would be to slew both approaches 2° away from the opposite approach. There are two operational disadvantages to offset approaches. First, there is a penalty in the decision height. In the design used for this study, this penalty was 50 ft, resulting in a 250 ft decision height for a nominally configured runway. The second problem is that the offset approach requires the pilot to manually turn the aircraft onto the runway centerline during a critical phase of flight, thereby adding to pilot workload. Although neither of these disadvantages is overwhelming, they can add to the operational "cost" of the AILS concept.

Pilot Alerting for Off-Path Performance

The AILS concept alerts an aircraft when it deviates further than one half the width of the lateral boundary and also when the lateral boundary has been exceeded. From a piloting standpoint, this is the traditional half-scale needle deflection (or greater) on the course deviation indicator (CDI). The second LOCALIZER alert is issued whenever ownship deviates further than the full-scale width of the lateral boundary from the approach path centerline. From a piloting standpoint, this is the traditional full-scale needle deflection on the CDI.

Potential Loss of Lateral Separation

On the rare occasions that one aircraft flies off path and produces a potential collision situation with an aircraft on the other approach, the AILS concept provides a series of alerts for both the intruding aircraft and the nonintruding, evading aircraft. Caution alerts are provided in both aircraft to heighten the crew's awareness to the developing situation (ref. 10). If the potential collision situation continues, warning alerts are then provided. Again note that the AILS warning alert requires an immediate EEM. Also note that these alerts are sequenced such that the intruding aircraft is alerted first. The normal sequence for alerts for this rare event would be: intruder-caution, evader-caution, intruder-warning, and finally, evader-warning. If the flight crew of the intruder corrects the situation either when they receive the caution alert or they perform an EEM on their warning, the warning to the noninterfering aircraft may never occur. This sequencing then penalizes the intruder first (with a climb-turn warning) and reduces the ATC disruption that would be caused by both aircraft executing an EEM.

Ownship Threatening Adjacent Aircraft

The AILS "PATH" alerts are designed to aid in avoiding collisions in the event that the ownship maneuvers in a manner that would threaten the adjacent aircraft. For these alerts, the onboard alerting algorithm uses state information from the traffic on the parallel approach, transmitted by ADS-B, to detect situations where the potential path of the ownship may be threatening the adjacent traffic. If this situation occurs, the onboard alerting system generates a PATH caution alert as this situation begins to evolve. This alert is intended to heighten the crew's awareness of their flight path management and traffic situation and is annunciated to the flight crew through both auditory and visual means. A voice alert is provided with the phrase "path parallel approach" spoken twice. Visually, the message "PATH" is presented on the EADI in the color amber. As an enhancement to pilot situation awareness, the ownship symbol on the navigation display (ND) is also color-coded amber to highlight the fact that it is the performance of ownship that is causing the alert. Because of the relative closeness of the adjacent aircraft, AILS uses a nonstandard, higher resolution ND map scale. For this implementation, the minimum map scale was 2.5 nmi, whereas traditional convention is typically a 5 or 10 nmi minimum. At this time, the crew should be taking action to place their aircraft back on course.

As the path performance further degrades and the collision danger becomes imminent, a PATH warning alert is generated. Since an immediate EEM is the correct response to this alert, the voice alert phrase is "climb turn," spoken twice, and the message "CLIMB TURN" is presented on the EADI in the color red. In addition, the ownship symbol on the ND is also color coded in red. In this situation, the annunciation of this warning alert requires the flight deck crew to execute an EEM.

Ownship Threaten by Adjacent Aircraft

Like the PATH alert, the AILS "TRAFFIC" alerts are designed to aid in avoiding collisions in the event that the adjacent aircraft maneuvers in a manner that would threaten ownship. This alert set is obviously the "other side" of the alerting scheme. Again, with the state data of ownship and the adjacent aircraft, the onboard alerting algorithm determines if a situation is evolving in which the adjacent aircraft is threatening ownship. If this situation occurs, the onboard alerting system generates a TRAFFIC caution alert. As with all other potential collision alerts, the TRAFFIC caution alert is annunciated to the flight crew through both auditory and visual means. A voice alert is provided with the phrase "traffic parallel approach" spoken twice. Visually, the message "TRAFFIC" is presented on the EADI in the color amber (fig. 2). On the ND, the adjacent aircraft is now presented in a manner similar to a TCAS Traffic Advisory traffic advisory (TA) (fig. 3). This symbology is augmented over basic TCAS in that the traffic’s groundtrack vectors are included in the symbol. It should be noted that the groundtrack information is provided over the ADS-B data link. This alert is intended to heighten the crews' awareness of the traffic situation. No crew action is required for a TRAFFIC caution alert.

As the collision danger becomes imminent, a TRAFFIC warning alert is generated. Since an immediate EEM is the correct response to this alert, the voice alert phrase is “climb turn,” spoken twice, and the message “CLIMB TURN” is presented on the EADI in the color red (fig. 4). In addition, the traffic symbology changes to the conventional TCAS Resolution Advisory (RA) red box for the TRAFFIC warning alert (fig. 5). In this situation, the annunciation of this warning alert requires the flight deck crew to execute an EEM.

Alert Priority and Sequence

The alerting system is designed such that only one of the six alerts (Table 1) can occur at any instance in time and they are timed and sequenced to eliminate lower priority and nuisance alerts. For example, a LOCALIZER caution alert would not be issued after a PATH caution alert. All of the collision alerts have priority over the LOCALIZER alerts. In addition, from examining the alert threshold times in Table 2, it can be seen that the intruding aircraft is alerted first to the collision risk. As noted previously, the normal sequence for alerts for this rare event would be: intruder-caution, evader-caution, intruder-warning, and finally, evader-warning. This sequencing therefore penalizes the intruder first (with its climb-turn warning) and reduces the ATC disruption that would be caused by both aircraft executing the EEM.

Implementation details for the traffic and path alerts are provided in reference 11. Table 1 summarizes the alerting representations. Table 2 shows the threshold values used in the alerting algorithm. Note that the alerting values for the traffic warning condition closely match the values obtained in an independent test conducted by the FAA using a prior version of this alerting algorithm (ref. 12).

Hardware Architecture

The AILS concept requires a DGPS (or equivalent) navigation source, an aircraft-to-aircraft data link, AILS alerting logic, and supporting flight crew displays. For the aircraft-to-aircraft data link, the Automatic Dependent Surveillance Broadcast (ADS-B) format (ref. 13), which provides aircraft state data and custom, operation’s specific data packets, will satisfactorily provide for all AILS requirements. The current AILS hardware architecture, developed primarily by Honeywell, Inc., places the AILS alerting functions into the TCAS hardware. There are several advantages to this design. First, there needs to be interoperability between TCAS and the AILS alerting. That is, while AILS should provide alerting of the appropriately “paired” aircraft, TCAS alerting should still be available for all other aircraft. Second, by using the standard TCAS visual and audio inputs into the flight deck display equipment, no new aircraft cabling is required for that part of the installation.

The DGPS, ADS-B (internal to the MODE-S transponder), and TCAS were all provided by Honeywell and were integrated into the NASA Boeing 757 test aircraft and the Honeywell Gulfstream IV test aircraft. The airborne system hardware with special AILS capabilities is identified by Honeywell as their CASPER system. A simplified integration diagram is provided in figure 6.

Table 1. AILS Alerts

Alert state	Alert Level	Representation		Description
		Visual[a]	Audio	
Localizer	Advisory	LOCALIZER		Ownship is off centerline by one half path width (traditional one half full-scale error on lateral deviation indicator)
Localizer	Caution	LOCALIZER		Ownship is off centerline by full path width (traditional full-scale error on lateral deviation indicator)
Path	Caution	PATH	Path parallel approach	Ownship performance producing possible collision situation
Path	Warning	CLIMB TURN	Climb turn	Ownship performance producing probable collision situation
Traffic	Caution	TRAFFIC	Traffic parallel approach	Ownship being threatened with possible collision
Traffic	Warning	CLIMB TURN	Climb turn	Ownship being threatened with probable collision

[a] Visual alerts are color coded as follows:
Advisory: cyan
Caution: amber
Warning: red

Table 2. AILS Alerts Threshold Values

Alert state	Alert level	Alert area threshold, ft, for ---			Alert time threshold (sec)
		Lateral	Longitudinal	Vertical	
Path	Caution	1800	5000	1800	30
Path	Warning	1250	3400	1250	21
Traffic	Caution	1300	3500	1300	22
Traffic	Warning	900	2500	900	16

Evaluation Design and Conditions

The focus of this flight test was to validate the previous simulation evaluation (ref. 2) relative to pilot performance, pilot acceptability, and minimum miss-distances for the rare situation that an aircraft on one approach intrudes into the path of an aircraft on the other approach. That is, this test only examined situations that another aircraft flies off-path towards ownship, which activates ownship TRAFFIC alerts.

Previous analytical studies, showing a suitable level of operational safety, were based on the assumptions that pilots would respond to the AILS TRAFFIC warning alerts in a timely and reasonably aggressive manner. The assumptions used for this study, which greatly influenced the selection of the alert threshold times, were a 2-sec pilot delay (pilot reaction time) followed by a roll rate of 4deg/sec until a roll angle of 30° was obtained. These assumptions, along with the selection of the alert thresholds, were designed to produce a minimum miss-distance of 1200 ft. Therefore, the critical objective criteria for this test, based on these assumptions, were pilot reaction time and minimum miss-distance. See reference 14 for an analysis of alert threshold criteria.

Test Subjects

The test subjects used in this study were Boeing 757 airline captains, all with TCAS experience. Six pilots were used for data collection, all having previously participated in the simulator evaluation.

The subjects participated in a typical two-crew operational scenario, with the second crewmember being both a safety pilot and a "confederate" of the research team. This crewmember confederate was a NASA test pilot. For this evaluation, the subject's role was always that of the captain, pilot flying.

Test Aircraft

The primary test aircraft used for the evaluation was the NASA Boeing 757 research airplane. This airplane is used primarily to integrate, test, and evaluate new systems and operational concepts. The aircraft flight deck can replicate a conventional 757 aircraft, which was the condition for this evaluation. The one significant exception to this standard flight deck layout was the addition of a supplemental ND control panel (fig. 7), which provided optional feature selection and a greater number of map scale selections. For this experiment, map scales down to 2.5 nmi, versus the 10 nmi minimum on a standard 757, were provided.

The aircraft used as the intruder for this test was a Honeywell Gulfstream IV that was modified in a manner similar to the NASA Boeing 757 aircraft (fig. 6).

DGPS Navigation Source and Approach Profiles

A DGPS ground station and airborne receivers were provided by Honeywell. The ground station was a Honeywell Satellite Landing System (SLS-2000) and was installed at the NASA Wallops Flight Facility, where this test was conducted. This system can simultaneous support multiple runways with precision approach guidance with ILS-lookalike navigation capability.

Runway 35 at the Wallops Flight Facility was as the primary runway for this test. In addition to the existing Runway 35, two additional "pseudo" parallel runways were created, one representing the 2,500 ft lateral separation, the other 3,400 ft. Each final approach course was offset 2° outboard from the extended runway centerline to alleviate the problem of overlapping azimuth courses. The extended centerline of the runway and the final approach course intersected approximately 0.4 nmi from the runway threshold. The glide slope angle was 3° for all approaches.

Intruder Synchronization

Because the relative geometry at the time of the ownship TRAFFIC warning alert was critical for representing the simulation scenarios, the positioning of the intruder aircraft relative to ownship was carefully planned and choreographed. Assistance from ground-based radar information and onboard FMS data were used to obtain this positioning. In addition, a special purpose display that provided predicted relative flight path information was used by research personnel on the NASA aircraft for final aircraft positioning. A representative staging plot is provided in figure 8.

Independent Variables

This experiment was designed with three independent variables: intruder geometry, runway separation, and flight control mode. These independent variables were a subset of the variables used in the simulation test. The dependent measures were pilot reaction time and miss-distance. For this study, pilot reaction time is defined as the time interval between the initiation of the TRAFFIC warning-alert and the pilot's initial response to that alert (e.g., autopilot disconnect, application of Take Off Go-Around power). Miss-distance is defined as the slant-range distance between the aircraft centers of gravity points.

In addition to pilot response to an AILS warning alert, the intrusion geometry and aircraft speed differential have an obvious impact on miss-distance for potential NMAC situations. For this test, the general intrusion geometry selected was chosen for the worst-case situation from the PRM analysis (ref. 1). For this situation, the intruding aircraft (the Gulfstream) banked toward ownship at a moderate rate until a 10º bank angle was obtained. This bank and resulting turn was maintained until a 30º heading change was obtained. At that time, the intruding aircraft continued at a constant speed along this 30º off-course heading.

Intruder Geometry and Relative Speeds

A secondary factor for the intrusion geometry is the lateral separation between aircraft at the start of the intrusion event. This lateral separation distance itself was influenced by two factors: lateral runway separation and the lateral offset angles for the approaches. Two runway separations were selected for this test: 2500 ft and 3400 ft. The 2500 ft value was selected as the minimum since this is the current lateral separation minimum due to wake vortex considerations for independent approaches. The 3400 ft value was chosen since this was the minimum value for PRM.

As in any potential collision situation, large differences in relative speeds tend to increase the collision hazard. For this study, a 30-knot speed difference between the intruder and the ownship was considered to be the maximum difference and was used also as the maximum in the simulation study. All scenarios had the intruder speeds set at either 30 knots faster or 30 knots slower than ownship.

One other variable that was included in the definition of the intrusion geometries was the planned crossing point along the ownship's approach path for the intruder, assuming that the ownship did not maneuver. Two points were used: a direct collision and 2000 ft behind the ownship. These points would activate a TRAFFIC warning alert on ownship.

Aircraft Control Modes

The aircraft control mode, manual or autopilot, prior to an AILS warning alert was considered to potentially affect pilot response time. That is, the additional pilot task of disconnecting the autopilot or autothrust system prior to the manual execution of the EEM may increase the assumed pilot delay interval (2 sec.) for the EEM. Because of this, one of the independent variables of the test design was the control mode prior to the TRAFFIC alert.

Pilot Run Matrix

The run matrix for this test is shown in the Appendix. The major blocking factors were control mode and runway separation. Each pilot flew six approaches, with all of these approaches containing intrusion events. The ordering of the scenarios was counterbalanced by these major blocking factors and the intruder geometry, which included nonmaneuver miss-distance and intruder speed differential.

Results

Quantitative Results

This experiment was designed with three independent variables: flight control mode, runway separation, and intruder geometry. The dependent measures were pilot reaction time and slant-range miss-distance. For flight safety reasons, the Gulfstream aircraft did not continue along the intrusion path after the NASA 757 began the EEM procedure. To compute the slant-range miss-distance, a computed projected path of the Gulfstream aircraft, based on its position and velocity prior to the EEM, was used in this calculation. An example of this projection is shown in figure 9.

Although the flight data set was not meant to be a statistically valid sample, the trends acquired in flight followed those of the simulator and therefore met the intent of validating the findings from the simulator.

Miss-Distance

As with the simulator results, miss-distance did not appear to be affected by either runway separation or flight control mode. A comparison of simulator versus flight test slant-range miss-distance is given in Table 4. From the simulator evaluation, the design-goal mean miss-distance of 1200 ft with a 3σ range of ± 500 ft was surpassed, with the actual mean miss-distance of 2236 ft (at a 95% confidence interval of ± 52.645 ft and a standard deviation of 479 ft). The flight test results appear to support the simulation findings.

Table 4. Comparison of Slant-Range Miss-Distance

Control mode	Miss-distance category	Simulator slant-range miss-distance, ft, for runway separation of---		Flight test slant-range miss-distance, ft, for runway separation of---	
		2500	3400	2500	3400
Autopilot	Minimum	1418.8	1187.9	1707.8	1421.3
	Average	2169.1	2248.8	2012.2	1682.3
	Maximum	3262.1	3303.2	2521.6	1995.5
Manual	Minimum	1302.1	1187.2	1577.5	1389.2
	Average	2232.4	2295.1	1927.6	1817.0
	Maximum	3326.3	3613.6	2298.5	2517.9

Pilot Reaction Time

The simulator evaluation showed a statistically significant effect for the flight control mode, with autopilot use prior to the EEM leading to longer reaction times. It was also noted in the simulator evaluation that with less than a 0.3-sec difference in mean values between the two control modes, this difference is probably not operationally significant. The simulator evaluation showed an overall mean reaction time of 1.11 sec for all conditions, which was well below the design-goal reaction time of 2.0 sec. Flight test results were similar, noting however, a slightly larger difference in mean values between the control modes (approximately 0.5 sec). A comparison for pilot reaction times is given in Table 5.

Table 5. Comparison of Pilot Reaction Times

Control mode	Reaction time category	Simulator reaction time, sec, for runway separation of---		Flight test reaction time, sec, for runway separation of---	
		2500	3400	2500	3400
Autopilot	Minimum	0.040	0.2	0.400	0.6
	Average	1.124	1.107	0.556	1.111
	Maximum	2.680	2.44	0.700	1.400
Manual	Minimum	0.120	0.16	0.000	0.200
	Average	0.839	0.947	0.344	0.567
	Maximum	1.840	1.64	0.600	1.300

Qualitative Results

Subjective data were taken in the form of a questionnaire, with 11 scaled questions and 6 free-response questions. The 11 scaled, discrete questions were analyzed for minimum, maximum, and rounded-average values. The free-response questions were summarized with the significant comments reported below.

Scaled, Discrete Questions

The scaled, discrete questions of the questionnaire and their analysis are as follows:

1. From a real-world line-operations viewpoint, would AILS be practical (please exclude equipment specific issues such as the displays and alerting system)? [1=not practical, 5=very practical]. The analysis results were: minimum = 4, maximum = 5, and rounded-average = 5.

2. Were the operational procedures clear and easy to understand? [1=not clear, 5=very clear]. The analysis results were: minimum = 4, maximum = 5, and rounded-average = 4.

3. Was the AILS training adequate? [1=extremely inadequate, 5=excessive]. The analysis results were: minimum = 4, maximum = 4, and average = 4.

4. Regarding your safety (collision risk) relative to the other aircraft, the situation was: [1=never clear, 5=always clear]. The analysis results were: minimum = 3, maximum = 5, and rounded-average = 5.

5. Were the alerts clear and unambiguous (did you know what each alert meant)? [1=never clear, 5=always clear]. The analysis results were: minimum = 4, maximum = 5, and rounded-average = 5.

6. When you received an alert (advisory, caution, or warning), did you understand the necessary response? [1=never, 5=always]. The analysis results were: minimum = 5, maximum = 5, and rounded-average = 5.

7. Was the procedure for the Emergency Escape Maneuver (EEM) reasonable? [1=not reasonable, 5=very reasonable]. The analysis results were: minimum = 3, maximum = 5, and rounded-average = 4.

8. Was the Emergency Escape Maneuver (EEM) easy to perform? [1=very difficult, 5=very easy]. The analysis results were: minimum = 3, maximum = 4, and rounded-average = 3.

9. Which flight control mode would you use to fly the AILS approach? [1=auto, 2=doesn't matter, 3=manual]. The analysis results were: minimum = 1, maximum = 3, and rounded-average = 2.

10. Was your response to the EEM alert slowed by flying an autopilot approach (that is, the manual takeover to perform the EEM)? [1=greatly, 2=slightly, 3=not at all]. The analysis results were: minimum = 2, maximum = 2, and rounded-average = 2.

11. Do you think the 2.5nmi map scale setting was necessary for AILS operations? [1=not important, 5=very important]. The analysis results were: minimum = 3, maximum = 5, and rounded-average = 4.

From these results, it can be seen that the general rating was positive regarding this concept, with ratings toward the high end of "practical" or "reasonable." The two exceptions to this were in regard to training, rated between adequate and excessive, and the ease of performing the EEM, which was rated as being neither easy nor difficult.

Free-Response Questions

The free-response questions with their significant comments are as follows:

1. Please provide your comments on the AILS operational concept.
   - Clear and quick to learn.
   - It would be nice to know how close the traffic was or know when the "climb turn" was about to happen.

2. While the AILS concept is not dependent on the specific implementation of the alerts that were presented, it would be useful to know if you had any comments on the alerts.
   - It was distracting having the visual warning display within the target pitch and roll of the EADI.
   - The traffic alert was helpful in preparing for the EEM maneuver.

3. While the AILS concept is not dependent on the specific implementation of the displays that were presented, it would be useful to know if you had any comments on the displays.
   - Aural warning—the word "traffic" is used too many times. Perhaps "conflict" or some other thing after the initial "traffic."
   - Visual and aural were alerting were both helpful. Aural warning during normal operations may be the first warning if visual alert is missed.

4. Please provide your comments on the Emergency Escape Maneuver (EEM).
   - Consider no configuration change at a critical moment, i.e.; “terrain—terrain”, “wind shear.”
   - Needs to be practiced a lot to become proficient—recurrent training would be a must.
   - I think that 25° with passengers would be appropriate. The use of climb power is sufficient for the maneuver, maximum is not needed.

5. During the experiment, did you pick up any technical cues about how the system is designed to help you be more prepared for the EEM? (E.g., color changes, symbol changes, etc.) If so, please state what they were. You may prefer to discuss it with the researcher.
   - Color is important to intuitive reaction.
   - The traffic alert allowed me to review the EEM procedures.
   - The change in color of the intruder, change of shape of intruder, audio calls traffic/traffic parallel approach/climb turn were important.

6. Do you have any other comments?
   - A system I think pilots and airlines will like.
   - Provides me with a confidence level that would allow me to fly the maneuver on line operations and provide a safety margin throughout the procedure.

Summary of Qualitative Results

These subjective ratings and comments are consistent with the responses from the simulator evaluation, with a summary of the most significant findings as follows:

1. The operational concept is reasonable.

2. The AILS alert sequencing was good.

3. No significant display issues were noted.

4. The aggressive nature of the EEM requires the crew to be mentally prepared to execute it on every approach.

5. The EEM should be evaluated using a maximum of 25° of bank angle.

6. The EEM training will be important.

Summary of Results

The Airborne Information for Lateral Spacing (AILS) concept is designed to support independent parallel approach operations to runways spaced as close as 2500 ft. This report briefly described the AILS operational concept and the results of a flight test of one implementation of this concept. The focus of this test was to validate the results of a prior ground-based simulator study (ref. 2) in an actual flight environment with the overall premise of evaluating pilot performance, pilot acceptability, and minimum miss-distances for the rare situation that an aircraft on one approach intrudes into the path of an aircraft on the other approach. From this flight validation, the following results were obtained:

1. Although the flight data set was not meant to be a statistically valid sample, the trends acquired in flight followed those of the simulator and therefore met the intent of validating the findings of the simulator.

2. From an operational standpoint, the concept is reasonable.

3. The measured mean miss-distance was higher (better) than the design-goal mean miss-distance range of 1200 ft. The actual mean miss-distance was 1859 ft.

4. Pilot reaction time was not affected by runway separation.

5. An overall mean pilot reaction time of 0.65 sec was noted for all conditions, which was well below the design-goal reaction time of 2.0 sec.

6. An effect was noted for the flight control mode, with autopilot use prior to the emergency escape maneuver (EEM) leading to longer reaction times. It should be noted however, that with less than a 1.4 sec maximum reaction time for all control modes, this longer reaction time with autopilot use is probably not operationally significant.

The results of this flight test confirmed the findings of the previous simulator study. From the results of both of these tests, it can be concluded that this operational concept, with supporting technology and procedures, may provide an operationally viable means for conducting simultaneous, independent instrument approaches to runways spaced as close as 2500 ft.

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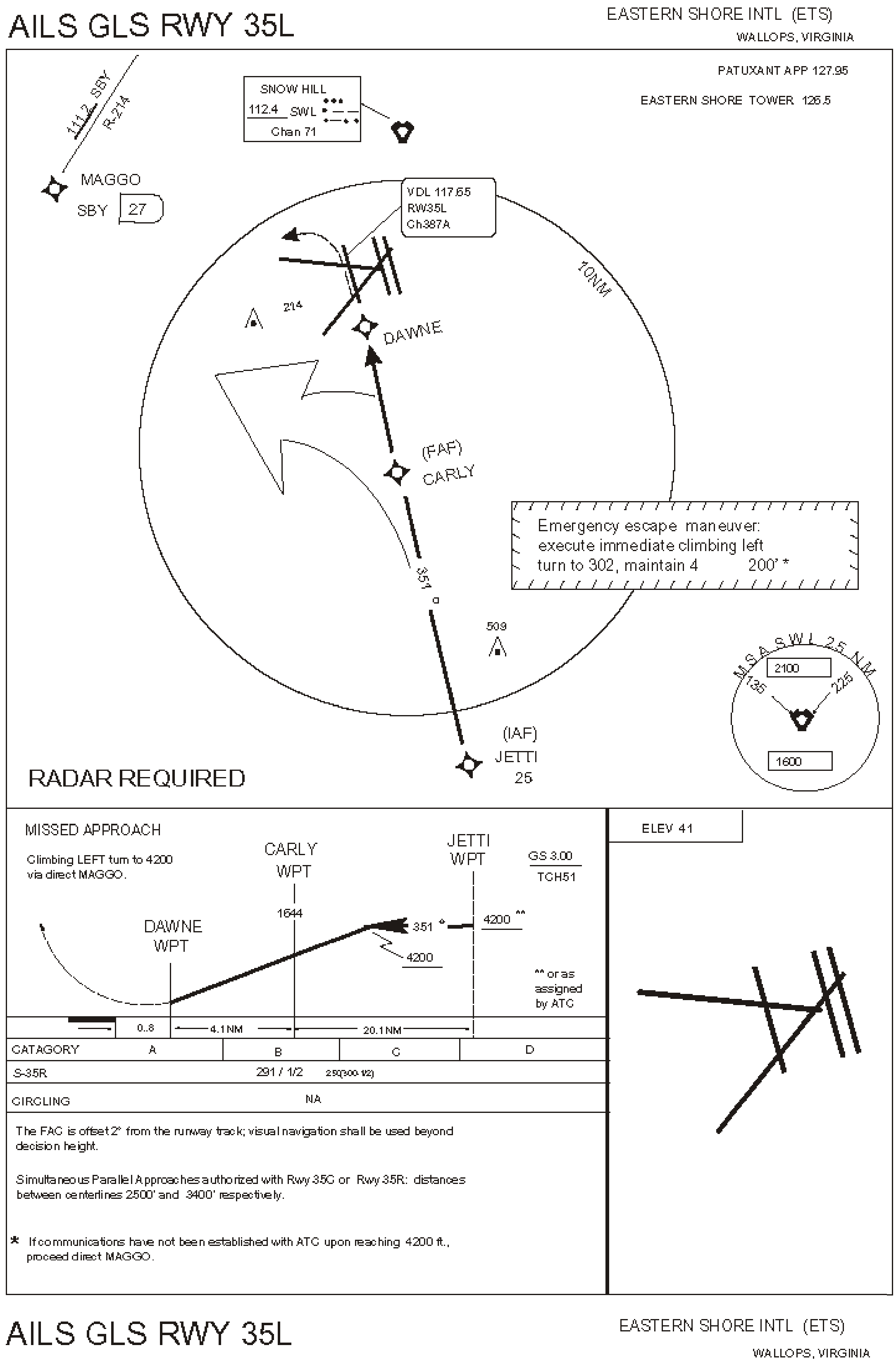

Figure 1. Representative AILS approach chart.

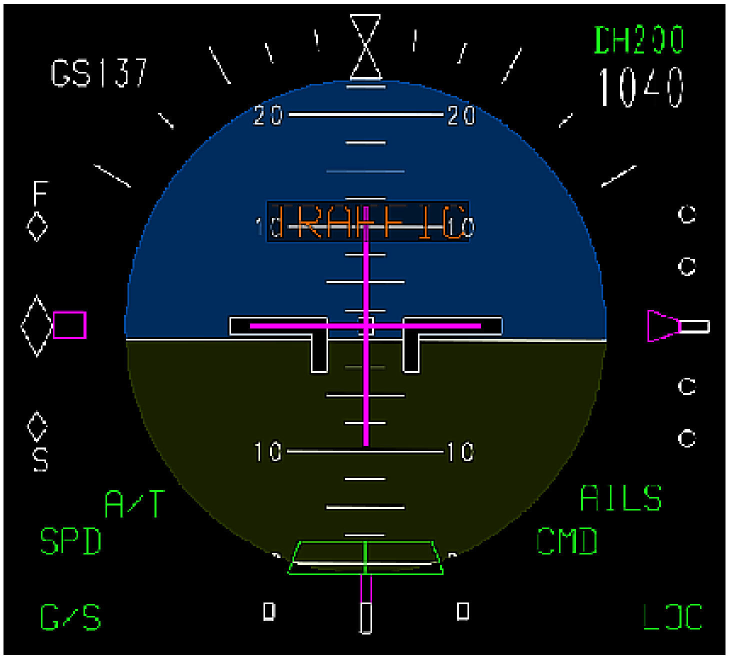

Figure 2. EADI with traffic caution alert.

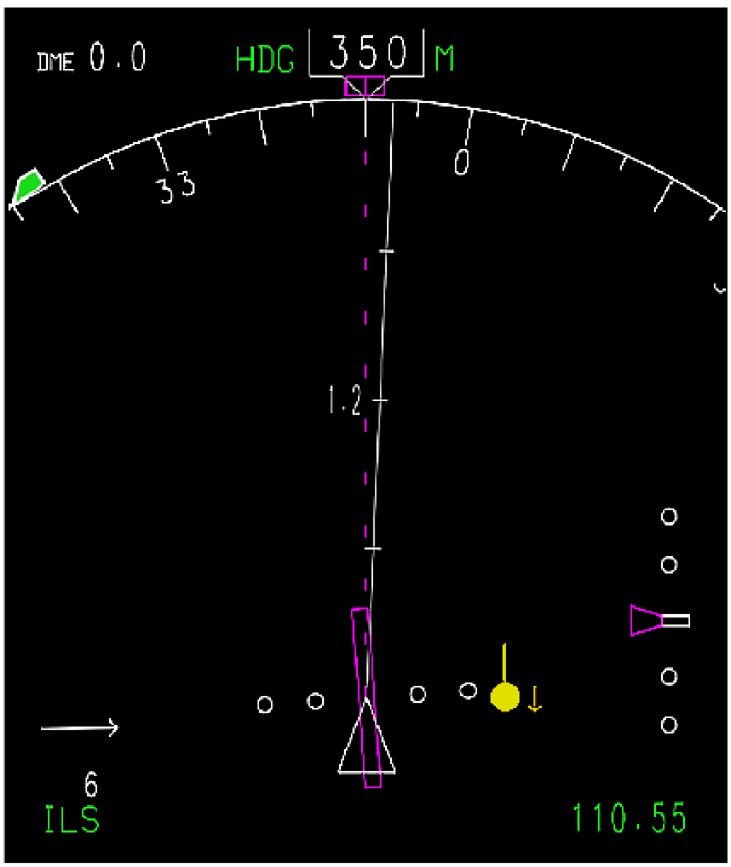

Figure 3. ND with traffic caution alert.

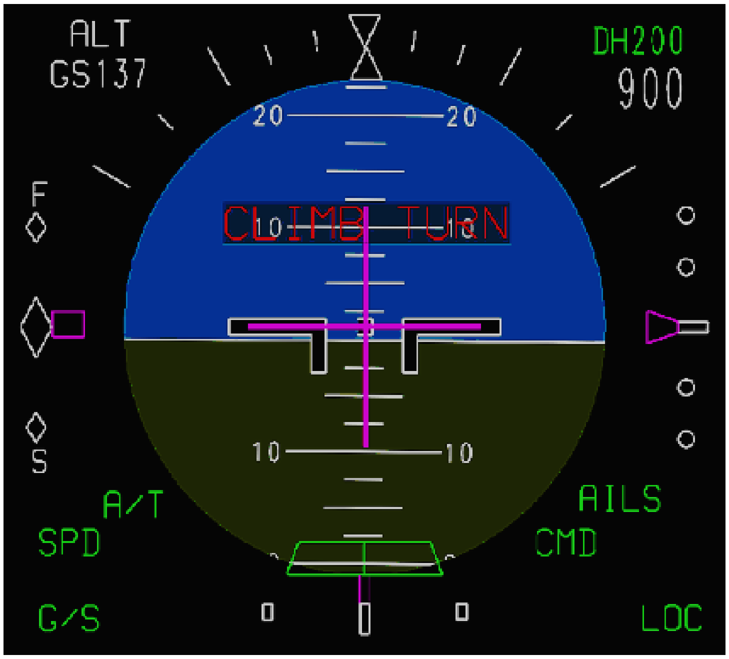

Figure 4. EADI with traffic warning alert.

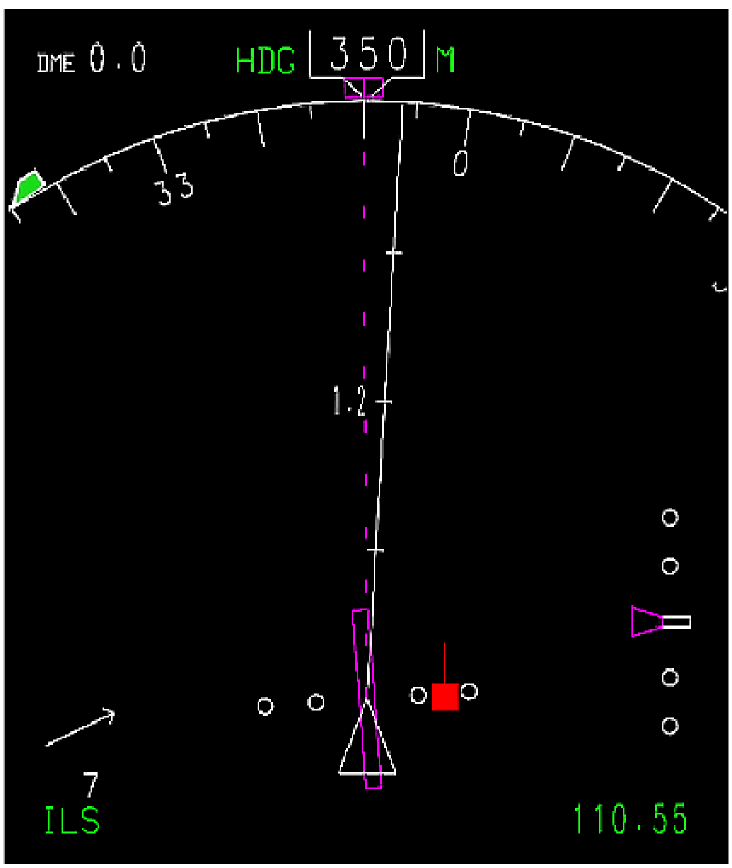

Figure 5. ND with traffic warning alert.

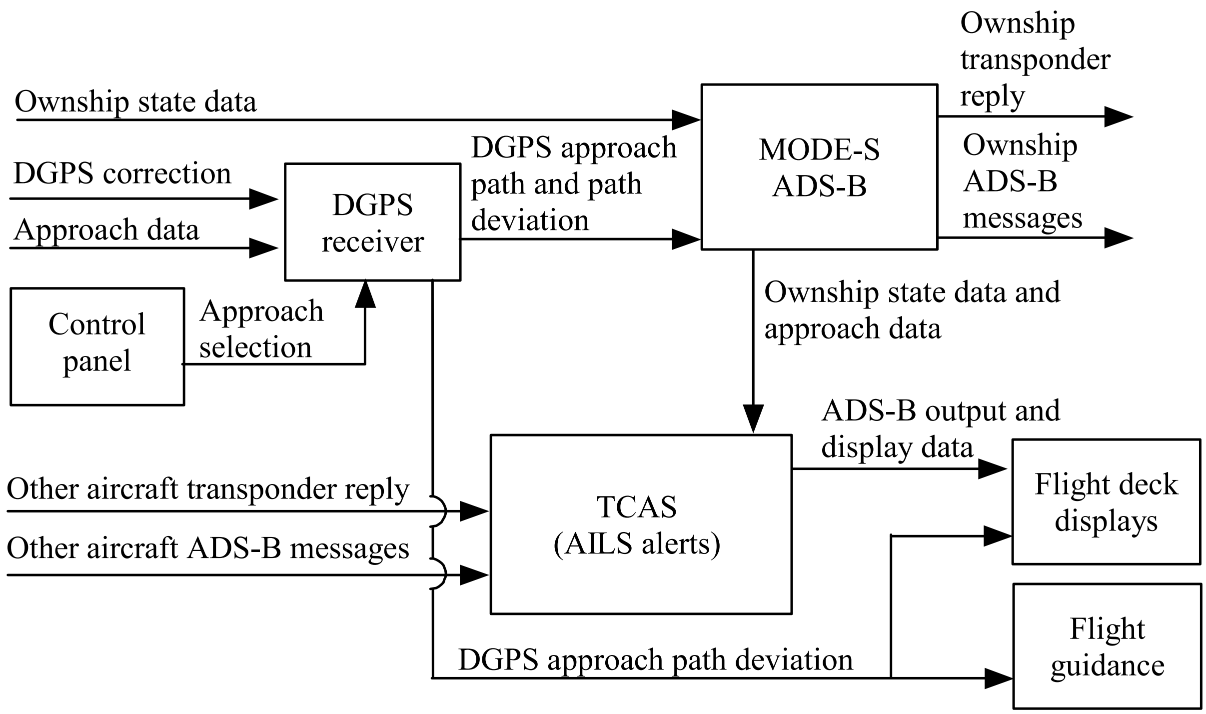

Figure 6. Hardware architecture.

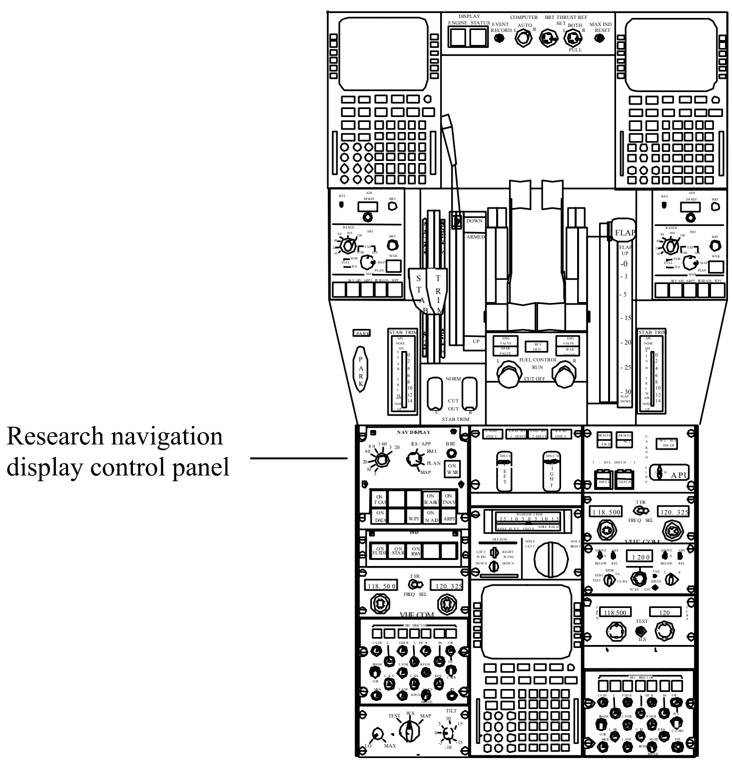

Figure 7. Center console layout.

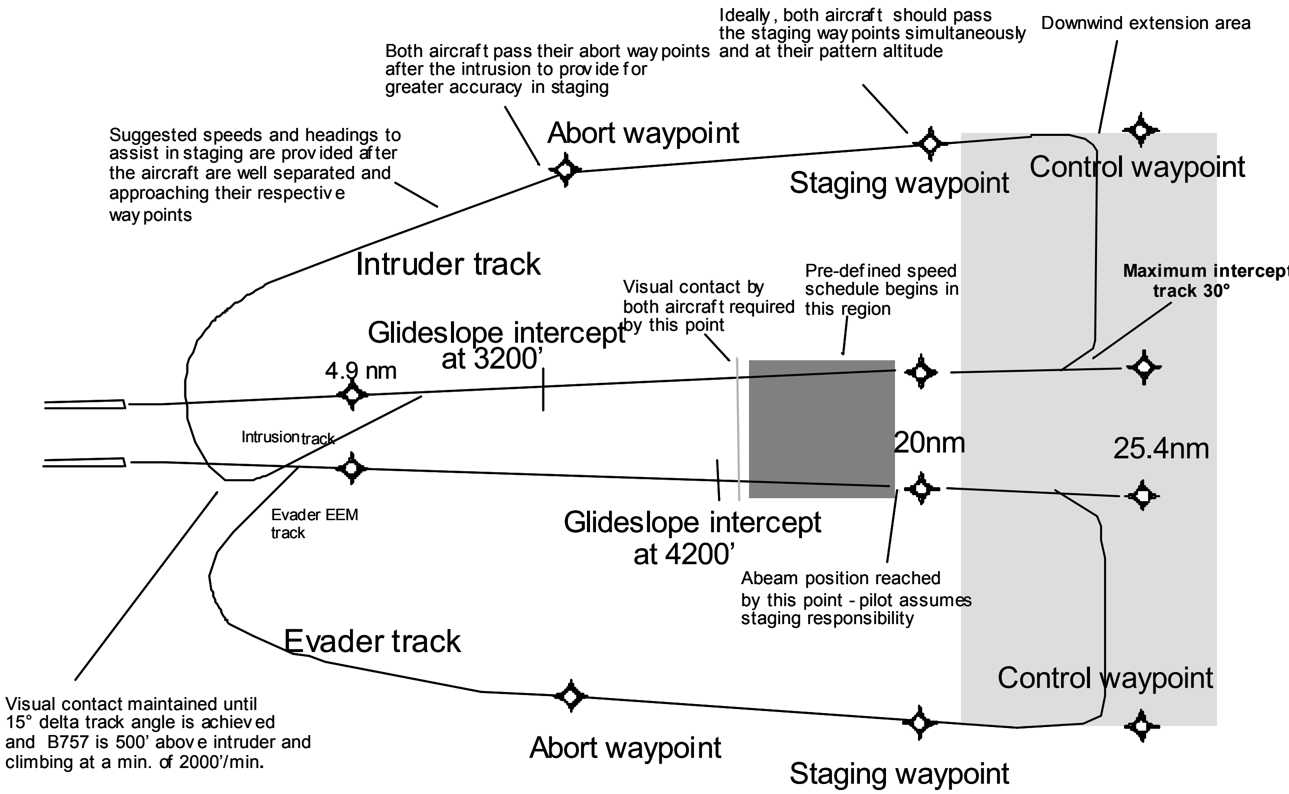

Figure 8. representative staging plot.

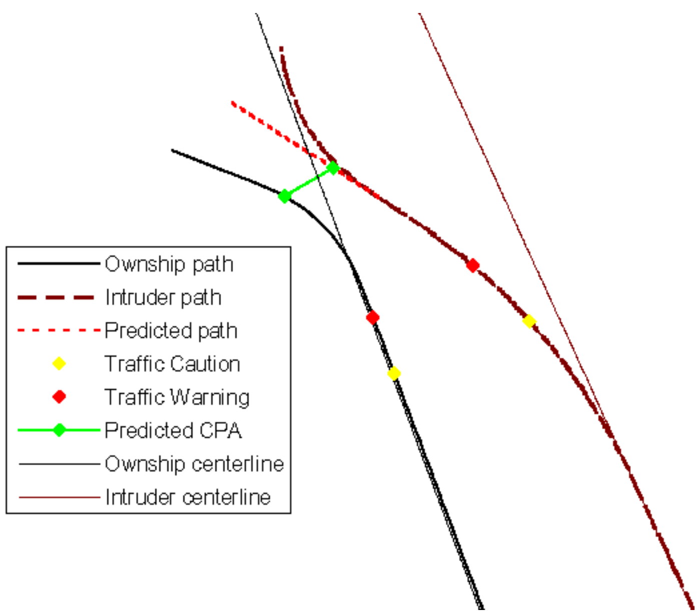

Figure 9. Projection for miss-distance calculation.

Appendix

Run Matrix

Subject number	Run number	Control mode	Runway separation, ft	Non-maneuver miss-distance, ft	Intruder speed difference, knots
1	1	Manual	2500	-2000	-30
1	2	Manual	2500	0	+30
1	3	Manual	2500	-2000	+30
1	4	Autopilot	2500	-2000	-30
1	5	Autopilot	2500	0	+30
1	6	Autopilot	2500	-2000	+30
2	1	Autopilot	3400	-2000	+30
2	2	Autopilot	3400	0	+30
2	3	Autopilot	3400	-2000	-30
2	4	Manual	3400	-2000	+30
2	5	Manual	3400	0	+30
2	6	Manual	3400	-2000	-30
3	1	Manual	2500	-2000	-30
3	2	Manual	2500	-2000	+30
3	3	Manual	2500	0	+30
3	4	Autopilot	2500	-2000	-30
3	5	Autopilot	2500	-2000	+30
3	6	Autopilot	2500	0	+30
4	1	Autopilot	3400	-2000	+30
4	2	Autopilot	3400	-2000	-30
4	3	Autopilot	3400	0	+30
4	4	Manual	3400	-2000	+30
4	5	Manual	3400	-2000	-30
4	6	Manual	3400	0	+30
5	1	Manual	2500	-2000	-30
5	2	Manual	2500	0	+30
5	3	Manual	2500	-2000	+30
5	4	Autopilot	2500	-2000	-30
5	5	Autopilot	2500	0	+30
5	6	Autopilot	2500	-2000	+30
6	1	Autopilot	3400	-2000	+30
6	2	Autopilot	3400	0	+30
6	3	Autopilot	3400	-2000	-30
6	4	Manual	3400	-2000	+30
6	5	Manual	3400	0	+30
6	6	Manual	3400	-2000	-30

<table>
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OMB No. 0704-0188</td></tr>
<tr><td colspan="4">Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.</td></tr>
<tr><td>1. AGENCY USE ONLY (Leave blank)</td><td>2. REPORT DATE
April 2002</td><td colspan="2">3. REPORT TYPE AND DATES COVERED
Technical Memorandum</td></tr>
<tr><td colspan="3">4. TITLE AND SUBTITLE
Flight Test Evaluation of the Airborne Information for Lateral Spacing (AILS) Concept</td><td rowspan="2">5. FUNDING NUMBERS
727-01-26-01</td></tr>
<tr><td colspan="3">6. AUTHOR(S)
Terence S. Abbott</td></tr>
<tr><td colspan="3">7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
NASA Langley Research Center
Hampton, VA 23681-2199</td><td>8. PERFORMING ORGANIZATION REPORT NUMBER
L-18175</td></tr>
<tr><td colspan="3">9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001</td><td>10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NASA/TM-2002-211639</td></tr>
<tr><td colspan="4">11. SUPPLEMENTARY NOTES</td></tr>
<tr><td colspan="3">12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified-Unlimited
Subject Category 03 Distribution: Standard
Availability: NASA CASI (301) 621-0390</td><td>12b. DISTRIBUTION CODE</td></tr>
<tr><td colspan="4">13. ABSTRACT (Maximum 200 words)
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<tr><td colspan="3" rowspan="2">14. SUBJECT TERMS
Aircraft operations; Closely spaced parallel approach; Aircraft displays; Flight test</td><td>15. NUMBER OF PAGES
26</td></tr>
<tr><td>16. PRICE CODE</td></tr>
<tr><td>17. SECURITY CLASSIFICATION OF REPORT
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