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An Analysis of the Role of ATC in the AILS Concept

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April 2000

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Abstract

Airborne information for lateral spacing (AILS) is a concept for making approaches to closely spaced parallel runways in instrument meteorological conditions (IMC). Under the concept, each equipped aircraft will assume responsibility for accurately managing its flight path along the approach course and maintaining separation from aircraft on the parallel approach.

This document presents the results of an analysis of the AILS concept from an air traffic control (ATC) perspective. The process has been examined in a step by step manner to determine ATC system support necessary to safely conduct closely spaced parallel approaches using the AILS concept. The analysis resulted in recognizing a number of issues related to integrating the process into the airspace system and proposes operating procedures. Terminal area operations at three airports were examined in terms of applying AILS technology -- San Francisco International Airport, Seattle-Tacoma International Airport, and Minneapolis-St. Paul International Airport. The discussions include suggested experiments to address AILS ATC issues as they relate to those environments.

Preface

This document represents the report of a NASA Langley Research Center Airborne Information for Lateral Spacing Air Traffic Control Ad Hoc Team established to initiate development of the concepts necessary to integrate the proposed AILS process into the ATC system in terminal area operations. It was recognized from the outset that the team could not resolve all of the issues that would surface in the time allotted for its initial work. It was believed that generating a document highlighting the issues and suggesting answers to some of the ATC related questions would be a useful start. It is expected that this document will present a platform from which additional development can be launched. It is also hoped that it will be instrumental in stimulating ATC experts and other stakeholders in the close parallel runway approach problem to start addressing the issues in the necessary detail to bring the AILS process to reality in the National Airspace System.

Three experiment plans are presented to help stimulate the thinking of those who have more experience in conducting ATC experiments. It is anticipated that experiments actually conducted may be significantly different from those proposed. Nevertheless, the ideas of the team are presented for initial consideration. One of the important aspects of the experiments is that their design has provided an incentive to explore realistic issues related to how the AILS process might be tailored to fit into different terminal areas. This exercise has highlighted the need to study the AILS process in realistic airspace environment models.

The AILS ATC Ad Hoc Team members are Marvin Waller, Thomas Doyle, and Frank McGee. Marvin Waller has been involved in the AILS concept development for the last five years and provided the team with the background information related to the AILS process from the flight deck perspective. Tom Doyle, Adsystech, Inc., is a recently retired FAA Air Traffic Controller with extensive experience in ATC facility management. His most recent experience was at the Dallas-Fort Worth Terminal Radar Approach Control (TRACON) and Tower as manager of operations. NASA and the FAA jointly sponsor his involvement on the Ad Hoc Team. Frank McGee, Lockheed Martin, is a retired United States Navy Master Chief Air Traffic Controller. His background includes facility supervision and experience as an ATC Safety Analyst conducting safety inspections at military installations worldwide. He was also a Master Training Specialist responsible for control tower operator certification. As well as bringing extensive ATC expertise to the team, Tom Doyle and Frank McGee used a number of contacts with individuals at ATC facilities throughout the country to update information on the details of current operations in various terminal areas.

A number of individuals at various ATC terminal facilities contributed to the information assembled in this document through telephone conversations and through providing copies of relevant sections of their operations handbooks. Air traffic staff members at Seattle-Tacoma International Airport, San Francisco International Airport, Bay TRACON (located in Oakland, CA), Dallas-Fort Worth International Airport, Minneapolis-St. Paul International Airport and St. Louis/Lambert International Airport provided extensive input that was invaluable in developing this document.

Particular thanks to Gene Wong, FAA AND-450 and his support team including Hans Peter Strassen, and Frank Buck of the Mitre Corporation, and Sherri Morrow of SRC for their review of the ideas in an early draft of this document.

1.0 Introduction

This document presents the requirements for airborne information for lateral spacing (AILS) approaches to close parallel runways. It describes the ATC interaction and requirements for two versions of approaches to close parallel runways, straight-in approaches and segmented approaches. Paired-staggered approaches are also discussed, but in less detail. The approaches are described from the ATC perspective and some of the detailed ATC system considerations in designing the approaches are addressed in the discussions. Critique and comments on the role of ATC as represented in the document are encouraged.

Independent straight-in approaches in all weather conditions are the baseline for AILS approaches. They are somewhat similar to visual approaches on an IFR flight plan in that the controller has transferred responsibility for lateral separation to the flight deck crew. The assumption is that AILS equipment will support the flight deck crew in maintaining separation from traffic on the parallel approach and that the traffic alert and collision avoidance system (TCAS) will assist in maintaining separation from other traffic operating in the area. The assumed airborne equipment includes an accurate flight path management system based on technology such as the differential global positioning system (DGPS) and data communication between aircraft such as with automatic dependent surveillance broadcast (ADS-B). It also includes an alerting and warning system that will warn a participating aircraft deviating from its assigned airspace. It will also present an alert should nominally parallel traffic deviate from its airspace in a manner that poses a collision threat involving the own aircraft. A display of proximate traffic may be incorporated in the airborne system. Also, procedures for taking evasive action in the event of intrusions are clearly defined. Conventional TCAS will continue to operate and protect against intrusions from other traffic not monitored by the AILS system. However, this does not preclude an implementation where the AILS system may be incorporated in an expanded version of TCAS, a possibility which is under study.

Appendix A, AILS from the Flight Deck Perspective, provides an overview of the AILS system under development and summarizes the results of earlier NASA studies. Reference 1, comprises the presentations at the NASA workshop on AILS held in October of 1996, and provides details of four NASA studies completed at that time as well as other presentations and discussions from the workshop. Reference 1, includes a discussion describing the paired staggered approach concept written by Rocky Stone of United Airlines and Chairman of RTCA SC-186.

Figure 1 presents a illustration of the generic airspace environment assumed for the parallel approaches. In much of the discussion to follow, including figure 1, example values of parameters will be provided, e.g., speeds, altitudes and distances from the runway threshold. It is emphasized that the values provided are examples and that, in an application, the particular values of parameters will need to be determined from the geometry and other constraints of the particular airspace under consideration. As shown in figure 1, there are three control positions normally involved: the feeder controller, the final controller and the tower local controller. The tower local controller is responsible for the tower traffic pattern and runways. The feeder and final controllers are radar controllers located in the terminal radar approach control facility (TRACON) and are responsible for setting up the approach sequence. The assumption is that traffic is initially under the control of a feeder controller and is handed off to a final controller and then to a tower local controller. A typical approach involves a flight along a downwind leg, a turn to base leg, and then a turn to the final approach corridor.

Airborne information for lateral spacing is a system for making approaches to close parallel runways based on flight deck centered technology and accurate flight path management. Differential global positioning system (DGPS) navigation could be used to support the flight-path-management accuracy requirement. In the procedure, each equipped aircraft will assume responsibility for accurately managing its flight path along the approach course and maintaining separation from aircraft on a parallel approach. It should be viewed as a system capable of meeting objectives similar to those of the instrument landing system precision runway monitor (ILS PRM) by enabling approaches to closely spaced parallel runways in all weather conditions. However, AILS technology is envisioned to enable operations to parallel runways laterally spaced closer than the 3400-foot limit imposed on PRM operations. It is envisioned that the AILS procedure will be described on an approach plate and will require a level of pilot certification to participate in the process. The aircraft will be required to have a minimum set of equipment which may include DGPS navigation capability, equipment for data exchange with proximate traffic, and a processor which integrates data received from traffic with its own state to warn the flight deck crew of collision threats.

2.0 Glossary of Terms and Abbreviations

ADS-B	automatic dependent surveillance broadcast
AILS	airborne information for lateral spacing
airport acceptance rate	Sometimes referred to as the “flow rate”; it is a dynamic input parameter specifying the number of arriving aircraft that an airport can accept per hour.
AR	arrival radar control position, feeder and final
ARC	NASA Ames Research Center
ARTS	automated radar terminal system
ATC	air traffic control
ATCRBS	air traffic control radar beacon system
ATCT	air traffic control tower
ATIS	automatic terminal information service
Breakout	A technique to direct aircraft out of the approach stream
CC	cab coordinator (formally, coordinator tower position)
CI	radar coordinator (formally, coordinator interphone position; located in the TRACON)
close parallel runways	Two parallel runways whose centerlines are separated by less than 4300 feet
Com	communications
CTAS	center/TRACON automation system
DBRITE	digital bright radar indicator tower equipment
DGPS	differential GPS
EEM	emergency escape maneuver
FAF	final approach fix
FDAD	full digital ARTS display
FM	final monitor controller

FMS	flight management system
GPS	global positioning system
Handoff	An action taken by controllers to transfer the radar identification of an aircraft from one controller to another if the aircraft will enter the receiving controller's airspace and radio communications with the aircraft will be transferred.
IAF	initial approach fix
IFR	instrument flight rules
ILS	instrument landing system
ILS PRM Approach	An instrument landing system approach conducted to parallel runways whose extended centerlines are separated by less than 4300 ft. and the parallel runways have a precision runway monitor system that permits simultaneous independent ILS approaches.
IMC	instrument meteorological conditions
LaRC	NASA Langley Research Center
LC	tower local control position
LDA	localizer type directional aid
Level Five Facility	Rating for FAA air traffic control terminal facilities. Related to the traffic volume the facility is certified to handle. A level 5 facility handles in excess of 100 aircraft per hour. *(See: Wickens, C., Mavor, A., and McGee, J., eds: Flight to the Future, 1997, pg. 38 for information on levels.*)
MAP	missed approach point
Missed Approach	A maneuver conducted by a pilot when an instrument approach cannot be completed to a landing.
MR	AILS monitor controller
NAS	national airspace system
MSP	Minneapolis-St. Paul International Airport
NASA	National Aeronautics and Space Administration

ND	navigation display
NM	nautical mile
NTZ	no transgression zone
Outer Fix	a point along the route of flight normally just prior to entering the TRACON area
PFD	primary flight display
PRM	same as ILS PRM
PPC	pseudo position controller (used in experiments)
RTO	rejected take off
RWY	runway
s.d.	standard deviation
SIAP	standard instrument approach procedure
SFO	San Francisco International Airport
SEA	Seattle-Tacoma International Airport
STL	St. Louis/Lambert International Airport
TCAS	traffic alert and collision avoidance system
Tower	A terminal ATC facility that uses air/ground communications, visual signaling, and other devices to provide services to aircraft operating in the vicinity of an airport or on the movement area; provides control instructions to aircraft for landing and takeoff.
TRACON	terminal radar approach control. A terminal ATC facility that uses radar and non-radar capabilities to provide approach control services to aircraft arriving, departing, or transiting airspace controlled by the facility.
VFR	visual flight rules: Rules that govern the procedures for conducting flight under visual conditions. The term “VFR” is also used to indicate weather conditions that are equal to or greater than minimum VFR requirements. In addition, it is used by pilots and controllers to indicate a type of flight plan.
Visual Approach	An approach conducted on an instrument flight rules (IFR) flight plan that authorizes the pilot to proceed visually and clear of clouds to the airport. The pilot must, at all times, have either the airport or the

preceding aircraft in sight. This approach must be authorized and under the control of the appropriate air traffic control facility. Reported weather at the airport must be ceiling at or above 1,000 feet and visibility of 3 miles or greater.

Visual Separation	A means employed by ATC to separate aircraft in terminal areas and en route airspace in the National Airspace System (NAS). There are two ways to effect this separation: a. The tower controller sees the aircraft involved and issues instructions, as necessary, to ensure that the aircraft avoid each other. b. A pilot sees the other aircraft involved and upon instructions from the controller provides his own separation by maneuvering his aircraft as necessary to avoid it. This may involve following another or keeping it in sight until it is no longer a factor.
VMC	visual meteorological conditions - Meteorological conditions expressed in terms of visibility, distance from clouds, and ceiling equal to or better than specified minimum.
$\overline{\underline{50}}$	Mandatory altitude, traffic under the control of the referenced position must maintain 5000 feet.
$\overline{50}$	Maximum altitude, traffic under the control of the referenced position must be at or below 5000 feet.
$\underline{50}$	Minimum altitude, traffic under control of the referenced position must be at or above 5000 feet.
$\overline{50}$ $\underline{30}$	Mandatory block altitude, traffic under the control of the referenced position must be between 3000 and 5000 feet.

3.0 Independent Straight-in AILS Approaches to Parallel Runways

The straight-in AILS approaches under consideration in this document are to parallel runways laterally spaced at least 2500 ft. apart, where wake vortex considerations do not limit independent parallel approaches. Straight-in approaches are frequently characterized by a handoff from the feeder controller to the final controller. Normally, the feeder controller will place the aircraft on a descent into the final controller's airspace. Figure 2 illustrates an example of AILS approaches following conventional straight-in approach profiles. In application, the downwind and base legs may be replaced with an approach profile from other directions, as illustrated in the approach to the right-side runway in figure 2. A step-by-step listing of the air traffic controller actions is included in the figure. The numbers along the illustrated flight path correspond to the numbers in the list of actions and are placed in the approximate location along the flight path where the action would be completed. It is emphasized again that this is a model which when applied in a particular airspace may need to be adjusted for the specific requirements of that airspace. The layout of airspace around different airports varies greatly. Some of the actions indicated in the figure are optional.

Current considerations for wake turbulence will permit independent parallel runway approaches to runways laterally spaced no closer than 2500 ft.; however, it is the intent that the process developed will be applicable as wake turbulence solutions are found. The more general operation will be planned in this examination under the assumption that the resulting process will be applicable to cases where the runway spacing is 2500 ft. up to the 4299 ft. It is also expected that the proposed procedures will be applicable to closer runway spacing where both the independent AILS process and a wake turbulence solution might be combined in the future. This will obviate the need to establish one set of requirements for runways laterally spaced or more apart and a second set for runways spaced less than 2500 ft., e. g. 2000 ft. or 1700 feet. It is anticipated that initial applications will be in environments where the runway spacing is 2500 ft. or more.

The AILS concept requires the flight deck crew to monitor traffic on the parallel approach path using electronically displayed data linked information as opposed to direct out-of-the-window viewing. This protocol more closely resembles close parallel visual approaches when the approach paths are closer than 2500 ft., as at San Francisco. Also, the current expectation is that the ATC system will provide the longitudinal separation from traffic operating in the same stream. The process is not exactly analogous to the visual approach protocol.

To summarize, the AILS protocol will require the flight deck crew to be responsible for maintaining separation from traffic on the adjacent parallel approach and require the ATC facility to be responsible for longitudinal separation of in-trail traffic operating in the same stream.

Another important assumption made defines the point at which the AILS process becomes the active means by which lateral separation of traffic is provided. The AILS system becomes the means for providing safety and separation when the final controller gives the flight the AILS approach clearance. Before that point the final controller is responsible for separation. After accepting the AILS approach clearance, the flight deck crew assumes responsibility for lateral separation. The final controller will transfer communications to the tower local controller after the clearance is issued and prior to the final approach fix. This must occur before aircraft on the higher initial path starts to descend, giving up the 1000-foot altitude separation.

The following are controller procedures for independent straight-in AILS approaches.

3.1 Inform aircraft that independent straight-in parallel AILS approaches are in use prior to an outer fix, and confirm that the aircraft will be able to conduct that approach. The automatic terminal information system (ATIS) will state the type of approaches in use.

3.2 Handoff from the feeder controller to the final controller will be conducted prior to the final controller's airspace. (This is the point at which responsibility for the traffic is offered to the final controller. The final controller must accept the handoff prior to traffic entering final controller airspace.)

3.3 The final controller will insure that the aircraft's flight path remains within final's delegated airspace.

3.4 Appropriate coordination will be conducted prior to the aircraft entering another controller's airspace.

3.5 The final controller will issue a traffic point-out to aircraft prior to turning on to final approach when appropriate.

3.6 Aircraft crews will confirm that they have their traffic in sight (under electronic surveillance) prior to being issued an approach clearance.

3.7 The final controller will apply standard separation between aircraft during turn-on to final approach.

3.8 The final controller will issue the appropriate AILS approach clearance prior to glide slope interception.

3.9 The airborne systems will assume separation responsibility before standard separation is given up.

3.10 In the event of an emergency escape maneuver within the final controllers jurisdiction, the final controller will insure coordination is conducted with the controller of the airspace the aircraft will enter. Subsequent coordination will be the responsibility of the controller whose airspace the aircraft will be leaving.

3.11 Communications transfer to the tower controller frequency shall be completed prior to the final approach fix. (This is when the tower controller assumes ATC responsibility for that traffic.)

3.12 The tower controller will issue the landing clearance to the aircraft.

3.13 In the event of an emergency escape maneuver while within tower jurisdiction, the tower controller will insure coordination is conducted with the controller of the airspace the aircraft will first enter. Subsequent coordination will be the responsibility of the controller whose airspace the aircraft will be leaving.

3.14 In the event of a missed approach, aircraft shall execute the missed approach as published in the Standard Instrument Approach Procedure (SIAP).

4.0 Segmented AILS Approaches to Parallel Runways

The segmented AILS approach is illustrated in the approach to the right-side runway in figure 3. This approach procedure allows aircraft to use flight management system (FMS) capabilities along with DGPS to fly a path that converges to a parallel runway spaced as close as 700 ft. The term “segmented” relates to the two straight-line segments that make up the final approach path. The first segment is flown at a twelve-degree angle, converging to the extended runway centerline. The second segment is along the extended runway centerline to the runway touchdown point. This procedure requires the aircraft to be in VMC and the airport to be in sight before the minimum certified AILS capability is violated. Assuming that the AILS application has been approved for operations as close as 2500 feet, the designed location of the missed approach point will be at that lateral distance from the adjacent parallel runway extended centerline. When the aircraft on the segmented approach reaches the missed approach point it must be in visual conditions and the crew must have both the runway and parallel traffic in sight. Basically, the other aspects of the discussion provided for the straight-in AILS approach are applicable in the segmented AILS approach. Handoff of responsibility for lateral separation is made to the flight deck crew when the approach clearance is given and before less than standard separation occurs.

The question of what procedures will be used as the AILS portion of the approach is terminated in the vicinity of the 2500 feet lateral separation from the parallel approach path has been examined. The nominal expectation is that the flights will continue under visual approach protocols after being cleared to land. A condition for clearing an aircraft to land is either that the leading aircraft on the same approach path, or the airport, is in sight. An aircraft will have to acquire visual separation from the traffic approaching the parallel runway prior to reaching the 2500-foot lateral separation point. The Ad Hoc Team decided to draw on the localizer type directional aid (LDA) approach experiences of San Francisco (SFO) and St. Louis (STL) airports for guidance since the processes are somewhat similar. Also, see the discussion of operations at MSP provided in section 8.3.

4.01 The LDA Approaches at St. Louis

Exploring the details of how LDA approaches are conducted at the St. Louis airport and how they were managed at San Francisco airport has provided some insight into how some of the issues of segmented approaches may be dealt with. For the St. Louis airport operation, the traffic is paired and staggered with one aircraft spaced longitudinally ahead of the traffic on the adjacent approach. In order to receive landing clearance, the trailing aircraft in the pair must confirm to the local controller that the leading aircraft on the adjacent approach is in view and that the runway is in sight prior to the missed approach point. The local controller may provide visual separation as an alternative at the discretion of the controller.

The St. Louis airport has an LDA distance measuring equipment (DME) approach authorized to operate in conjunction with simultaneous approaches to the parallel runways.

Air traffic control attempts to position the aircraft on the LDA DME approach slightly behind the aircraft making the approach to the adjacent runway. This makes it more efficient and easier for the aircraft to acquire visual contact with the other aircraft prior to the missed approach point, a requirement for this operation (Reference 2). Spacing between the LDA and ILS parallel approach courses is 4,500 feet. Once the aircraft on the LDA approach has the runway and other aircraft in sight it will start maneuvering laterally to the runway, closing the gap between aircraft. The runways are 1,300 ft. apart. This operation has increased the flow rate during instrument meteorological conditions (IMC) from 32 arrivals per hour to 52-60 arrivals per hour.

4.02 The LDA Approaches at San Francisco

When the LDA was used at SFO, a similar situation was in effect. The aircraft on the LDA approach was cleared to land only after entering VMC and confirmation to the controller that the runway and traffic on the straight-in approach was in sight. Note: In both cases (SFO and STL) heavy jet aircraft were required to use the straight-in approach in lieu of the LDA approach. This will be a consideration when managing traffic at SFO using the segmented AILS approach.

San Francisco International Airport previously used an LDA DME runway 28R approach in conjunction with an ILS runway 28L approach. The aircraft on the ILS approach were set up in a close stagger, 1/2 to 3/4 mile in trail of the aircraft on the LDA approach. This enabled the aircraft on the ILS approach to acquire visual contact with the aircraft on the LDA approach once they entered VMC, a requirement prior to the missed approach point. Prior to the missed approach point, the localizer separation between the two approaches was over 5,000 feet. After the aircraft had visual separation from the other, the aircraft on the LDA was cleared to proceed direct to the runway and land (Reference 3). Distance between runway centerlines is 750 feet. This operation was intended to increase the arrival flow while maintaining an efficient departure flow.

Use of the segmented AILS approach will require that aircraft are paired and staggered so that the crew of the aircraft on the segmented approach path, when it enters VMC, will be expected to see the aircraft on the straight-in path. The aircraft on the straight-in approach will be positioned ahead of the one on the segmented path. Following such a protocol, the flight deck crew on the segmented approach would be required to see the traffic on the straight-in path prior to 2500-foot lateral separation. If this is not the case the aircraft making the segmented approach will be required to break off the approach using the EEM procedure.
The following outlines the responsibility of the air traffic controllers in the process.

4.1 Inform aircraft that segmented AILS approaches are in use prior to an outer fix. This is normally accomplished using ATIS. Confirm that the aircraft will be able to conduct this approach.

4.2 Handoff from the feeder controller to the final controller will be conducted prior to the final controller's airspace. (This is the point at which responsibility for the traffic is offered to the final controller. The final controller must accept the handoff prior to traffic entering final controller airspace.)

4.3 The final controller will insure that the aircraft's flight path remains within final's delegated airspace.

4.4 Appropriate coordination will be conducted prior to the aircraft entering another controller's delegated airspace.

4.5 The final controller will issue a traffic point-out to aircraft prior to turning onto final approach.

4.6 Both aircraft will confirm that they have their traffic in sight (under electronic surveillance) prior to being issued approach clearance.

4.7 The final controller will apply standard separation between aircraft during turn-on to final approach.

4.8 The final controller will issue the appropriate AILS approach clearance prior to glide slope interception.

4.9 The airborne system will assume lateral separation responsibility before losing standard separation.

4.10 In the event of an emergency escape maneuver within the final controller's jurisdiction, the final controller will insure coordination is conducted with the controller of the airspace the aircraft will enter. Subsequent coordination will be the responsibility of the controller whose airspace the aircraft will be leaving.

4.11 Communications transfer to the tower controller frequency shall be completed prior to the final approach fix. (This is when the tower controller assumes ATC responsibility for that traffic.)

4.12 The tower controller will issue the landing clearance to the aircraft.

4.13 In the event of an emergency escape maneuver, while within tower jurisdiction, the tower controller will insure coordination is conducted with the controller of the airspace the aircraft will first enter. Subsequent coordination will be the responsibility of the controller whose airspace the aircraft will be leaving.

4.14 In the event of a missed approach, aircraft shall execute the missed approach as published in the SIAP.

5.0 Paired-Staggered Approaches

The paired staggered approach concept was first introduced in a NASA Langley briefing to RTCA SC 147 in 1995 *(RTCA paper No. 346-95/SC147-634, meeting minutes available from RTCA, Inc.)*. This concept is a dependent approach procedure that requires aircraft making approaches on adjacent parallel paths be paired. It is a dependent procedure in that the two aircraft within a given pair are required to maintain a specified longitudinal relationship to one another. For example, one aircraft must trail a leading aircraft on the parallel approach path at a longitudinal distance of approximately one-half mile. Setting up and maintaining this relationship is primarily the responsibility of the aircraft crews involved with some assistance from ATC. Figure 4 illustrates the primary features of this concept.

For the purposes of this discussion it is postulated that the air traffic control system will:

1. Initially assign the aircraft to pairs.
2. Provide initial staging of the two aircraft.
3. Hand off responsibility for separation to the flight deck.
4. After initial resolution (by the airborne systems) of an incident where an aircraft has deviated from its clearance, resume responsibility for separation of all traffic involved.

It is further assumed that the paired aircraft will:
1. Accept responsibility for separation. Probably the trailing aircraft will be primary in this function.
2. Make any adjustments to their initial relative positions to meet the longitudinal spacing requirements.
3. Monitor the longitudinal and lateral spacing during the approaches.
4. Execute any maneuvers required to maintain safe flight should the required separation be threatened or lost.
5. Contact ATC for further instructions when a deviation from clearance occurs.

5.1 Assigning aircraft to pairs
The actual procedures for assigning aircraft to pairs will have to be worked out possibly by an implementation team including FAA representatives along with the interested airlines and stakeholders. It is assumed that ATC will assign the aircraft to pairs with the knowledge that both aircraft are equipped. One possibility is that the feeder position will make the assignments. Because of implementation and equipage issues, a likely scenario is that only aircraft of a single airline will be involved initially. United Airlines hubs at SFO and has taken a lead in the development of this procedure.

5.2 Providing initial staging
ATC will place the two aircraft of the pair on the final approach with a minimum of 1000-foot altitude separation and an estimated longitudinal stagger as will be specified in the concept design. For example, the controller may be required to place aircraft B approximately one nautical mile behind aircraft A. The precedence for this task requirement is the previously used LDA approaches into SFO. Automation tools such as the center/TRACON automation system (CTAS) may be used to assist the controller in setting up the initial spacing. The aircraft systems will be expected to make final adjustments to this spacing as may be required by the procedure.

5.3 Handing off responsibility for separation to the flight decks
The controller will hand off responsibility for longitudinal and lateral separation to the flight decks involved, clearing them for a paired staggered approach to their respective runways. The controller will clear the two aircraft for a paired staggered approach specifying which aircraft will trail the other. Appropriate coordination between ATC and both aircraft will be completed. Once given the clearance to make the approach, the flight crews will assume responsibility for separation.

5.4 After an incident has been initially resolved

In the event of an incident where separation is threatened and one or both aircraft deviates from its approach path, ATC will be expected to resume control after the initial separation problem has been resolved by the airborne systems. At that point, ATC will issue instructions to maintain safe separation of all traffic involved. High priority will be given to directing the deviating aircraft back into the approach stream as it would be after an AILS EEM, described in Appendix A.

There will be an additional complication that the paired-staggered paradigm will have been compromised. The two aircraft were initially operating as a pair and at this point they must each be integrated back into the traffic flow pattern. Can they resume operation in a paired-staggered paradigm? What if one aircraft continues to landing and the other breaks off the approach? The implications and consequences of these issues should be the subject of studies of this concept from the ATC perspective.

Deliberation of the detailed procedures to be used in the paired staggered approach concept is an ongoing (1999) activity of a working group of RTCA SC-186. An attractive feature of the concept is that the aircraft pair is required to maintain a minimum longitudinal spacing of some specified amount such as ½ mile. It should also be noted that there would normally be no collision threat if the trailing aircraft deviates laterally in the direction of the parallel approach course when the required longitudinal spacing is maintained. This reduces the chance of ATC having to manage two aircraft simultaneously deviating from their clearances. An AILS type EEM will probably be required should the leading aircraft pose a collision threat. However, the longitudinal spacing maintained would allow an additional buffer for a somewhat less time critical EEM.

6.0 The Role of ATC in the Event of an Intrusion Incident

The AILS process as currently envisioned assumes that separation from the aircraft nominally operating in the parallel approach stream will be the responsibility of the flight deck crews participating in the process. The AILS systems and procedures to support the requirements have been developed both to provide flight deck capability to reduce the chance of incursion, and to maintain safe separation from an erring aircraft. In the event of an intrusion, no direct involvement by ATC is expected until the flight deck crews have resolved the initial conflict.

Once the initial conflict has been resolved and safe separation achieved, the flight deck crew will expect ATC to assume responsibility for separating the two aircraft involved in the incident from all traffic, and to vector the aircraft back into the approach pattern. The question addressed in this section is: What are the requirements and issues related to the controllers being able to step in at that point and resume responsibility for the safe separation of the deviating aircraft from each other and from other traffic? In analyzing the issues, it is necessary to understand the tasks and responsibilities of the controllers involved, as well as which control positions will likely be impacted.

The deliberations of the Ad Hoc Team on this question have highlighted four issues which will be addressed in some detail in Sections 6.1 - 6.4. Section 6.01 through Section 6.04 describe the issues.

6.01 Air Traffic Control Tower Differences

Towers are organized and operated according to different designs. Some towers split their operations into a north airport and a south airport, for example, with basically separate tower operations for the two sectors. Some will have one tower local controller and one communication frequency for the traffic on the two parallel approaches. Some have a separate local controller and a separate frequency for each of the parallel approaches.

6.02 Number of Tower Local Controllers (LC) and Other Staff involved in the resolution of a incident

It is important to understand what would likely transpire in the tower should an intrusion incident occur. Important issues include the number of LC and other staff positions in the tower and how the tower interacts with the TRACON should such an incident occur. One central question is how many tower local controllers will be involved in resolving the conflict.

6.03 Use of an AILS Monitor Controller (MR)

Related to the above question, in all current simultaneous independent ILS approach operations, regardless of runway spacing, there is a final monitor controller (FM) located in the TRACON. This FM assures that separation is maintained between traffic on the final approach. The FM has override capability on the tower radio communication frequency. Since a final monitor position is used in all current simultaneous independent ILS approach operations, the central issue of this section is whether a similar position is needed in the AILS operations.

The Ad Hoc Team has concluded that a specially defined AILS monitor controller (MR) could be used in some circumstances, but that such a position should not be a general requirement. The discussions that follow elaborate on this conclusion.

The basic task of the final monitor, in current simultaneous independent ILS approach operations, is to observe the traffic in the stream being monitored and to detect any traffic deviation from its own airspace toward the path of parallel traffic. The final monitor will also intervene if longitudinal separation of traffic within the stream is violated. Specific responsibility is defined for each terminal area and varies from terminal area to terminal area. In any event, the responsibility for managing traffic ahead of and behind the traffic involved in an intrusion incident continues for the tower local controller. In some busy environments the workload of the local controller will be too high to expect that position to absorb the additional responsibility of managing deviating aircraft. In a worst case scenario, the aircraft that initially caused the incident could have a radio communication problem.

One scenario under consideration is that the aircraft on the parallel approaches are all on a single tower frequency with a single local controller. This is the type of operation that is envisioned in an environment such as SFO. The single local controller will be responsible for both aircraft should an intrusion incident occur. Also, that controller may have to coordinate with appropriate adjacent airspace controllers. The issue is that it is quite possible that the workload of the single local controller can easily get too high for that one controller, and assistance in managing an emergency by a special AILS monitor (MR) would be required in such a case. The role of the tower cab coordinator must also be taken into consideration in this scenario.

6.04 Requirements Related to Controllers Accepting Responsibility for Separation
One of the premises of the AILS process is that the controller will have no effective way to manage conflicts in the closely spaced parallel runway environment. Responsibility for separation from traffic nominally on a parallel approach path will be handed off to the flight deck crew as in visual approaches. When an emergency escape maneuver is executed to avoid a collision threat, the controller will be contacted at some point. The flight deck crews involved will expect the controller to accept responsibility for separation from other traffic. An issue is that there are requirements that need to be met to enable controllers to accept the responsibility for separation at that point. One concern is that the digital bright radar indicator tower equipment (DBRITE) and full digital ARTS display (FDAD) and the radar systems that support them do have limits on their resolution. A central question is the following. When can the controller, using the radar display, adequately determine the relative positions and movement of the two aircraft? Only when that condition has been reached can the controller accept responsibility for their safe separation and vector them back into the traffic pattern. The process and timing for the controller accepting separation responsibility after an EEM must be clearly defined.

The following paragraphs will address the issues raised in Sections 6.01 - 6.04 respectively. An important point to be made in the discussions of this report from the Ad Hoc Team is that, although there are some generic issues which can be addressed, any AILS solution will need to be tailored to the conditions of a particular terminal area. Those details will probably make the solution unique to that particular application. This point will be made more clear as the recommendations for experiments for the three terminal areas, Seattle-Tacoma (SEA), San Francisco (SFO), and Minneapolis-St. Paul (MSP) are discussed in Section 8.0 of this document.

6.1 Inter-Airport Operational Variations

The Ad Hoc Team has prepared a separate document (ref. 4) that presents information on airports that have parallel runway pairs. As the AILS program is evolving, and partnerships with interested potential customers for the technology are forming, airports that are of particular interest are being identified. Initially, the airports of interest are assumed to be Seattle-Tacoma, San Francisco and Minneapolis-St. Paul.

The Seattle-Tacoma airport environment was selected because there is a current construction project to complete a parallel runway spaced 2500 ft. from an existing runway. Operating independent parallel AILS approaches to that pair could potentially be of benefit to the Seattle-Tacoma airport operations. Also, the initial targeted closest approach for application of independent AILS approaches is 2500 ft., a limit based on wake turbulence considerations. From the vantage point of the Ad Hoc Team, SEA is the optimal selection for studying such an application.

The San Francisco airport environment was selected because it was the model terminal area where the initially proposed AILS experiment was designed. The initial plan was to study application of a segmented approach in that terminal environment. Inasmuch as that plan was still under consideration in the AILS Team deliberations as this report was being prepared, the

Ad Hoc Team concluded that it would be appropriate to develop a plan using that terminal area model.

The Minneapolis-St. Paul airport environment was selected because it has close parallel runways that are approximately 3400 ft. apart. Another benefit is that the air traffic controllers at MSP are experienced at operating simultaneous approaches using the recently approved ILS PRM system. Some of the procedures used for this operation are similar to procedures anticipated for AILS approaches there.

Table1 presents a listing of the airports reviewed for potential AILS technology application and related information from reference 4. Included is identification of the parallel runway pair of interest, parallel runway lateral spacing in feet, number of LC positions, and a brief comment on any other relevant feature of the operation to aid in understanding. The information in the table is intended to aid in understanding the differences in the operations at the airports under deliberation as they relate to considering the role of air traffic controllers in the AILS process. The lateral spacing of the parallel pairs included ranges from 4000 feet at Fort Lauderdale, FL, to 750 feet at San Francisco, CA. The list includes airports with one, two and three LC positions. The information presented in this table illustrates in more detail the inter-airport variation in the terminal area operations that use close parallel runway operations. The additional information contained in reference 4 includes the amount of traffic operating at the airport and a brief description of how the parallel runway pairs are used for landing and take-off operations.

The central issue of this topic is the following: If the controller is involved in dealing with an intrusion incident, will the resources be available to safely meet the requirements? Depending on the position description of the tower local controller, study of the role in completing the resolution of an incident in one terminal area may not be applicable to the solution in another terminal environment. A primary factor seems to be the degree of loading (in the workload sense) of the local controller.

In Table 1, the number of local controllers is listed as one of the entries. Although it is good information to have, it has to be interpreted in view of the defined responsibilities of the local controller. An example to make this point clearer is found in comparing the San Francisco air traffic control tower and the Portland air traffic control tower. They both have a single local control position responsible for departure and arrival traffic to all runways. The issue at Portland Tower is that low traffic volume and relatively simple flow management requires only one LC. On the other hand, at the San Francisco tower the issue is that the coordination of traffic on the two parallel runways and the coordinated timing of arrival and departure traffic are very critical. The use of two local controllers is regarded as presenting significant coordination problems and raising safety issues.

Table 1. Tower Operations at Select Airports with Close Parallel Runways

Airport	Rwy Pair	Parallel Rwy Spacing	No. of Tower LC positions	Comments (Tower Operation)
Ft. Lauderdale	9L/R	4000	2	Low traffic volume
Detroit	21R/C	3800	3	RWY 21C used for departures
Salt Lake City	16L-17	3700	3	Primary operations on RWY 16L/R
Phoenix	26L/R	3565	2	Low visibility unusual
Raleigh	23L/R	3400	2	Low traffic volume
Memphis	36L/C	3400	3	RWY 36C used for departures
Minn.-St. Paul	30L/R	3380	2	ILS PRM Approaches RWY 30L/R
Portland	10L/R	3100	1	Low traffic volume
Kennedy	4L/R	3000	2	Primary operations on RWY 31L/R
Detroit	21L/C	2000	3	RWY 21C used for departures
Orlando	18L/R	1500	2	RWY 18L used for departures
Boston	4L/R	1500	3	1 LC Helicopter Position
Philadelphia	27L/R	1400	2	RWY 27R used for departures
St. Louis	30L/R	1300	3	LDA Approaches RWY 30L
Dallas-Ft. Worth	17C/R	1200	2	RWY 17R used for departures
Dallas-Ft. Worth	18L/R	1200	2	RWY 18L used for departures
Pittsburgh	28C/L	1200	3	RWY 28C used for departures
Atlanta	26L/R	1000	2	RWY 26L used for departures
Atlanta	27L/R	1000	2	RWY 27R used for departures
Houston	14L/R	1000	3	Primary RWYs 26/27
Las Vegas	25L/R	1000	2	Low visibility unusual
Oakland	27L/R	1000	3	RWY 29 used for departures
San Francisco	28L/R	750	1	1 LC for all 4 RWYs. Normally arrivals
San Francisco	1L/R	750	1	Normally departures

6.2 6.2 Tower Operation Procedures and Number of Local Controllers

This discussion has significant overlap with the discussion of the differences in airport terminal areas in Section 6.1 above. The primary issue in the current section is to acquire an appreciation of how the towers are operated in terms of staffing and task assignments. This varies from airport to airport and depends on factors such as traffic volume, air space constraints, and complexity of the operation.

The tower operation should be viewed as a team of controllers conducting the tasks necessary to guide and manage traffic landing and departing from the airport. There will normally be a supervisor who is responsible for the overall tower operation. The supervisor will be present in the tower and will get directly involved in the resolution of any emergency event that occurs. Clearly, from the tower operation vantage point, an aircraft crossing into the path of another, posing a collision threat, would be treated as an emergency event. All available personnel will come to the aid of the local controller to assist in resolving the problem.

Secondly, there is a tower position commonly referred to as the cab coordinator (CC). The cab coordinator is responsible for providing proper coordination between the tower controller positions and the radar coordinator (CI) who has a similar responsibility in the TRACON. Normally, the job of the cab coordinator is to maintain an overall perspective of the traffic in the tower pattern and provide necessary coordination between the controllers. In an emergency, the cab coordinator will get directly involved and offer assistance to the local controller in resolving a problem, including coordination between the tower positions and with the positions in the TRACON including the radar coordinator. The cab coordinator will normally inform the radar coordinator about the deviating aircraft (although the TRACON controllers will likely have already detected it on their radar displays). The CI and CC will coordinate a planned route and handoff of the deviating aircraft to the appropriate TRACON positions.

Typically, there will be one, two, or three local control positions in a tower. Their responsibilities can be divided in a number of ways when there is more than one, depending on the facility plan. Usually, one LC position is responsible for traffic operating on or making an approach to one of the parallel runways, and a second LC position is responsible for traffic approaching or operating on the other runway. A third LC position may be responsible for traffic on or making an approach to a third runway.

The number of local controllers involved in the traffic conflict and its resolution has a significant impact on the event. This factor needs to be considered in addressing the issue of the role of the local controller in resolving conflicts. Two local controllers working the problem will require coordination, but might lessen the workload compared to the same problem managed by just one controller. Table 1 provides a list of the selected airports with close parallel runways and includes an entry presenting the number of local control positions in the tower at these airports.

To date, tests at LaRC have assumed separate frequencies. Simulation processes would possibly need to change for environments where a single LC controls both approaches. An application of AILS that targeted an environment like San Francisco would be an example. It may be important to consider that if the two aircraft involved in an intrusion incident are on the same ATC frequency, they may have some warning that an incident is starting. The controller will possibly be urging the erring aircraft back to its approach course. An alternate view is that this ("party line" effect) may not be an important issue in the AILS process inasmuch as the controllers would have transferred responsibility for separation to the flight deck crew. Yet, ATC authorities say that it is difficult to imagine that a controller, viewing the traffic display, would see an incident evolving and not communicate with the deviating aircraft in an attempt to prevent it from crossing into the airspace of the parallel traffic. Controller display resolution is expected to limit this type of participation by the controller.

6.3 Use of an AILS Monitor Controller

In considering the ATC activities when an intrusion incident occurs, a point that needs clarification is whether there is a need for a final monitor controller or a similar position tailored to the AILS process. There are a number of issues related to this question that need to be taken into consideration. The overall conclusion of the Ad Hoc Team regarding use of a monitor controller is summarized first in the next paragraph of this section. The subsequent discussions in this section and its subsections document the rationale that led to the conclusion.

The Ad Hoc Team has concluded that, generally the use of a monitor position should not be a requirement for AILS operations. However, in some very unique environments-- San Francisco is a prime example-- such a position would probably be advisable. When used, the role of the AILS monitor will be defined differently from that of the final monitor controller currently used in simultaneous independent approaches, but will include responsibility for assuring longitudinal separation of same stream traffic. This recommendation is related to a recommendation, to be discussed later, that in AILS operations, ATC will be responsible for longitudinal separation of aircraft from other traffic within a given stream.

In current terminal area operations, whenever there are simultaneous independent ILS approaches closer than 3 miles (virtually all), final monitor positions are required, one for each runway. Whether a final monitor position should be used in AILS operations is a natural question that requires some deliberation. The job of the final monitor is to observe the parallel traffic and assume primary responsibility for resolving intrusion threats and incidents. That position has the priority override on the tower local control communication frequency. The final monitor position is located in the radar room of the TRACON, not in the tower.

The following are the points which appear to be factors in making a decision regarding the use of an monitor position in the AILS process.

With AILS Monitor Position	**No AILS Monitor Position**
1. Relieves LC workload	1. Higher workload for local controller
2. High safety	2. LC workload could raise safety questions
3. Increased frequency congestion	3. No frequency override by monitor position
4. Increased staffing requirements	4. Lower staffing requirement
5 Increased equipment and maintenance	5. Less equipment and maintenance
6. Possibly necessary for SFO where tower controller handles departures	6. Probably applicable where two local controller position environments exist
7. AILS monitor task definition different from existing FM's · No lateral monitoring task - No NTZ · AILS alerts on the ground side · Participates in incident resolution only	7. Local controller intervenes after initial incident resolution. Increased LC workload.

There are some related points to consider in addressing the issue of whether a monitor controller is needed in an AILS application. Sections 6.3.1- 6.3.3 along with their subsections address some of these points.

6.3.1 Longitudinal Separation Responsibility Issue

The issue of responsibility for longitudinal separation between aircraft on approach in the same stream during an AILS operations has been highlighted. Should this be an ATC function or a flight deck function? The Ad Hoc Team has concluded that it should be an ATC function in the AILS process. The rationale for this conclusion is presented in the following paragraphs.

6.3.1.1. The final monitor controller, used for all simultaneous independent ILS approaches, normally has the responsibility for longitudinal separation once the traffic is switched to the tower local controller frequency. The final monitor or tower local control, depending on the protocols of the particular terminal area can give speed adjustments to aircraft operating in the flow, up to the final approach fix (FAF). Inside the FAF, the final monitor (or local controller) can advise the aircraft of the speed causing a separation problem but may not issue speed adjustment instructions. If a violation of separation standards appears imminent, the final monitor (or local controller) has the option to issue breakout instructions to the problematic aircraft. Some of the specifics of this process as discussed in this paragraph are options of the particular terminal area. For example, whether the local controller or the final monitor will be responsible for longitudinal separation may vary from terminal area to terminal area.

6.3.1.2. A question of whether the flight deck crew can accept the responsibility for longitudinal separation from leading traffic in the same stream is raised. How can this be accomplished? Should there be specialized displays and alerts to support this task requirement? Reference 5 may be of interest in providing flight deck aids to conduct such a task. The bottom line is that the current AILS process does not include procedures and equipment including displays to support the flight deck crew in maintaining longitudinal separation. On the surface, this does not appear to be an unsolvable problem; however, a method has not been developed and validated to date.

From the ATC vantage point, the following is an issue: In current IFR operations when ATC is directly responsible for separation during the entire approach, the requirement is that traffic be maintained at approved separation standards, which includes a minimum 3 miles in-plane or 1000 ft. altitude separation. Actual in-plane minimum separation requirements depend upon aircraft types involved and wake turbulence separation standards. If the standard separation is violated then a reportable incident has occurred and disciplinary action may be taken against the controller. As pointed out earlier, the final monitor assures that separation standards are maintained by applying various control techniques to traffic prior to any loss of separation.

6.3.2 Issues of Controller Responsibility for Longitudinal Separation

The question under consideration in this section is the following: In an AILS environment, can controllers maintain responsibility for longitudinal separation of traffic in the same stream, while responsibility for lateral separation between traffic operating in parallel streams is handed off to the flight deck crews involved. Some of the considerations are discussed below.

6.3.2.1. For independent straight-in approaches, longitudinal separation of traffic in a given stream is independent of the separation from traffic operating on an adjacent runway. However, for segmented AILS approaches the problem is more complicated. At SFO traffic is expected to be paired and staggered, consequently not independent of the other stream.

6.3.2.2. In current single-stream ILS approach operations, the longitudinal spacing between aircraft is largely dependent on the approach speeds of successive aircraft in the same stream. Spacing is managed by a controller using speed advisories (for example: “maintain one seven zero knots to the final approach fix”). Once inside the final approach fix (FAF), aircraft adjust to their final approach speed, which is different for various aircraft. The controller has to be aware of these speed adjustments and advise the flight deck crew if their aircraft is overtaking the leading aircraft in the same stream. At most airports there will be one controller managing only a single stream of traffic to a particular runway. If this same paradigm were to be used in AILS operations, no additional workload above what a local controller is normally used to would be implied.

6.3.2.3. With the above details in mind, in general, there appears to be no additional workload for the controller responsible for a single stream of traffic to maintain responsibility for longitudinal spacing between aircraft on the final approach. San Francisco Airport is recognized as an exception since a single local controller is responsible for traffic in the two parallel streams during VFR conditions. The flight crews maintain both longitudinal and lateral separation in VMC (technically IFR visual approaches are flown into SFO). Only single streams of traffic are flown into SFO in current IMC operations. AILS could require the ATC system manage longitudinal separation for two streams of traffic. An unassisted single local controller managing longitudinal separation of two streams of traffic would raise additional workload issues for an already busy LC position. (See section 8.2 and appendix E for additional details.)

6.3.2.4. A plausible paradigm is that responsibility for separation between traffic operating on adjacent runways can be handed off to the flight deck crew as in visual approaches, but responsibility for separation between traffic in a given longitudinal stream can be maintained by the air traffic controllers. If there is a longitudinal in-trail threat or violation, air traffic control will manage it. If there is a lateral threat or violation from traffic nominally operating on the parallel approach the flight deck crew with an AILS system will be required to manage it. There will be no longitudinal constraint between aircraft operating in adjacent streams. This last statement may not be a pure condition and some related issues will be raised later. These issues relate to requirements to pair aircraft in the streams to make holes to facilitate departures. The pairing and staggering also has an additional benefit that needs to be understood as the AILS process is tailored for particular terminal areas.

6.3.2.5. The goal of the AILS research is to enable approaches to closely spaced parallel runways in IMC with a capacity similar to that obtained in VMC. The proposed methodology requiring ATC management of longitudinal separation of in-stream traffic gives up any single stream capacity gains normally realized in a VFR operation over the capacity of an IFR operation of a single stream. The longitudinal spacing provided by ATC will be according to current longitudinal spacing standards based on wake turbulence considerations. The gain realized from AILS will result from the use of both closely spaced parallel runways during IFR conditions. Other elements of the NASA Terminal Area Productivity activity (see appendix A) address wake vortex issues and use of on board automation in combination with ground based automation to avoid capacity losses bought on by increased longitudinal spacing requirements in IMC.

6.3.2.6. The recommendation of the Ad Hoc Team for the SFO situation, where a single local controller is responsible for the traffic on the approach to two runways is the following. A specially defined AILS monitor position, similar to the final monitor position, whose responsibility will include assuring the longitudinal spacing of aircraft on the approach could be used. As mentioned earlier, the longitudinal spacing task is frequently the responsibility of final monitor controllers in parallel runway operations. This requirement to leave the longitudinal spacing between aircraft in a stream as an ATC responsibility adds additional weight to the argument that an AILS monitor should be required for AILS operations in SFO. Whether the AILS monitor may be recommended for use in other proposed AILS applications will be determined by examining the details of the particular airport operation. Note: At SFO the arrival-final controller sets up traffic on final with 5 miles between aircraft during both VFR and IFR conditions to accommodate departures.

6.3.3. Issues Related to Transferring the Responsibility for Same Stream Spacing to the Flight Deck Crew

One possibility that was considered by the Ad Hoc Team is that the flight deck crew will be responsible for longitudinal separation from traffic in the same stream, this is the protocol followed in visual approaches. The Ad Hoc Team has decided against making such a recommendation, in favor of the ATC system having the responsibility. However, it is appropriate to document the points that surfaced in the deliberations.

The question under this alternate paradigm is whether the flight deck crew can perform this task in addition to the other requirements of the approach operation in an AILS environment. The considerations are outlined below.

6.3.3.1. In current VFR close parallel runway operations, the flight deck crew has the responsibility to manage longitudinal spacing behind leading aircraft visually through out-of-the-window viewing. The discretionary latitude that the flight deck crew takes in this process usually increases the runway capacity in a given stream because the pilots are generally less conservative in their spacing than the wake-turbulence based standards used by ATC. Also, having their traffic in view, pilots use other techniques to avoid wake turbulence from aircraft they are following. For example, they may attempt to fly above the path of the leading aircraft. There have been concerns raised that pilots may not always do this accurately in VMC. There is no information presented in the flight deck displays designed to assist pilots in accomplishing this task in VMC or in IMC.

6.3.3.2. The present AILS research display formats do not allow an adequate viewing distance ahead to continuously see the leading aircraft if the display range selections currently advocated for AILS monitoring of traffic on adjacent runways is utilized. At LaRC where 2500 ft. laterally spaced parallel runways have been studied, two display ranges were used, a 2 mile range and a 10 mile range. These ranges represent the total field of view of the display from the bottom edge of the map and traffic display to its top edge (or equivalently, from the left edge of the display screen to its right edge). A significant outcome of the experiment was that performance in the emergency escape maneuver (EEM) was not dependent on the display range or scale factor used when these two values were tested. However, the pilots who were the subjects of the tests indicated a significant preference for the 2 mile display format where they could resolve relevant lateral displacement of traffic on the parallel approach. The AILS Team has continued to pursue use of the higher resolution, low field of view display formats. This format offers the advantage of displaying information to support determining how well the emergency escape maneuver is working and to make timely adjustments where appropriate. It does not support the viewing of in-stream longitudinal traffic.

6.3.3.3. Giving the flight deck crew the responsibility to manage the longitudinal spacing will require that procedures and tools to manage that spacing be provided. Viewing the traffic on a map display presented along with the parallel traffic presents a dilemma. The requirement to monitor the adjacent traffic demands a display that will allow resolution of significant deviations (250 ft., best approximation) when parallel approach paths are laterally separated by 2500 feet. This information is displayed on a 6 ¼ inch by 6 ¼ inch viewing screen roughly 30 inches from the pilot's eyes. The 10 mile scaling used in some of the AILS testing translates to 1.6 mile/inch, which implies the 250 ft. on the display will be represented by 0.026 inches. One thousand feet is equivalent to 1/10 inch. This display format does not support modifying and adjusting evasive actions to assure separation in close operations. It will support viewing of leading traffic five to seven miles ahead of the own aircraft. The 2 mile display format, favored in the AILS testing, will provide 5 times the display resolution, representing 250 ft. as 0.11 inches. However, it will not allow viewing traffic more than about a mile and a half ahead.

6.3.3.4. The Ad Hoc Team recommends that the responsibility for separation from traffic on the parallel approach should be given to the flight deck crew. Responsibility for in-trail separation in a given longitudinal stream should be an ATC function in the AILS process.

6.4 Controller Requirements to Resume Responsibility for Separation

It is not a trivial matter for the controller to accept control of the aircraft and responsibility for separation at any point in time that the flight deck crew requests ATC control and vectoring. This becomes apparent in examining the proposed process to be followed after completing an emergency escape maneuver. The particular issue is the following. Under what circumstance can the controller legitimately accept responsibility for separation of the aircraft involved? The controller must have the resources to resume control of the situation. ATC must be ready to accept the additional workload and have an adequate view of the situation to make safe and accurate decisions. What are the requirements? Controller display resolution, and the relative positions and headings of the two aircraft are key considerations.

A primary consideration is that when the controller is requested to accept responsibility for separation, the appropriate tools must be available to support execution of the necessary tasks. Specifically, the radar display used by the controller should allow clear resolution of the aircraft targets to be controlled, that is, they should not be touching. When this is the case, the controller will be able to assign headings to the aircraft putting them on diverging courses if they are not already diverging.

Figure 10 illustrates the appearance of symbols on the controller’s display. As the figure indicates, the width of the target covers a 1/2-mile area of the display. This scaled size of the aircraft symbols is maintained as the selected display scaling is changed. Figure 11 illustrates a number of possible display conditions of two target aircraft operating in close proximity and illustrates some situations where they may not be judged acceptable for the controller to assume separation responsibility. If there is not 1000-ft. altitude separation indicated in the targets data tag and the targets are touching, the controller is required to advise the aircraft requesting instructions that the targets are merged. The controller can not accept responsibility or issue instructions in that situation until there is resolution between the targets.

The AILS procedures and supporting avionics in the flight deck should provide the capability for the pilot of the evading aircraft to gain appropriate separation from traffic to permit the controller to assume ATC responsibility. The information necessary to generate a visual or aural signal in the flight deck indicating adequate separation or diverging flight paths is similar to that which the AILS algorithms use to generate a traffic alert. This implies that it is possible to compute information to tell the pilots when separation is adequate to expect ATC help.

The measurement accuracy of the ARTS and air traffic control radar beacon system (ATCRBS) was reported in reference 6. The data summarized in Table 2 is based on the information provided there. The entries in the table of particular interest are the range and azimuth errors. The ARTS equipment is the older and least accurate, therefore it represents the worst case. The measured azimuth error of 0.16 degrees standard deviation (s.d.) is interpreted to mean that at 20 nautical miles 1.0 s.d. error is 0.058 nautical miles and 3.3 s.d. (bounding 99.9% of all measurements) is 0.18 nautical miles. At 10 nautical miles 3.3 s.d. azimuth error is 0.09 nautical miles. According to this rationale, a target size of 0.5 nautical miles (0.25 nautical mile half width) is conservative. With the newer equipment coming on line (SSR mode of mode S listed in the table), having a measured accuracy reported in reference 6 (0.04 degrees azimuth error) four times better than the older equipment, some review of the 0.5 nautical mile target size might be in order. This is the extent of the data used by the team and is included here to present the reader with as much information as was available to the Ad Hoc Team in its deliberations.

Table 2. - Surveillance Radar Performance

	ARTS		SSR Mode of Mode S	
	ALL	Crossing	ALL	Crossing
Blip/scan	94.6 %	86.9 %	98.0 %	96.6%
No altitude	2.7 %	8.3 %	1.4 %	3.0 %
No code	1.5 %	7.4 %	0.7 %	3.0 %
Range error (1 s.d.)	124 ft.		24 ft.	
Azimuth error (1 s.d.)	0.16 deg.		0.04 deg	

Blip/Scan Ratio - the probability of generating a target report during one scan.

No Altitude - the percentage of Mode C reports that did not contain a valid altitude.

No Code - the percentage of Mode A reports that did not contain a valid code.

Range Error - the standard deviation from a second order polynomial fit to a sliding sequence of range measurement points centered on the report being evaluated. The error is calculated only for established straight-line tracks at elevation angles between 0.5 and 40 degrees and at ranges between 2 and 45 miles.

Azimuth Error - same as range error, but in the azimuth dimension.

Based on this information, the 1/2-nautical-mile target size may be conservative. A consideration is that there are other factors that may contribute to the total error. No factor is included in the above discussion for signal dropout, the blip/scan ratio in table 2, other than perhaps the conservatism of the target size and the application criteria discussed above. Additional details are included in Reference 6. The Ad Hoc Team makes no specific recommendations in this area other than a suggestion for review of this area by appropriately knowledgeable experts on the subject.

7.0 Alerting Information for the Controller

This section is intended to recognize the issues that some individuals interested in the evolving AILS technology have raised. They advise that the best available information should be provided at the controller station. If the DGPS information providing aircraft position measures with accuracy of a few meters is available for use in the flight deck, why should it not also be presented at the controller's station? Also, if AILS alerts are generated in the flight deck, that information should be presented at the ATC stations involved in AILS operations.

The Ad hoc Team has not explored this issue in any great detail. The guiding principle for the team has been that the AILS concept depends on flight deck technology to protect against lost of separation. The anticipated role of ATC is to manage the recovery after separation has been ascertained. However, if economically acceptable displays and information quality improvements can be provided at ATC stations using the same technology, it seems reasonable to move in that direction. Yet there have been no requirements incorporated in the AILS concept for improved technology at the ATC station to successfully conduct AILS operations. Any improvements in the ATC displays and provisions for presenting the AILS alerts are regarded by the Ad Hoc Team as nice-to-have features and not as requirements.

Given recommendations that air traffic controllers involved with the flight should be notified if an AILS alert is presented in the flight deck, the following is a consideration. If there is an AILS monitor position, that position should be alerted as well as the local controller and the final controller. Initial comments by knowledgeable individuals involved in the development process have suggest the following mechanisms by which the alerts could be issued:

- The crew of the evading aircraft informs the controller via voice radio.
- ADS-B or other data link transmits information bits from the aircraft to the ground when a flight deck alert is issued.
- Ground equipment independently computes alerting algorithm using ADS-B information from aircraft.

At the time of this reporting, the specifics of informing the controllers of an AILS alert have not been explored in any detail. The Ad Hoc Team is therefore not making a recommendation on this issue.

As a final point in this topic, the Team cautions against a pitfall already uncovered in the PRM research and development. A significant finding there was that even if ATC can detect conflicts, timely communication with flight crews to get the problem resolved is a limiting factor. Therefore AILS developers should be careful not to place requirements on the ground-based

ATC operations that might prove to be technically infeasible and not necessary for the effectiveness of the concept.

8.0 Suggested AILS ATC Simulation Experiments

In this section and Appendix D through F the Ad Hoc Team has attempted to design experiments that could be conducted to study, from an ATC perspective, parallel approaches in airspace models of three different terminal areas. The three terminals selected are Seattle-Tacoma, San Francisco, and Minneapolis-St. Paul. The reasons for these selections are briefly stated in Section 6.1. The actual experiment definitions are presented in the appendices of this document in significant detail. One of the hopes of the Ad Hoc Team in developing these three example experiments is that the process and discussions will highlight the significance of the particular features of the terminal area in shaping the format of an AILS application.

The selection of three terminal areas to design example experiments reflects the view of the Ad Hoc Team that an implementation of AILS in any given terminal area would need to be tailored to the specific details of that airspace. Particular issues would need to be addressed that might not be applicable the other airspace environments. The experiments described address airspace environments that have high interest because of capacity issues and dependence on parallel runway operations as a part of their solutions. Yet, the ATC operations at the airports are quite different and present different issues in considering application of AILS technology.

Also under consideration when deciding to present three example experiments was the fact that at the time of the initial drafting of this report, which was widely distributed for comment, a decision had not been made. It was not clear which environment might be the target of additional NASA investigation or demonstrations. San Francisco, Seattle-Tacoma and Minneapolis-St. Paul were at the forefront of discussions.

8.1 Straight-in AILS Approaches in a Seattle-Tacoma Terminal Airspace Model

Appendix D presents an experiment plan for a simulation test of straight-in AILS approaches in a model of the Seattle-Tacoma terminal area. A full discussion of the assumptions and experiment plan is provided. The experiment plan includes a subjective evaluation form, Appendix G, to be completed by the controller test subjects. It also includes test incident scenarios to be used in the study. These scenarios assume that the intrusion incident would be staged using pre-recorded data as in previous AILS simulation experiments, and that final resolution of the incident by the controllers will involve issuing instructions to guide the flights along routes described in the incident scenarios, once separation responsibility is accepted. The designed scenarios include the assumption that the flights will continue two to three minutes beyond the start of the intrusion incident, until the erring aircraft are integrated back into the approach streams.

Figure 12 illustrates the assumed nominal traffic flow pattern in the SEA terminal area. Figures 13 through 16 present four suggested incident scenarios for use in the tests.

8.2 Segmented AILS Approaches in a San Francisco Terminal Airspace Model

Appendix E presents a plan for simulation testing of the AILS process in a model of the San Francisco terminal area. Suggested scenario details are also included. Figure 17 shows the general traffic flow pattern assumed for the SFO terminal area using a segmented AILS approach. Figures 18 through 23 illustrate suggested incident scenarios for use with that traffic model.

This is the terminal area for which a segmented AILS approach is being considered. The parallel runway pair, 28L and 28R are laterally spaced 750 ft. apart. In VMC operations where both runways are used for simultaneous approaches, the aircraft on the two runways are paired and the flight crews are cleared to make visual approaches. The reason for the pairing is that at least a 5-mile gap is needed between landings on the runway pair to allow departures on the two runways 1L and 1R which cross the 28L/28R pair at 90-degree angles. Therefore, a pair of aircraft will land approximately simultaneously on runways 28L and 28R, then during the gap, aircraft will be released to depart on runways 1L and 1R. Then, the next pair will land on runways 28L and 28R. The attempt is to keep the paired traffic together to make the process efficient.

Because there is an issue of meeting requirements for visual approaches when the AILS portion of the segmented approach is ended, the Ad Hoc Team recommends that the traffic be paired and staggered for the segmented AILS approach. Pairing will also be needed to achieve efficiency in managing the departures. The intent will be to maintain the aircraft on the segmented approach in a relative position behind the aircraft on the straight-in approach. This will put the aircraft on the straight-in approach in the forward field of view of the aircraft making the segmented approach when it enters visual conditions, facilitating visual acquisition of the traffic on the straight-in approach. The requirement for the trailing aircraft to continue on the segmented approach as its lateral spacing from the adjacent approach path closes to less than 2500 ft. will be that the crew sees the traffic on the adjacent approach. The point where the approach paths close to 2500 ft. is the missed approach point. If visual acquisition has not occurred when the trailing aircraft reaches that point, that aircraft is required to execute a missed approach.

8.3 Straight-in AILS Approaches in a Minneapolis-St. Paul Terminal Airspace Model

Appendix F presents a plan for testing of the AILS process in a model of the Minneapolis-St. Paul terminal area. The traffic flow pattern assumed for the MSP terminal area is illustrated in figure 24. Suggested scenarios are also included for the test, figures 25 through 28.

A significant feature of this plan is that it is patterned after the ILS PRM process currently approved for MSP and does not represent a purely independent parallel approach process. In order to manage the departure traffic efficiently, the controllers generally pair the traffic on the approaches to the two runways. This is not a requirement, although it is the normal practice because it provides a more efficient operation. An in-trail interval of at least 5 miles for both of the parallel approach streams is required to provide adequate spacing for departures.

An additional factor further explains of why the pairing is done. When the traffic volume is low, PRM is not required and dependent approaches are used. In that event, the two aircraft are staggered according to separation standards. Maintaining the aircraft in pairs makes it easier to set up the stagger in dependent streams. Having them paired in both the dependent operations and the ILS PRM operation simplifies transitions between the two modes of operation. The controllers set up the pairs in the feeder and final airspace and either stagger one longitudinally behind the other (dependent operations) or allow them to continue paired, side by side, during the ILS PRM operation. In spite of the pairing, it is emphasized that the PRM approaches at MSP are simultaneous independent ILS PRM approaches.

An important aspect of the above discussion is that the MSP operation provides an additional precedence for using pairing and staggering in the segmented AILS approach concept. This information is highlighted here along with the descriptions given of the pairing and staggering currently used in LDA operations at STL, and formerly used at SFO (see sections 4.01 and 4.02). These existing applications form the basis for justifying the recommendations of the Ad Hoc Team to use pairing and staggering in the segmented AILS approach concept.

9.0 Recommendations for ATC Operations in the Planned Simulation Study

Appendix B presents a table that summarizes the deliberation of the Ad Hoc Team related to conducting simulation studies of the AILS ATC activities. The table details experiment objectives including different levels of simulation, cost and time factors, and facilities that may be capable of conducting the planned simulation. The table also depicts expected benefits derived from the simulation, a relative rating of the simulation objectives, and pertinent comments with a numerical ranking of the simulation levels deemed to have the most realistic chance of success considering cost and time (first choice, second choice, etc.).

The first simulation level, row one, represents a complete full up simulation with all relevant positions staffed by qualified air traffic controllers. The positions listed for the full up simulation in the first row, column one are feeder controller, final controller, tower local controller (LC), tower coordinator (CC), and TRACON coordinator (CI). Column two presents an estimate of the number of personnel directly participating in the simulation and a rating of the relative cost factor. As shown in row one, column two, the “high” entry reflects the Ad Hoc Team’s belief that this would be a very costly way to conduct the experiment. The time factor rates the Ad Hoc Team's estimate of the time required setting up and conducting an experiment under the conditions of the particular row relative to the assessment made for the other rows of the table. Column three lists known facilities that may have the capability of conducting that simulation. Next, the Ad Hoc Team analyzed the benefits that may be derived from each level of simulation and assigned a relative rating to each one in the column labeled "Benefits."

Seven experiment objectives are listed at the bottom of the table for reference. The columns titled “Objectives” labeled "1" through "7", refer to these objectives respectively. The entries in these columns (H, M, and L) are an estimate of the (high, medium of low) contribution toward meeting these objectives for the simulation level in the particular row.   The last column gives pertinent comments and, where applicable, the Ad Hoc Team’s ranked choice of the various levels of simulation. The choices, one through five and a fall back position, represent the Ad Hoc Team’s assessment of the most practical and realistic level of simulation. The fifth choice and fallback position would not involve qualified air traffic controllers, only pseudo controllers. The first choice is simulation level four. The view of the Ad Hoc Team is that this choice would provide data on the critical controller positions in the process while also providing a realistic simulation environment in support of the flight deck experiment. The simulation requires two tower local controllers and a TRACON final controller. All the other controller positions will be simulated through software or by a pseudo controller. The Ad Hoc Team expects all objectives of the experiment can be fully realized by using this level of simulation. The second through fourth choices represent options with fewer positions fully simulated, and therefore provide lower benefits than the first choice. Clearly, fewer resources will be required to conduct the experiment in these modes. The fifth choice and the fall back choice would adequately support the flight deck simulation but would not provide any ATC process evaluation.

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Appendix A

11.0 AILS from The Flight Deck Perspective

Airborne Information for Lateral Spacing is an effort within the Reduced Spacing Operations (RSO) element of the Terminal Area Productivity (TAP) program at NASA. The objective of the AILS research being conducted at the Langley Research Center (LaRC) and at the Ames Research Center (ARC) is to enable approaches to close parallel runways in IMC with a capacity similar to that obtained in VMC. This research is examining options to enable airborne flight deck crew responsibility for aircraft separation during close parallel runway approaches. The initial focus of the NASA work has been on independent straight-in parallel runway approaches with intentions of investigating segmented and paired staggered approach concepts as time and resources permit.

Within the TAP program element, LaRC and ARC have planned a number of studies to address the problem, with LaRC taking the lead in this activity. A concept design team was assembled to address the problem. The team at LaRC designed an initial concept after concluding that the problem of flying parallel approaches has two major components. The first is to provide accurate navigation and flight path management for aircraft on the close parallel runway approach paths and to provide alerts to help keep intrusions from occurring. The second is to provide adequate protection for aircraft should one aircraft deviate from its assigned airspace in a manner that threatens another aircraft on a parallel runway approach path. The research at ARC has focused on providing TCAS like display guidance during collision avoidance maneuvers. The AILS work to date has addressed parallel pairs as opposed to parallel triplets or quadruplets, since examining pairs presents a simpler, yet significant payoff potential.

Figure 5 illustrates technology that could potentially be used to implement the concept. DGPS provides the basis for the accurate navigation required to make the approach, while ADS-B, currently under development, will enable aircraft to broadcast their position and other state information such as track, and rate of turn. The other aircraft will receive the transmitted information and maintain an accurate fix on aircraft operating on a parallel approach. The transmitted state information will provide an indication of whether the traffic is operating normally, has become a threat, or is headed back to its nominal path after an inconsequential deviation.

As mentioned above, the AILS concept focuses on two aspects of the problem. One aspect is to provide accurate navigation to keep aircraft in their own assigned airspace along the approach paths and keep aircraft from threatening others. LaRC engineers are investigating whether the conventional localizer path can be replaced (in AILS applications) with capabilities such as using DGPS to provide parallel approach paths where there is less potential for path overlap. Figure 6a illustrates a modified localizer path designed for use in AILS approaches. This localizer path format was used in the two studies conducted at NASA Langley in 1996. Under this concept, in the area of “localizer” capture, the two-dot deviation is 2000 ft. on either side of the extended runway centerline. Also, as is normal for parallel runway operations, the approach paths are separated by 1000-ft. altitude during localizer capture. At about 12 miles from the runway threshold, the path width begins to taper down to 500 ft. (400 ft. in some applications) on either side of the extended runway centerline at 10 miles. After the 500-foot half-width area is entered, the higher aircraft starts to descend and altitude separation is given up. The 500-foot half width of the path is held from that point to a location near the middle marker where a conventional localizer angular beam shape and width are captured (using DGPS to emulate the conventional localizer signal).

A more conventionally configured angular-shaped localizer beam derived from DGPS signals is also under consideration and was used in NASA studies conducted in 1999. In these studies the centerlines of DGPS-based conventionally-shaped localizer beams were skewed approximately 2.0 degrees away from the parallel approach direction, in opposite directions, to avoid the overlapping airspace (see fig. 6b). This design is more consistent with planned use of DGPS in ILS localizer look-alike implementations currently under development.

An alerting feature has also been incorporated in the concept to prevent aircraft from straying from their prescribed airspace. Figure 7 shows the primary flight display (PFD) and the navigation display (ND) used in one simulation study completed at LaRC in 1996 as they appeared during nominal AILS approaches. The AILS specific information is labeled. Should an aircraft deviate one dot or more from its nominal path, a caution or level two alert (reference 7) is issued to the deviating aircraft. The displayed information is presented in amber alphanumeric and symbolic formats (figure 8) in the primary flight display and in the navigation display, to warn the flight deck crew to maintain a tighter path adherence. Should an aircraft deviate two dots or more from the prescribed path, a level three alert is issued using red colors for the displayed information, requiring an emergency escape maneuver (EEM) in the direction away from the parallel traffic. In the version of the LaRC concept implemented for the second phase of testing, depending on the severity of the situation, level two or level three alerts are also used to prevent one aircraft from threatening another with excessive bank angles or tracks. The current LaRC concept requires use of a single, identical EEM for all parallel approach deviations. The aircraft required to abandon the approach must execute an emergency escape maneuver consisting of a turning climb to a heading 45 degrees away from the nominal runway heading, in the direction away from the parallel approach traffic. A heading bug is automatically set to the (45-degree) escape heading when the alerting algorithms are armed in the approach sequence. Note: The degree of turn may have to be modified in the case of segmented approaches or airspace restrictions at certain airports. Also, flight-director-command-bar escape guidance was used in the second of the two studies conducted in 1996 but was not implemented in the1999 studies.

The second aspect of the LaRC version of the AILS concept addresses procedures to avoid collisions and near misses in the event one aircraft strays from its airspace and approaches the path of another in a threatening manner. An onboard alerting algorithm will use state information from traffic on the parallel approach path, transmitted by the ADS-B link, to detect threatening aircraft and provide an onboard alert to the flight deck crew of the threatened aircraft. The alert is again presented in the primary flight display and the navigation display. A caution is presented in amber as the alerting system first detects the threat as it starts to evolve. As the danger becomes imminent based on the computations associated with the alerting algorithms, a red (level three) alert is issued in the flight deck of the protected aircraft. In the concept, the red level three alert (figure 9), requires the flight deck crew to execute the emergency escape maneuver. Again this is an immediate, accelerating, climbing turn away from the approaching traffic and parallel runway to a heading of 45 degrees from the nominal runway heading. The version of the concept under study at LaRC displays information in the primary flight display and in the navigation display. A computer controlled voice message complements the displayed information with a “Climb, turn, climb turn.” aural advisory when the level three alert is activated.

The concept design team at LaRC completed a fixed base simulation test of the initial concept in May 1996. In the test, sixteen pilots each flew 56 parallel approaches, with about one third of the cases presenting collision or near miss threats. The test subjects were line pilots from a number of airlines and airfreight companies. They were trained for the task, in a manner similar to the way they are trained and tested for rejected takeoffs (RTOs) and category II approaches. The reaction time of the pilots in executing the turning maneuver and the closest approach were key parameters measured in these tests. Parallel approaches spaced 3400 ft. and 2500 ft. apart were examined in the initial study. The test findings show that all of the pilot reaction times were well under the two seconds targeted by the NASA design team, and that no trials resulted in violations of the 500 ft. minimal separations used for defining near misses in the parallel runway approach environment. The mean miss distance measured was in access of 1900 ft., with the closest encounter at 1183 feet.

A second phase of testing was completed in July 1996, at LaRC**.** The follow-up tests included new alerting algorithms and modifications to the displays based on observations and pilot comments from earlier tests. Runway lateral spacing was reduced to 1700 ft. and 1200 feet. Eight, two-member airline crews were tested in the second phase. The results were very promising for the 1700-ft. runway separation, with no encounters closer than the targeted minimum 500 ft. miss criteria. The 1200 ft. case resulted in one encounter closer than the 500 ft. two dimensional near missed criterion used, and is regarded as marginal by the design team when the current experimental AILS technology is used.

The study at ARC was completed in August 1996, and explored application of TCAS concepts to the closely spaced parallel runway approach problem. This study showed that a display based on the TCAS formats, but enhanced with a higher resolution navigation display and specially designed alerting algorithms, resulted in better performance than the TCAS implementation using a conventional navigation display format. The performance with the enhanced display features and alerting algorithms resulted in no near misses and good pilot evaluations. The study at ARC investigated an auto-pilot coupled approach, in contrast with the manual mode used in the LaRC studies, and addressed the 4300 ft. and 2500 ft. runway spacing cases.

In interpreting these results it is important to realize that they show the feasibility of the AILS concept in initial testing in a research simulator environment. A significant amount of additional testing and validation is required before a concept of this nature could be implemented in the national airspace system. Among the issues that must be resolved or managed are the effects of wake turbulence considerations.

Appendix B

12.0 ATC Experiment Options and Down Selection Recommendations

Table Comparing Potential Levels of Simulation with Evaluation Parameters

Description of Simulation Level	Cost Factor	Time Factor	Where	Benefits	* Objectives							Comments and Recommendations
					1	2	3	4	5	6	7	
1. Complete arrival environment • Feeders (2 ea., all full sim.) • Final (2 ea., all full sim.) • Tower (1 or 2 ea., full sim.) • CC • CI	• High • Staff: 7-8	• High	• ARC • Tech Center • Mitre	• High • Most needed measurements • Position interactions	H	H	H	H	H	H	H	- Inline with a live demonstration at a real facility, e.g. SFO. - Viewed as more than LaRC can manage within time and resources
2. Full sim. of select position(s), alternative A • Tower - full simulation • Final - full sim., 2 ea. • Pseudo-Controller/scripts for other positions • CC/CI	• Medium • Staff: 4+	• Medium - High	• ARC • Tech Center • Mitre	• High but limited • Some position interactions	H	H	H	H	H	H	H	- Viewed as not practical in the scope of resources available.
3. Software representation of non-targeted positions. Use # 2 type full sim. for ATC controller for select position(s) • Like # 2 except software sim. non-selected positions. • CC/CI (combine, not tested)	• Medium-High • Staff: 3+	• Medium - High	• ARC • Tech Center • Mitre	• High but limited • Some position interactions	H	H	H	H	H	H	H	-Viewed as not practical in the scope of resources available. -Req. software development of pseudo controllers.
4. Full sim. of select positions, (minimized), alternative B • Tower full • Final- one full, one pseudo • Pseudo ATC or SW sim. of others	• Medium • Staff: 3+	• Low-Medium	• ARC • Tech Center • Mitre	• Medium with limits • Some interactions	H	H	H	H	M+	H	H	• First choice

5. Full sim. of select positions (minimized), alternative C • Tower- Full Simulation • Others- pseudo or SW sim. • CC/CI combined	• Low-Medium • Staff: 3	• Low-Medium	• ARC • Tech Center • Mitre	• Medium with limits • Limited interaction	M	H	M+	M-	L+	H-	H	• Third choice
6. Full sim. of select positions (minimized), alternative D • Arrival full • All others pseudo or SW • CC/CI combined	• Low - Medium • Staff: 3	• Low-Medium	• ARC • Tech Center • Mitre	• Medium with limits • Limited interaction	M	H	M+	M-	L+	M+	H	• Fourth choice
7. Split simulation runs between 5 and 6 above	• Low - Medium • Staff: 3	• Low-Medium	• ARC • Tech Center • Mitre	• Medium with limits • Limited interaction	M	H	M+	M-	L+	H	H	• Second choice
8. All ATC controllers Pseudo realistic display - Demonstration essentially separate from tests	• Low-Medium • Staff: 1	• Low-Medium	• ARC • LaRC	• No ATC data • Support sim. • Good demo.	N	M	N	N	N	N	H	• Fifth choice
9. Pseudo controller positions only	• Low • Staff: 1	• Low	• ARC • LaRC	• No ATC data • Supports sim.	N	N	N	N	N	N	H	• Fall back
Description of Simulation Level	Cost Factor	Time Factor	Where	Benefits	1	2	3	4	5	6	7	Comments
					* Objectives							

* Experiment Objectives (H = high, M = medium, L = low, N = none):

1. Validate that the AILS requirements and processes are realistic at the ATC positions
2. Demonstrate to stakeholders example of ATC position functions
3. Provide an opportunity to identify problems that might have been overlooked in earlier planning
4. Explore human factors aspects of AILS at the ATC position, including controller workload
5. Examine aircraft-ATC interaction from the ATC perspective
6. Provide an opportunity to identify, design, and demonstrate any needed new ATC interface features
7. Support the flight deck simulation with acceptable ATC simulation

Appendix C

13.0 ATC Procedures and Phraseology

13.1 Independent Straight-in AILS Approaches (See figure 2)

1. Automated radar handoff of aircraft from feeder controller to final controller including communications transfer.

2. (*Aircraft call sign)*, Approach, fly present heading, descend and maintain 5000, over.

3. *(Aircraft call sign)*, reduce speed to 210.

4. Turn base leg *(where applicable).*

5. *(Aircraft call sign)*, traffic eleven o'clock, 5 miles, a heavy Boeing 747 at 4000 turning final for AILS Runway 28 Left. Report traffic, over...

6. *(Aircraft call sign)*, turn right heading 250.

7. Altitude assignment as appropriate.

8. *(Aircraft call sign)*, two miles from *(IAF)*, maintain 5000 until established on the localizer, cleared AILS Runway 28 Right Approach.

   (About nine miles from the runway.)
9. *(Aircraft call sign)*, three miles from *(FAF)*, contact tower on 120.5.

10. Tower, *(Aircraft call sign)* is two and one half miles outside *(FAF)* for 28 right.

11. *(Aircraft call sign)*, Tower, Runway 28 Right, cleared to land. Traffic a heavy Boeing 747 eight o'clock, landing Runway 28 Left, over.

12. Complete approach, missed approach or EEM.

13.2 Segmented Approaches (See figure 3)

1. Automated radar handoff of aircraft from feeder controller to final controller including communications transfer.

2. *(Aircraft call sign)*, Approach, turn left heading 090, then descend and maintain 5000, over.

3. *(Aircraft call sign)*, reduce speed to 210.

4. *(Aircraft call sign)*, turn right heading 190.

5. *(Aircraft call sign)*, traffic eleven o'clock, five miles at 4000, a heavy Boeing 747 turning final for AILS Runway 28 Left . Report traffic, over...

6. *(Aircraft call sign)*, turn right heading 240.

7. Final controller monitors progress.

8. *(Aircraft call sign)*, two miles from *(IAF)*, maintain 5000 until established on the localizer, cleared Segmented AILS Runway 28 Right Approach.

(About nine miles from the runway.)

9. *(Aircraft call sign)*, three miles from *(FAF)*, contact tower on 120.5.

10. Tower, *(Aircraft call sign)*, two and one half miles outside *(FAF)* for 28 right.

11. *(Aircraft call sign)*, Tower, Runway 28 Right, cleared to land. Traffic a heavy Boeing 747 eight o'clock, landing Runway 28 Left, over.

12. Complete approach, missed approach or EEM.

Appendix D

14.0 Suggested AILS-ATC Experiment Plan, Seattle-Tacoma Terminal Model

14.1 Introduction

A simulation study using a terminal area model based on the Seattle-Tacoma (SEA) terminal area environment has been chosen to study parallel runway operations where the approaches are spaced 2500 ft. apart. This selection is based on information received that construction has started on a new runway 2500 ft. west and parallel to the existing runway 16L/34R. The purpose of this study is to further validate that the AILS process can be implemented in a simulation of a real world terminal environment. Twenty-five hundred feet is the targeted minimum lateral spacing for the first independent AILS operations. Seattle-Tacoma appears to be the terminal area that will have parallel runways spaced 2500 ft. apart, and that could possibly benefit from AILS technology. The AILS approaches in this study will be straight-in as opposed to segmented.

The approach to developing this plan is to assume that the experiment can be conducted either as an integrated part of a flight deck experiment with a high fidelity real-time flight simulator or else as a stand-alone ATC simulation. As a stand-alone ATC simulation, it is anticipated that at least one pseudo-pilot facility, or several low fidelity flight deck simulators, will support the experiment by representing the roles of the aircraft involved in the scenarios.

The scenarios should include the entire relevant airspace operation beginning in the feeder controller’s airspace, through the final controller’s airspace, and handoff into the tower local controller traffic pattern. It should continue to landing or through execution of an emergency escape maneuver (EEM) or a missed approach. If either the EEM or a missed approach is executed, the aircraft should continue through the airspace that would normally be impacted. It is estimated that the flights should be extended for approximately three minutes beyond the EEM execution time until the two aircraft involved in the initial incident are on stable paths with appropriate clearances, and the impacted ATC positions have resolved the emergency situation.

The Seattle-Tacoma terminal area affords an opportunity to test in an environment where only two controller positions are tested and yet valid and valuable data can be acquired. Analysis and discussions of an intrusion event in this terminal area has resulted in concluding that it is unlikely the track of either aircraft would proceed into the airspace of the departure controller. Even if one does proceed in that direction, it would be very similar to a missed approach operation and managing such an event is a relatively routine occurrence, or at least a type of event with which ATC has considerable experience. Therefore, this experiment will be developed to test a single local controller position (LC) and a single final controller position (AR). All other controller positions and tasks will be represented by a pseudo-controller operation, including a second local controller position, the departure controller position, and the feeder controller position. Coordinator positions may be exceptions to this general methodology.

As previously discussed, each facility, that is, the tower and the TRACON, will have a coordinator position, CC (cab coordinator) in the tower, and CI (radar coordinator) in the TRACON. In the event of an emergency condition such as an intrusion incident, these positions will normally intervene, teaming with the LC and approach controller, and make some of the decisions about the resolution of the situation. They will provide direction and instruction to the LC and AR positions on what action to take. They will also assist with the coordination between the facilities (tower and TRACON) and positions. Therefore, the operation will not be a process involving only the LC and the AR, but it will include inputs and actions completed by the cab coordinator and the radar coordinator.

14.2 Description of the Seattle-Tacoma International Terminal Area

This study plan assumes that a new runway has been completed at the Seattle-Tacoma International airport so that the configuration is the three parallel runway layout illustrated in figure 12. As illustrated in the figure, the plan assumes that the approach to the new runway 16R is used as a parallel approach along with runway 16L. The planned runway 16R is located 2500 ft. west of the existing runway 16L, while the existing runway 16R will be re-designated runway 16C, and will be used primarily for departures. Heavy jet traffic will in all probability use runway 16L for departures and landings. The planned new runway 16R will be approximately 6800 ft. in length while the existing runway 16L is 11,900 feet. Runway 16C can handle the departing traffic; however, in IFR conditions it must operate as a single runway operation with runway 16L, because of the proximity of the other two runways.

A study of the Seattle VFR Terminal Area Chart and existing FAA approved Standard Instrument Approach Procedures confirms that there are no obstacles within a proximity of runway 16L and the planned runway 16R that would prevent the use of a turning and climbing AILS emergency escape maneuver. The terminal air traffic operation is supported through a basic four-corner post airspace configuration and traffic flow pattern.

It is assumed that two separate tower local controller (LC) positions will control traffic to runways 16L and 16R, and that they are physically located in the same tower cab, so one CC position is involved in the coordination. It is not clear at this point, whether it is likely that SEA will pair traffic for landing on runways 16L and 16R. It seems that pairing would be done to maximize the takeoff and landing capacity in independent operations. Also, it is reasonable to pursue a paired traffic operation because of the dependency of the three runways due to their close proximity. In this case they would probably pair the arrival traffic to be able to use the center runway for departures. The requirement is that runways closer than 2500 ft. laterally be treated as one runway during approaches in IFR conditions. Also, another consideration is the arrival flow to Boeing Field, four miles north, which has a direct effect on the arrival flow to SEA. Although we have made these observations and assumptions for this analysis, clearly Seattle air traffic control facility planners will determine how the runways are used. These observations are presented only to assist in designing a reasonably realistic study.

The following is an attempt to summarize the restrictions and requirements regarding departing in IFR conditions on parallel runways closer than 2500 feet.

1. If two aircraft, large or small, are departing, the first departure has to be a minimum of 1 mile ahead of the next departure and on a 15-degree diverging course.

2. If two heavies are departing, a 5-mile longitudinal spacing must be maintained at all times.

3. If a heavy and a large/small are departing, it is optimal to depart the large/small first and the heavy can depart 1 mile behind with the large/small having turned to a 15-degree diverging heading.

4. With a heavy or a B-757 departing first, standard separation must be applied. The 15-degree diverging rule is not applicable.

In conclusion, the comments given above relate to how one must model use of the three parallel runways at the Seattle-Tacoma airport. Any credible study that might be directly applied to that environment should be conducted with these constraints in mind.

14.3 Experiment Objective

The objective of this experiment is to determine the effectiveness of the tower local controller, and the final controller in performing the tasks required in an AILS operation. The test should determine effectiveness of the controllers handling the two aircraft which have departed from nominal operations, the erring intruder flight and the second AILS protected flight that executes the emergency escape maneuver to avoid a mishap. The emergency escape maneuver executed by the aircraft will be those used in the flight deck centered AILS testing. The test will also assess the acceptability of other features of the AILS process. This includes the initial transfer of responsibility to the flight deck crew for separation from traffic operating on the parallel approach. Air traffic controllers will retain responsibility for longitudinal in-trail separation.

14.4 Scope

The testing will allow evaluation of the effectiveness of the tower local controller and of a final controller. Those two positions will be fully simulated with no artifacts of the experiment hindering these controllers' performance of realistic operations. The other air traffic controller position functions will be represented in the experiment in a manner that supports the flight deck experiment (if conducted in concert) and the ATC experiment. No attempt will be made to represent other ATC functions realistically, but the interaction with a CC or CI position needs to be convincing from the perspective of the LC and the AR test subjects. A pseudo-controller function will simulate all other functions of the ATC system that need to be represented in the simulation. The pseudo-controller is assumed to be a person with a high level of automation background to support the requirements. The pseudo-controller should operate in the experiment in a manner that aids in presenting a realistic environment for the subjects of the experiment with no requirement for realism at the pseudo-controller station.

14.5 Additional Assumptions

It is assumed that the AILS parallel approaches are in the airspace for which the LC position has been delegated responsibility. That LC will be expected to re-establish control and assume responsibility for the AILS traffic once an incident or emergency escape maneuver has occurred. The local controllers will be expected to manage the two erring aircraft, including the completion of any necessary coordination with other controller positions. The expectation is also that they will safely manage the traffic not directly involved in the intrusion incident that may be continuing on the approach to the runway. The local controller must also continue, as appropriate, duties related to departure traffic and traffic already landed but not handed off to ground control.

14.6 Independent Variables

These will be the same independent variables used in the planned AILS simulation flight deck testing except for Item 4. Possible independent variables are the following:

1. Segmented vs. Straight-in.
2. Turning emergency escape maneuver (EEM).
3. Runway separation.
4. Nominal route for the two aircraft after the emergency escape maneuver.

At this time the Ad Hoc Team is not recommending that additional independent variables be included that are particularly selected to explore ATC related issues, except for Item 4 in the list above. It is not expected that introducing the route of the erring traffic will increase the number of runs that would otherwise be executed in the experiment. That part of the testing is conducted after the other independent variables of the test have been covered in the experiment. It is essentially an add-on to the length of each run, approximately three minutes. The primary purpose of this study, from the ATC perspective will be to establish, based on experimentation, that the proposed ATC processes are feasible.

14.7 Dependent Variables

1. <u>Subjective Evaluations by the Subject Controllers</u>

A typical Subjective Evaluation Form for Controller Subjects is in Appendix G.

2. <u>Subjective Evaluation/rating by an Observing Expert</u>

This will need to be done either in real time or during an off-line viewing of videotape of the operation. Video taping will be a requirement of the operation. A question will be whether to video tape each run at the four different control stations. The probable answer will be that this is a requirement for the data collection in the experiment; therefore, it will need to be done.

3. <u>Objective Measurements</u>

Attempts to define objective measures of ATC performance, that will be sensitive to changes in the experiment variables, presented a difficult task for the Ad Hoc Team. The list that follows is made up of potential measures suggested by the Ad Hoc Team for consideration. More deliberation on these possibilities is needed.

- 3.1 Coordination with other control positions.
- 3.2 Communication instructions with conflicting aircraft.
- 3.3 Communication instructions to other aircraft not in direct conflict.
- 3.4 Errors made.
- 3.5 Other aircraft violating separation standards.
- 3.6 Timeliness of instructions to other aircraft.
- 3.7 Use of incorrect ATC phraseology.
- 3.8 Secondary task - induced situations to be managed.
  - *3.8.1* Aircraft airborne and not switched to departure.
  - *3.8.2* Disabled aircraft on runway / aircraft too slow exiting runway.
  - *3.8.3* Departing aircraft delays too long before starting take off roll.
  - *3.8.4* There might be opportunities for secondary task measurements in the runway crossing situations in the experimental SEA environment.

3. Measuring the Controller's Ability to Re-establish Control and Responsibility

One measurement of interest is the amount of time that elapses before the controller accepts responsibility for separation of the erring aircraft. The request for the air traffic controller assistance will come from the flight deck of the evading aircraft, in the format: "Tower, *aircraft ID*, executing an emergency escape maneuver to avoid traffic, request instructions." When the tower issues instructions that will constitute ATC (the LC in this case) re-establishing control and accepting responsibility for separation of the aircraft from all traffic. A roger, unable, or standby reply from ATC, or a controller stating that radar targets are merged, shall be interpreted to mean that the controller has not accepted responsibility for control and separation; and that aircraft must continue to provide separation from each other using AILS technology. To accept control and provide separation of the evading aircraft, targets must be separated so that the controller can reestablish identity and provide separation. The same positive action protocol shall be applied to the intruder aircraft in order to assume responsibility for separation of aircraft.

The measurements made will be the time from the request of the crew of the evading aircraft for instructions until the controller acknowledges by issuing control instructions. Related to this will be a record of the initial reply of the controller, e.g., whether a "Standby" or " other control instruction, ...".

5. Additional Variables for Consideration

- 5.1 Number of communication events to coordinate with other controllers, counted from review of tape recording.
- 5.2 Number of communication events to the two aircraft involved in the incident, counted from review of tape recording.
- 5.3 Time elapsed from the start of the incident until traffic flow is stabilized. This will require a clear definition of stabilized traffic flow.
  - Completed instructions to both aircraft that fit them into the pattern.
  - No further unusual adjustments to any aircraft to accommodate.
  - Possibly use separate measurements for each of the two aircraft.

5.4 The time until an aircraft is allowed to depart safely might be a measurement of the stabilized traffic flow pattern.
5.5 A recorder switch should be put in the subject controller's station to be activated by the controller as soon as the start of an event is recognized.

14.8 Experiment Setup

The assumption in developing this plan will be that three individuals will be involved in the ATC testing and support of the experiment, not including a test conductor and any evaluators that may be necessary.

1. A local controller position will be evaluated.
2. A final controller position will be evaluated.
3. A pseudo-controller will carry out the other ATC support functions: A second AR position, a second local controller position, any feeder controller positions, a tower and TRACON coordinator positions, and any adjacent sector positions necessary.

The equipment required for the simulated air traffic controller stations in the experiment is indicated in Table D1.

Table D1. - Simulator Equipment Requirement

	SIMULATION EQUIPMENT	AR	TOWER LC	PPC	CC/CI
1	Radar display/software	FDAD	DBRITE	PC monitor	PC monitor
2	Air to ground AILS alert	x	x		
3	Ground generated alert	x	x		
4	Vox radio com channel	x	x		
5	Com head, push-to-talk	x	x	x	
6	Track ball and software	x	x		
7	Coordination line to AR		x		x
8	Coordination line to LC	x			x
9	Coordination line to PPC	x	x		x
10	Coordination line to CC/CI	x	x	x	x

AR - Final Controller   LC - Local Controller   PPC - Pseudo Position Controller
CC/CI - Cab Coordinator/Radar Coordinator

14.9 Conducting the Experiment

1. <u>Briefing the Controller Subjects</u>

An experienced controller should conduct this briefing, or at least some portions of it.

- Define and explain the AILS process.
- Define and explain the SEA terminal area and the future runway addition.

- Discuss the assumed traffic flow pattern.
- Discuss take-off and landing operations at the airport.
- Define the role and expectations of each position in the AILS process.
- Discuss the role of the local controller during EEM's.
- Discuss any assumed facilities policies regarding EEM's.
- Underscore that this is an evaluation of the AILS process and whether it is practical to expect controllers to manage tasks as defined.
- Discuss the simulated controller positions and test hardware.
- Describe the debriefing forms: a. each run, b. each session.

2. Practice Runs for the Controllers

Prior to data collection in a given position, the subjects will be given a practice session which will include a minimum of three AILS intrusion incidents with emergency escape maneuvers. The practice operations should continue until the subject controllers feel comfortable that they understand the requirements and can manage the tasks required at the position. The initial practice session with a given controller group will include having the controller complete an evaluation form (Appendix G) for each of the types of operations (normal landings, missed approaches, emergency escape maneuvers).

3. Test Session for Data Collection

A session will consist of a one-hour operation of traffic flow into the SEA terminal area. It will include 20 normal landings, 5 missed approaches, and 5 intrusions incidents. After each missed approach, each intrusion incident involving an emergency escape maneuver, and 5 of the normal runs, the simulation will be frozen and the controllers requested to complete an evaluation form. Approximately five minutes will be allowed to complete the forms. After completing the evaluation form, the simulation will be reactivated from the state at which it was frozen. The total operating time for a session will be approximately two hours and 15 minutes.

If the test subjects are brought in as a pair, assuming each is qualified to operate at each position, it will then be feasible to get a set of data from each subject in the two positions being tested during a one or two day operation. A session will consist of the data collected with a given subject operating in a single controller position. It will consist of one hour of operation with approximately 30 aircraft making an approach to each of the two runways. After completing a session of operation in a particular position, each controller will be requested to complete an evaluation form covering the task requirements in the respective position.

14.10 Scenarios for the Two Aircraft After the Intrusion Incident

If a live flight deck simulator is used, only the path of the intruder prior to the emergency escape maneuver can be preprogrammed. As the subject air traffic controller assumes responsibility for the aircraft, the intruder aircraft becomes a pseudo-pilot controlled aircraft, a transition initiated when it is given the first ATC instruction. Pseudo-pilot input to respond to controller instructions will execute the change over.

If a live flight deck simulator is not used, a pseudo-pilot can represent the evading aircraft with the emergency escape maneuver automatically initiated. After the incident starts the pseudo-pilot operation can represent the operation of both the aircraft involved in the incident.

Figures 13 through 16 present incident scenarios for the two aircraft including the route of the two aircraft involved after the intrusion incident. The path of the intruder aircraft can be preprogrammed up to the start of the emergency escape maneuver. When the scenario includes the intruder maneuvering in response to ATC instructions, the pseudo-pilot will make inputs to control the path of the intruder, alternately in some cases, the intruder aircraft will be scripted to not respond to ATC instructions.

14.11 Methods for Representing the Intruder Trajectories in the Scenarios

The following are some thoughts on how to conduct the simulation that include options to use a real time flight deck simulator or else to operate an ATC role study separate from a real time flight deck simulation activity.

- Intruder and evader fly prerecorded tracks taped in the flight deck simulation study (or some other source) until the evader pseudo-pilot requests air traffic controller instructions. The two aircraft are on different tower communication frequencies, with different local controllers.

- The evading aircraft, after executing the initial emergency escape maneuver, should contact the tower local controller.

- Upon deviating from the final approach course with a control problem, wake turbulence upset or wind shear encounter, as examples, the intruder pseudo-pilot should request ATC instructions.

- The evader aircraft continues on its pre-recorded track (if a pseudo-pilot is used for the evader, as might be the case if a real time flight deck simulator was not used) until the test local controller provides instructions. The idea here is that the prerecorded tracks of the evader and intruder will have been created simultaneously, e.g. tracks of the two aircraft from the LaRC AILS piloted simulation study. On receiving instructions, the evader aircraft pseudo-pilot executes the instruction. An evader pseudo-pilot input will disable and override the pre-recorded track. Clearly, if a real time flight simulator is used, the evader track will not be prerecorded, and the evader flight deck would execute the emergency escape maneuver, contact tower, and comply with instructions.

- The intruder aircraft should be on a different local control frequency than the test local controller.

Appendix E

15.0 Suggested AILS-ATC Experiment Plan, San Francisco Terminal Model

15.1 Introduction

The San Francisco (SFO) terminal area environment (figure 17) presents a number of issues related to the composition of a study of this nature. One such issue is the question of which air traffic controller positions are likely to be impacted by an AILS emergency escape maneuver. The analysis of the Ad Hoc Team indicates that several of the controller positions may be affected. An incident involving an EEM will usually start in the local controller's airspace and proceed, depending on a number of factors, most probably into the airspace of a final controller. There is also a remote chance that the deviating traffic could continue into the departure controller's or feeder controller's airspace.

Regardless of the initial directions of the deviating traffic and circumstances of the incident, the immediate objective of ATC is to guide the two aircraft safely and expeditiously back into the arrival stream. Having an aircraft actually proceed to a holding fix and hold, is not a desirable option from the air traffic controllers' perspective. It is more efficient to put the deviating traffic on a course that will integrate it back into the normal traffic pattern. When ATC assumes control responsibility, their priority will be to insure separation of all traffic involved and to handoff the deviating aircraft directly to a final controller if possible.

The TRACON has responsibility for the terminal airspace including the "tower's airspace," where control authority has been delegated by the TRACON. Decisions are coordinated between the tower and TRACON personnel involved as they deal with an incident such an airspace intrusion. These two facilities must work together as a team to resolve the situation and direct the deviating aircraft back into the arrival stream. In an incident, there are likely to be two aircraft that need to be integrated back into the airspace. Although less appealing than handing-off deviating traffic to the final controller, the option to handoff deviating aircraft to the departure controller exists. In this event, the expectation would be that the aircraft would be guided back to the arrival airspace via the feeder controller airspace. Clearly, the position and direction of the deviating aircraft and volume of the traffic will be factors in determining the resolution. Finally, a malfunctioning radio communication link will also impact the resolution, as would any other airborne system failure that could have contributed to the problem in the first place.

This suggested experiment plan will focus on the situation where an encroachment into the airspace of the adjacent final controller is developing as a result of the intrusion incident.

15.2 Background

The approach to developing this plan is to assume that the experiment can be conducted either as an integrated part of the flight deck experiment with a real-time flight simulator or else as a stand-alone simulation. As a stand alone simulation, it is anticipated that at least one pseudo-pilot facility or a number of stand alone flight deck simulators will support the experiment by representing the role of the aircraft involved in the scenarios.

The scenarios should include the entire relevant airspace operation beginning in the feeder controller's airspace, continuing through the final controller's airspace, to the tower local controller's traffic pattern to landing, missed approach, or execution of an EEM. If an EEM is executed, the aircraft should continue through the airspace that would normally be affected. It is estimated that the flights should be extended for approximately three minutes beyond the EEM execution time until the two aircraft involved in the initial incident are on stable paths with appropriate clearances, and the impacted positions have stabilized their operations.

15.3 Assumptions

It is assumed that a single local controller position will operate the San Francisco tower traffic, since that is the case in the current SFO tower operation. This assumption is based on discussions with SFO air traffic staff personnel indicating that an effort has been made previously to define a safe operation that divided the tasks between two controllers. However, the conclusion was reached that operating with one local controller makes the most sense from the vantage point of maintaining the complex coordination needed for the runway configuration.

Given the single local controller position in IFR operations, the use of an AILS monitor controller (MR) is recommended in a SFO application of AILS. The task of the MR will be distinctively different from that of current final monitors (FM) operating in other simultaneous independent ILS approach environments. The SFO AILS monitor, assumed to be a TRACON position, will perform the following functions.

1. Monitor aircraft operating on the parallel approaches.

2. Issue appropriate speed advisories to those aircraft to assure same-stream longitudinal spacing or have aircraft execute a missed approach where necessary for spacing violations. The logic is to avoid or minimize additional workload on the LC where feasible.

3. In the event of an EEM, the MR will assume ATC responsibilities for each of the deviating aircraft as the flight deck crew reports its deviation from its clearance or as the MR observes on the radar display, and appropriate separation and identification conditions are met.

4. During the process of resolving the mishap, the MR will coordinate with the control positions impacted and handoff the deviating aircraft to the appropriate controller.

15.4 Experiment Methodology

The tests should be conducted in a realistic traffic environment that represents departure traffic as well as approach operations. It is highly desirable that SFO local controllers participate in the testing. But it may not be necessary that testing be restricted to only SFO controllers as subjects. This point will be discussed in more detail later. However, it is evident that the job of the SFO local controller is different and perhaps more complex than local controllers at most other airports. Training will probably be a very significant issue.

1. Use of a Control Condition

A control condition can be used in an experiment to set a baseline of performance or behavior metrics in the environment in which the experiment is being conducted. Independent variable effects can then be evaluated relative to the baseline condition.

A methodology using a control condition might be to measure whether the experimental task under investigation (e.g. controller's role in an AILS EEM) would require significantly different controller performance than does a current SFO ATC operation. The idea is to use a sample of the general controller population in testing to measure differences in task requirements. The intent would be to quantify any differences in the tasks of the controllers in the two operations in terms of the metrics selected. The favorable outcome for AILS approaches would be that the two conditions were judged to be essentially the same in terms of the metrics selected or that the values of metrics were better in the AILS-condition. It would then stand to reason that the AILS task can be completed at least as safely as the control-condition flights are conducted, from the air traffic controller requirements perspective.

A feasible control condition would be an aircraft executing an EEM-like maneuver because of an intruder incident in VMC. The idea here is to simulate VMC flights into SFO with an intruder incident as the baseline for comparing control performance. Controllers would normally intervene immediately in such a situation similarly to how they would be requested to assume control in the proposed AILS operations. This control condition could require a high fidelity tower simulation with out-of-the-window viewing of the surrounding airspace. Alternately, the control condition tests could be limited to incidences outside of the outer marker where the local controller would need to use their DEBRITE display to issue control instructions.

2. A Risky Methodology that could be beneficial

This subsection describes methodology that does not require a large pool of experienced SFO controllers as subjects. The argument presented here is that although there is such a methodology, there is a significant risk involved. The risk is the possibility of ending up with results that are not definitive.

The premise of such an experiment would be that if the general population of controllers can perform the required tasks successfully, then in all certainty, experienced SFO controllers will have no problem with the tasks, from a task difficulty or workload perspective. The risk involved would be in conducting an experiment that will have two possible outcomes, one of which is no problem and the other having a significant problem. The favorable outcome possibility is no problem. This is the experimental result that the SFO AILS application works well from an ATC perspective when tested with a general controller population.

This problematic alternate outcome is that the experiment would show that the AILS operation is unacceptable for the general controller population tested. Consequently, the experimenter would not know whether the AILS application would have yielded favorable results if a well-trained contingency of controllers, experienced in SFO operations, had been used as subjects. The possibility of this alternative, which might be interpreted as having conducted a useless experiment, is the risk involved in this methodology.

This methodology would use available experienced controllers as subjects in the tests, but would not require that the majority of them be highly trained or qualified specifically for the San Francisco operations. The subjects would receive a "reasonable" amount of simulator training in the tasks prior to participating in the experiment.

Why take such a risky approach? An argument for using this methodology is that the AILS application is believed highly likely to result in the favorable outcome. In this regard, the previously stated recommendation of the ATC Ad Hoc Team is that a special AILS monitor controller be used in the SFO AILS operation. This monitor controller would have specially designed tasks tailored to the SFO environment. The judgement of the team members is that it would be a manageable task for air traffic controllers, in particular the monitor positions, the arrival controller positions, and the departure positions, to guide the deviating traffic back into the traffic flow pattern. The problem would be significantly intensified if additional tasks had to be carried out by the single LC instead of an intervening monitor controller. This is why the monitor controller position is recommended in this environment in the first place.

Also, the cost of resources required to conduct an experiment may weigh heavily in selecting this methodology. The resources required to conduct a better experiment, for example using all SFO local controllers in the LC position, that would have increased likelihood of resulting in a definitive result, may be unrealistic.

Both of the two factors stated above are elements to consider in designing an experiment to test the SFO terminal area environment. They might well be considered paramount in the case of the SFO AILS ATC experiment under discussion.

As a final point, including two or three experienced SFO local controllers in a study conducted using this methodology would provide a control group in the subject population to allow detecting unrealistic experiment features. It would also provide comparisons of the behavior of other subjects to that of the experienced SFO local controllers. This feature might also counter some of the risk discussed above in that it might provide an explanation for some of the unfavorable results if that turned out to be the outcome.

In the final analysis, the particular conditions under which the experiment will be conducted will have to be evaluated by the planners of the experiment. The discussion provided above has included some ideas that might be considered to reduce experimentation costs.

15.5 Scope

The testing will allow evaluation of the effectiveness of the tower local controller (LC), the AILS Monitor (MR), and of a final controller (AR). Those three positions will be fully simulated with no experiment artifacts hindering these controllers' performance of realistic operations. The other air traffic controller position functions will be represented in the experiment in a manner that supports the flight deck experiment (if conducted in concert) and the ATC experiment. No attempt will be made to represent other ATC functions realistically, i.e. beyond the extent necessary for a realistic appearance to the test subjects. A pseudo-controller function will simulate all other functions of the ATC system that need to be represented in the simulation. The pseudo-controller is assumed to be a person with a high level of computer support to manage the task requirements. The pseudo-controller should operate in the experiment in a manner that aids in presenting a realistic environment for the subjects of the experiment with no requirement for realism at the pseudo-controller station.

15.6 Experiment Objective

The objective of this experiment is to determine the effectiveness of the tower local controller, the AILS monitor, and a selected final controller in performing the tasks required in an AILS operation focusing on the segmented approach. The test should determine effectiveness of the controllers handling the two aircraft that have departed from a nominal operation: the erring intruder aircraft and the second AILS protected aircraft that executes the emergency escape maneuver to avoid a collision.

The test will also assess the acceptability of other features of the AILS process, including the initial transfer of responsibility to the flight deck for separation from traffic operating on the parallel approach while air traffic controllers retain responsibility for longitudinal in-trail separation.

15.7 Independent Variables

The independent variables will be the same as those discussed in the test plan for the SEA terminal area model presented in Appendix D.

15.8 Dependent Variables

The dependent variables will be the same as those discussed in the test plan for the SEA terminal area model presented in Appendix D.

15.9 Experiment Setup

The assumption in developing this plan will be that four individuals will be involved in the ATC testing and support of the experiment, not including a test conductor and any evaluators that may be necessary.

1. A local controller (LC) position will be evaluated.
2. A final controller (AR) position will be evaluated.
3. An AILS monitor (MR) will be evaluated.
4. A pseudo-controller (PPC) will carry out the other ATC support functions: A second AR-final controller, two feeder controllers, adjacent sector controllers, a departure controller, and a tower and TRACON coordinator.

The equipment required for the simulated air traffic controller stations in the experiment is indicated in Table E1.

Table E1. - Simulator Equipment Requirement

	SIMULATION EQUIPMENT	AR	TOWER LC	MR	PPC
1	Radar display/software	FDAD	DBRITE	FDAD	PC monitor
2	Air to ground AILS alert	x	x	x	
3	Ground generated alert	x	x	x	
4	Vox radio com channel	x	x	x	
5	Com head, push-to-talk	x	x	x	x
6	Track ball and software	x	x		
7	Coordination line to AR		x	x	
8	Coordination line to LC	x		x	
9	Coordination line to PPC	x	x	x	

AR - Final Controller LC - Local Controller PPC - Pseudo Position Controller
MR - AILS Monitor Controller CC/CI - Cab Coordinator/Radar Coordinator

15.10 Conducting the Experiment

The same discussion as in the experiment plan for the modeled SEA terminal area presented in Appendix D applies to this suggested experiment.

15.11 Scenarios for the Two Aircraft after the Intrusion Incident

Figures 18 through 23 present incident scenarios for the two aircraft including the route of the intrusion incident. The path of the intruder aircraft can be preprogrammed up to the start of the EEM. When the scenario includes the intruder maneuvering in response to ATC instructions, the pseudo-pilot will make inputs to control the path of the intruder.

Appendix F

16.0 Suggested AILS-ATC Experiment Plan, Minneapolis St. Paul Terminal Model

16.1 Introduction

The Minneapolis-St. Paul (MSP) terminal area environment is under consideration for testing the AILS concept in an ATC environment with closely spaced parallel runways approximately 3400 ft. apart. The actual lateral distance between parallel runways 30L and 30R is 3380 feet.

The approach to developing the test plan is to assume that the experiment can be conducted either as an integrated part of the flight deck experiment with a real-time flight simulator or else as a stand-alone simulation. As a stand-alone simulation, it is anticipated that at least one pseudo-pilot facility or low fidelity flight deck simulator will support the experiment by representing the roles of the aircraft involved in the scenarios.

The scenarios should include the entire relevant airspace operation beginning in the feeder controller's airspace, through the final controller's airspace, into the tower local controller traffic pattern for landing, and the execution of an emergency escape maneuver (EEM), or missed approach. If either the EEM or a missed approach is executed, the flight of the aircraft should continue for approximately three minutes so that the two aircraft involved in the initial incident are on stable flight paths with appropriate clearances and the impacted ATC positions have stabilized their operations.

The Minneapolis-St. Paul terminal area model affords an opportunity to test in an environment where only two controller positions are evaluated and yet sound and valuable data can be obtained. It is evident from the analysis and discussions of the operations in this terminal area that, in an intrusion event, it is unlikely that the track of either aircraft would proceed into the airspace of the departure controller. Even if one does proceed in that direction, it would be very similar to a missed approach operation and managing such an event is a relatively routine occurrence, or at least an event with which ATC has considerable experience. Therefore, this experiment will be developed to test a single local controller position and a single final controller position. All other controller positions and tasks will be represented by a pseudo-controller operation, including a second local controller position, the departure controller position, and the feeder controller position.

16.2 Minneapolis St. Paul Terminal Environment

Figure 24 presents an illustration of the Minneapolis-St. Paul terminal area. Its parallel runways, 12L/30R and 12R/30L, are crossed by runway 4/22. The usual traffic flow involves takeoff and landing operations on both parallel runways during all weather conditions.

Approval was received in October 1997, for MSP ATCT to utilize the Instrument Landing System Precision Runway Monitor (ILS PRM). This system allows for independent simultaneous ILS approaches to runways spaced 3400 ft. apart. The PRM system uses high-update rate radar and a high-resolution color monitor. Two final monitor controllers operate the PRM similar to conventional independent approaches where final monitor controllers are required.

The ILS PRM system was operational in MSP from October 1997 until March 1998. The planning necessary to integrate that system into MSP terminal airspace resolved a number of the issues of how an AILS system will need to be integrated in the MSP airspace. Therefore, an overview of the ILS PRM process at MSP is included in this discussion. It is emphasized that the AILS process does not in any manner depend upon the existence and operation of the PRM system.

Under ILS PRM protocol for IFR operations, the parallel approaches to runways 30L and 30R are independent. Based on information provided by MSP, the normal operating practice is to conduct paired approaches when ILS PRM approaches are in use. The following discussion explains why this is done.

Dependent staggered approaches and independent simultaneous approaches are the two operational modes for managing approaches to runway 30L/30R during IFR operations. A dependent staggered operation is used until traffic volume becomes so high that a greater capacity can be achieved by using independent simultaneous approaches. During these high volume periods, the operation is normally changed over to independent simultaneous ILS approaches using the PRM. When the demand diminishes at the end of these periods, there is a change back to the dependent staggered operation that does not require use of the PRM. Another consideration involves the need to get the departure traffic airborne between landing operations using the same two parallel runways. This need exists because the arrival and departure peaks occur at the same time. Once a pair of aircraft land, two departing aircraft taxi onto the two runways and depart before the next two arriving aircraft land. Pairing the aircraft has two functions. It facilitates providing gaps for the departing aircraft and it facilitates switching between independent ILS PRM operations and dependent staggered operations.

Prior to turning on the final approach course, the final controller will sequence the two aircraft for either a dependent staggered approach or an independent simultaneous approach. Successive aircraft pairs are longitudinally spaced four to five miles in trail to facilitate departures. It is emphasized that there is no safety requirement to pair the traffic in this manner for the ILS PRM operation. This procedure is used to increase traffic management efficiency.

16.3 Precision Runway Monitor at Minneapolis Airport

1. Authorization

   The FAA authorized Minneapolis-St. Paul ATCT to conduct simultaneous close parallel ILS PRM approaches in October 1997. These approaches are authorized for runways 30L/R and 12L/R. A waiver was required because the runways are 3380 ft. apart and not 3400 ft. apart as required for ILS PRM.

2. Methodology
The ATIS broadcast announces when ILS PRM approaches are in progress and the pilots notify ATC on initial contact if they cannot meet the requirement to perform the approach. Each aircraft is assigned two frequencies when conducting the approach: a primary frequency to transmit and receive control instructions from ATC, and a monitor-only frequency to avoid a blocked transmission from air traffic control.

3. ATC Traffic Flow
Arrival and departure peaks occur at the same time, consequently departure spacing is provided when conducting approaches. Departures use both parallel runways. Four to five mile spacing on final approach is needed to provide enough time for departures.

A staggered approach sequence is used until the flow reaches approximately 20 miles on the final approach path at which time a transition to simultaneous independent ILS approaches is made.

16.4 Experiment Objective

The objective of this experiment is to determine the effectiveness of the tower local controllers and the final controller in performing the tasks required in an AILS operation. The test will determine effectiveness of the controllers handling the two aircraft, which have departed from the nominal operation; namely, the erring intruder flight and the aircraft that executes the EEM to avoid a mishap. The EEM executed will be the turning-climb maneuver. The tests will also assess the acceptability of other features of the AILS process, such as the initial transfer of responsibility for separation from traffic operating on the parallel approach to the flight deck crew while the air traffic controllers retain responsibility for longitudinal in-trail separation.

16.5 Scope

The testing will allow evaluation of the effectiveness of the tower local controller (LC) and a final controller (AR). These two positions will be fully simulated with no artifacts of the experiment hindering these controllers' performance of realistic operations. The other air traffic controller position functions will be represented in the experiment in a manner that supports the flight deck experiment (if conducted in concert) and the ATC experiment. No attempt will be made to represent other ATC functions realistically. A pseudo-controller position will simulate all other functions of the ATC system that need to be represented in the simulation. The pseudo-controller is assumed to be a person with a high level of automation experience to support the requirements. The pseudo-controller should operate the experiment in a manner that aids in presenting a realistic environment for the subjects of the experiment.

It is assumed that the AILS approaches are controlled directly by the tower local controller managing traffic to that particular runway. That LC will be responsible for re-establishing control and assuming responsibility for the AILS traffic once an incident or EEM has occurred. The local controllers will be expected to manage the two erring aircraft, including the completion of any necessary coordination with other controller positions.

They will have to safely manage the traffic not directly involved in the intrusion incident that may be continuing on the approach to the runway. And further, they will have to continue managing departure aircraft and aircraft that have already landed and have not been transferred to a ground control position.

16.6 Independent Variables

The independent variables will be the same as those discussed in the test plan for the SEA terminal area model presented in Appendix D.

16.7 Dependent Variables

The dependent variables will be the same as those discussed in the test plan for the SEA terminal area model presented in Appendix D.

16.8 Experiment Setup

The assumption in developing this plan will be that three individuals will be involved in the ATC testing and support of the experiment, not including a test conductor and any evaluators that may be necessary.

1. A local controller position will be evaluated.
2. A final controller position will be evaluated.
3. A pseudo controller will carry out the other ATC support functions: A second AR position, a second local controller position, any feeder controller position, a tower and TRACON coordinator positions, and any adjacent sector positions necessary.

The equipment required for the simulated air traffic controller stations in the experiment is indicated in Table F1.

Table F1. Simulator Equipment Requirement

	SIMULATION EQUIPMENT	AR	TOWER LC	PPC	CC/CI
1	Radar display/software	FDAD	DBRITE	PC monitor	PC monitor
2	Air to ground AILS alert	x	x		
3	Ground generated alert	x	x		
4	Vox radio com channel	x	x		
5	Com head, push-to-talk	x	x	x	
6	Track ball and software	x	x		
7	Coordination line to AR		x		x
8	Coordination line to LC	x			x
9	Coordination line to PPC	x	x		x
10	Coordination line to CC/CI			x	x

AR - Final Controller LC - Local Controller PPC - Pseudo Position Controller
CC/CI - Cab Coordinator/Radar Coordinator

16.9 Conducting the Experiment

The same discussion as in the experiment plan for the modeled SEA terminal area presented in Appendix D applies to this suggested experiment.

16.10 Scenarios for the Two Aircraft after the Intrusion Incident

If a hardware-based flight deck simulator is used (as opposed to a software-only model), only the path of the intruder prior to the EEM can be preprogrammed. As the subject air traffic controller assumes responsibility for the aircraft, the intruder aircraft becomes a pseudo-pilot controlled aircraft. This transition is initiated when it is given the first ATC instruction. Pseudo-pilot input to control aircraft will initiate the transition.

If a hardware-based flight deck simulator is not used, a pseudo-pilot could represent the evading aircraft. Its trajectory can also be canned until the intrusion incident transpires. It is possible to consider incorporating the trajectories of the encounters of a previously conducted flight deck simulation study. After the incident starts the pseudo-pilot operation can represent the operation of both aircraft involved in the incident.

Figures 25 through 28 present the example incident scenarios developed for the MSP experiment.

Appendix G

17.0 Subjective Evaluation Form for Controller Subjects

Subjective Evaluation Form for Controller Subjects

Position: LC AR (AILS)MR Date: Subject:
(Circle one of the above)

Display Requirements

1. Were you able to see the separation between targets when initially requested to assume control after the EEM?
   a. never b. occasionally c. frequently d. entire operation

2. Could all of the traffic impacted by the emergency escape maneuver be easily observed on your radar display?
   a. never b. occasionally c. most frequently d. entire operation

3. Was there traffic not in view on the radar display that needed to be accounted for in dealing with the problem?
   a. never b. occasionally c. frequently d. entire operation

4. Was there other traffic that was immediately impacted by the maneuvering of the erring traffic?
   a. never b. occasionally c. frequently d. entire operation

5. How many other aircraft (excluding the two initially involved in the conflict) were given vectors, speed adjustments, or watched closely to avoid an additional conflict after the emergency escape maneuvering started?
   a. none b. one or two c. three or four d. five or six e. larger number

Communication Requirements (after the missed approach or incident)

6. Was there adequate time for communication with your aircraft?
   a. never b. occasionally c. frequently d. entire operation

7. Did you feel that you were able to make all of the communications necessary to manage the task in a timely manner?
   a. never b. occasionally c. frequently d. entire operation

8. Did you make all of the communications with aircraft that you desired to make?
   a. never b. occasionally c. frequently d. entire operation

9. How often did you feel that the situation was on the verge of being out of hand?
   a. never b . occasionally c. frequently d. entire operation

10. How often did you sense that you had fallen behind the pace of what was needed to be done?
    a. never b. occasionally c. frequently d. entire operation

Alerts

11. Did you find the caution (amber warning) alert adequate to cue you that an intrusion incident was evolving?
    a. inadequate b. some deficiencies c. neutral d. adequate
    e. above average

12. Did you find the caution alert a useful feature?
    a. unnecessary distraction b. slightly distracting c. neutral
    d. somewhat beneficial e. very beneficial

13. Was the audio tone associated with the caution alert useful?
    a. unnecessary distraction b. slightly distracting c. neutral
    d. somewhat beneficial e. very beneficial

14. Was the intrusion warning (red alert) adequate to cue you that an intrusion incident was in progress?
    a. unnecessary distraction b. slightly distracting c. neutral
    d. somewhat beneficial e. very beneficial

15. Did you find the red alert a useful feature?
    a. an unnecessary distraction b. slightly distracting c. neutral
    d. somewhat beneficial e. very beneficial

16. The aural sound warning of the intrusion incident was
    a. an unnecessary distraction b. slightly distracting c. neutral
    d. somewhat beneficial e. very beneficial

17. Do you feel that you could have done the job just as well without the alerts?
    a. never b. occasionally c. uncertain d. usually e. always

Coordination Requirements (controller and coordinator)

18. Was there adequate time available to coordinate with the controller position to whom the erring traffic was handed off?
    a. never b. occasionally c. uncertain d. usually e. always

19. Was the coordination process smooth and handled well?
    a. never b. occasionally c. uncertain d. usually e. always

20. Were there unexpected situations to coordinate during the incidents?
    a. never b. occasionally c. uncertain d. usually e. always

21. Did you complete all of the coordination communications you intended?
    a. never b. occasionally c. uncertain d. usually e. always

Other Traffic (*Control of traffic not immediately involved in the incident while the intrusion was in progress and immediately afterwards*)

22. Did you feel that there was adequate time available to continue your normal duties of controlling traffic not involved in the incident?
    a. too rushed b. slightly rushed c. adequate d. no effort

23. Did traffic not directly involved in the incident have to be maneuvered to resolve the problem and stabilize the traffic flow?
    a. no changes b. slight maneuvering required
    c. significant maneuvering required d. pushed to the edge
    e. unable to manage

24. Do you feel that the realism of the simulation was adequate to draw conclusions about the effectiveness of the controller in managing and resolving the situations you were exposed to in this study?
    a. excellent b. minor deficiencies c. average d. fair e. poor

Space for Comments on any Aspects of the Simulation:

Run Debriefing Form

Run no. ________ Date:

Subject no. ___ Position LC DR (AILS Monitor)MR AR

(Circle one of the above)

1. Prior to any incident (intrusion or missed approach), based on my workload, I would describe the task as
   a. not difficult b. somewhat difficult c. moderately difficult d. very difficult

2. Was the coordination among control positions adequate in this run?
   a. poor b. fair c. good d. above average e. excellent

   If you answered Poor or Fair , who did you have problems coordinating with?
   Circle response: LC DR MR AR CI CC other
   Comment:

3. Which other controllers did you coordinate with (directly communicate)?
   a. LC b. AR c. FR d. MR e. DR

4. Did you experience communication delays because the frequency was in use?
   a. big problem b. some problem c. mostly no problem d. no problem

--Stop here if no incident or missed approach occurred ----

5. Rate the difficulty of managing the erring traffic and bring the control of traffic in your airspace back to a stable flow.
   a. not difficult b. somewhat difficult c. moderately difficult d. very difficult

6. Planning my action to resolve the traffic conflict was
   a. not difficult b. somewhat difficult c. moderately difficult d. very difficult

7. The information available to assess the situation was
   a. significant deficiencies b. about right c. excellent

8. How would you rate the value of the caution and warning alerts?
   a. both very helpful c. caution helpful but warning unnecessary
   b. both unnecessary d. warning helpful but caution unnecessary

9. The impact of the intrusion on my control of traffic not directly involved in the incident was
   a. a big problem b. some problem c. mostly no problem d. no problem

Local Control Only:

10. When you were first notified (by the pilot) that an incursion was taking place between the two aircraft, the targets
    a. were merged with no altitude separation
    b. were not merged, but there was a loss of separation between the two aircraft
    c. separated

Please Make Any Additional Comments on this Run on the Back of this Sheet.

18.0 List of Figures

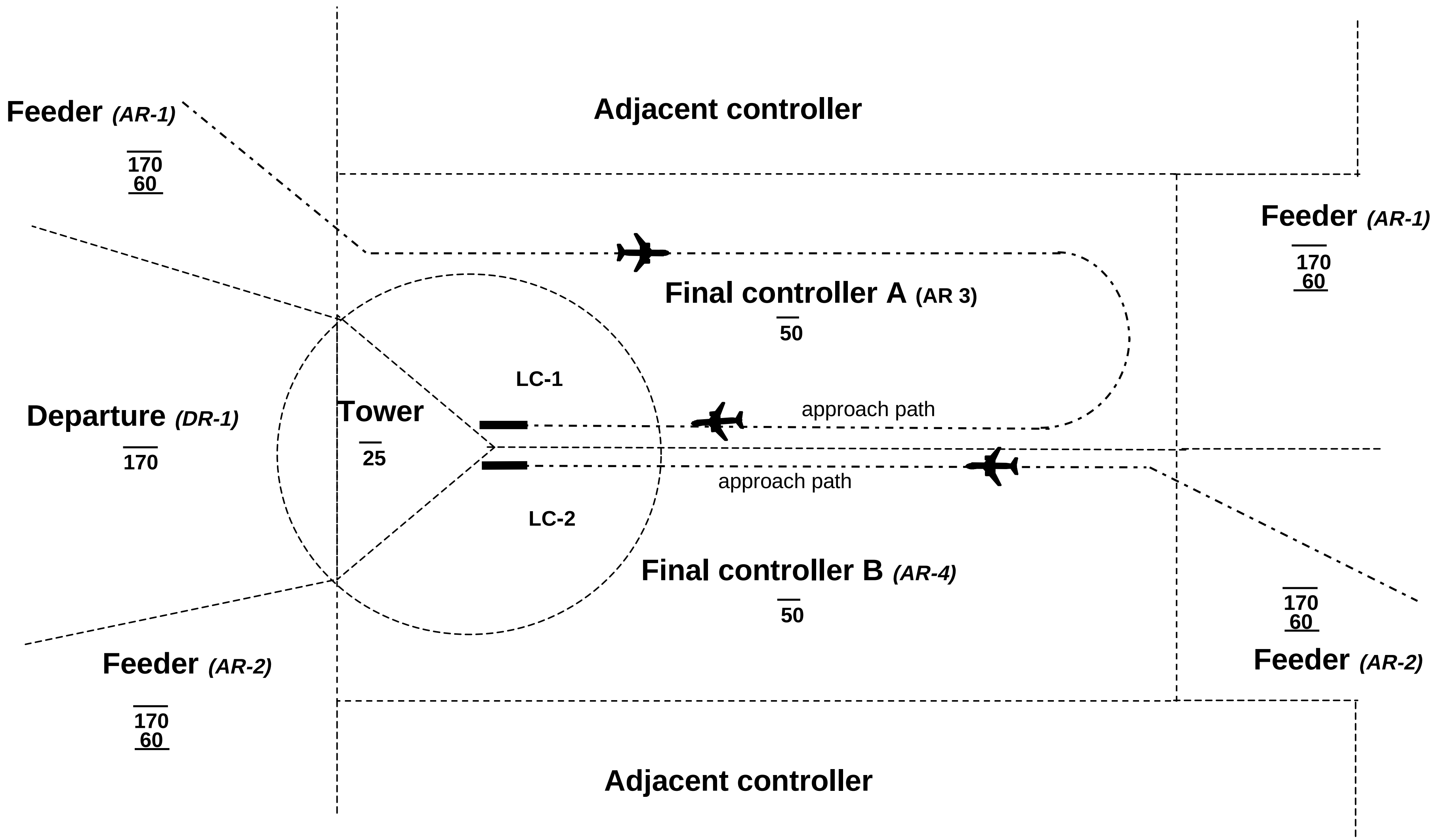
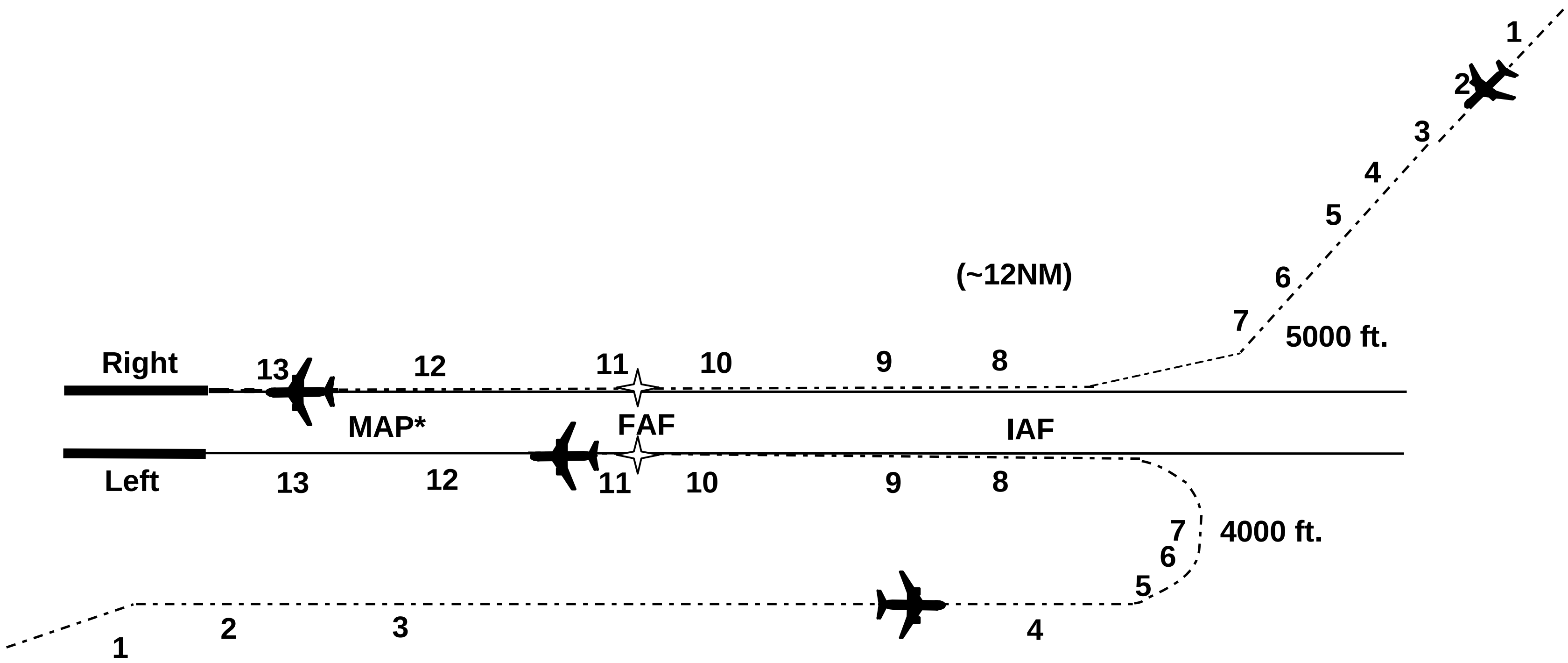


Figure 1. Typical terminal airspace allocation.

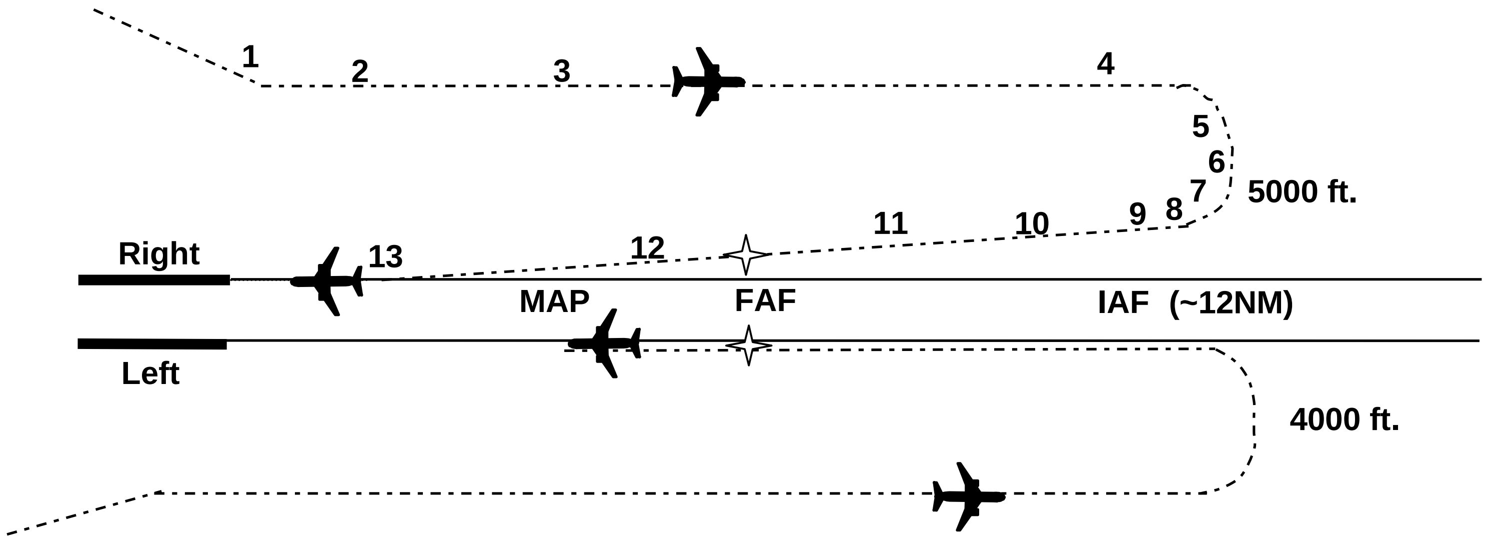


1. Feeder controller handoff to Final controller
2. Descend to 4000 ft./5000ft.
3. Speed adjustment (e.g. 210 kts.)
4. Turn base leg (where applicable)
5. Traffic pointed out
6. Turn to join localizer (≤30 deg.)
7. Altitude assignment as appropriate

8. Issue approach clearance
   (Flight deck crew assumes lateral separation responsibility)
9. Communications transfer to Tower prior to the Final Approach Fix (FAF)
10. Contact tower prior to FAF
11. Landing clearance from tower
12. Must be VMC at MAP *
13. Complete approach or missed approach

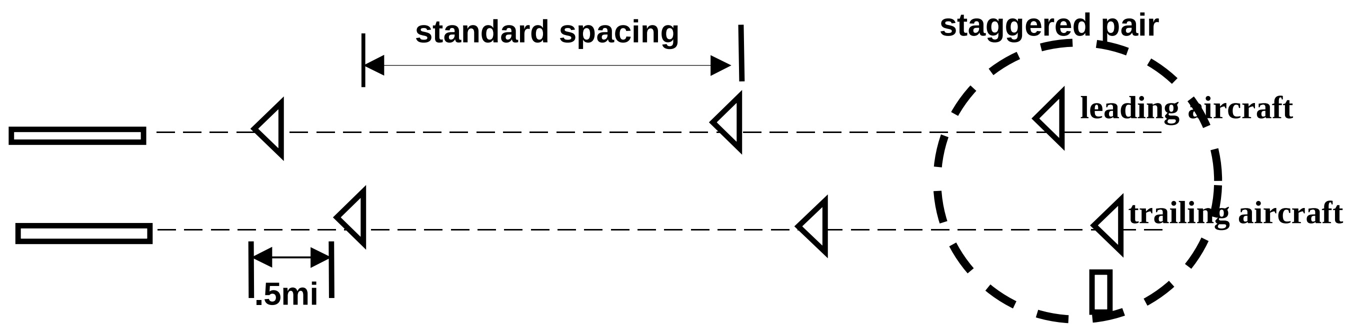
* Premise to continue approach: traffic in sight, flight deck crew maintaining visual separation.

Figure 2. Independent straight-in AILS approaches.



1. Feeder to Final handoff
2. Descend to 4000 ft/5000ft
3. Speed adjustment (e.g. 210 kts)
4. Turn base leg (as appropriate)
5. Traffic Pointed Out
6. (Turn to) join localizer
7. Final controller monitors progress
8. Issue approach clearance
   (Flight deck crew assumes lateral separation responsibility)
9. Transfer of control to tower prior to FAF
10. Contact tower prior to FAF
11. Landing clearance from tower
12. Must be VMC at MAP
13. Complete approach or missed approach

Figure 3. Independent segmented AILS approaches.



- Traffic on parallel approaches paired and staggered (e.g., 0. 5 miles)
- Exploits longitudinal spacing to achieve blunder protection

Figure 4. Paired staggered concept.

Two elements of AILS flight deck centered technology aid pilots in:

- accurate flight path management
- conflict detection and resolution

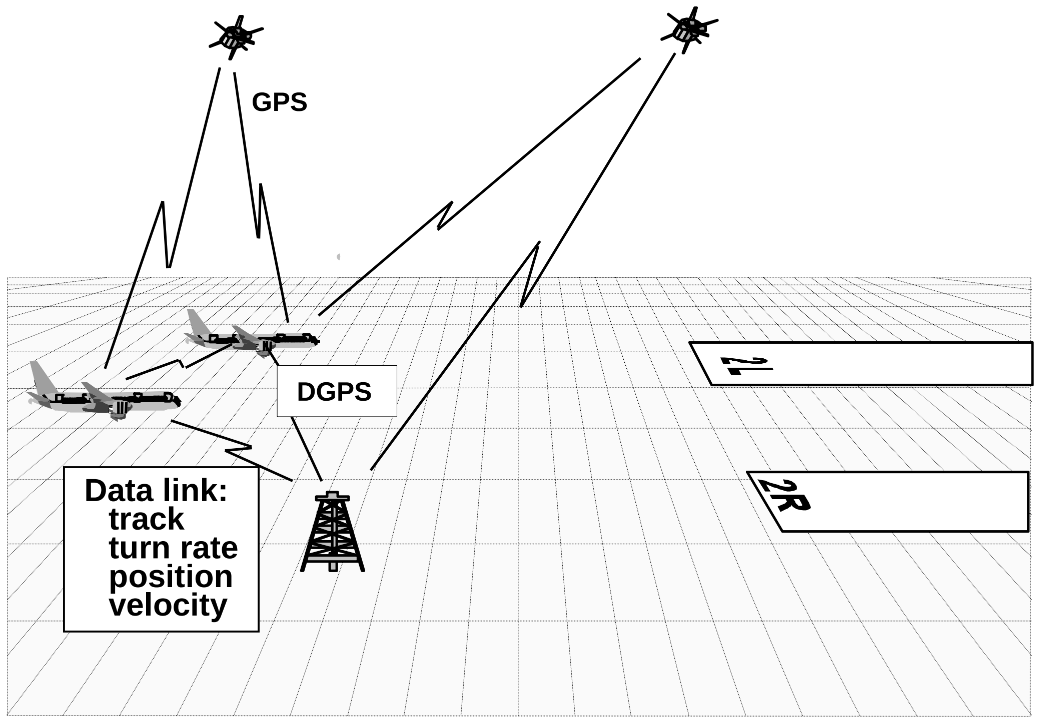
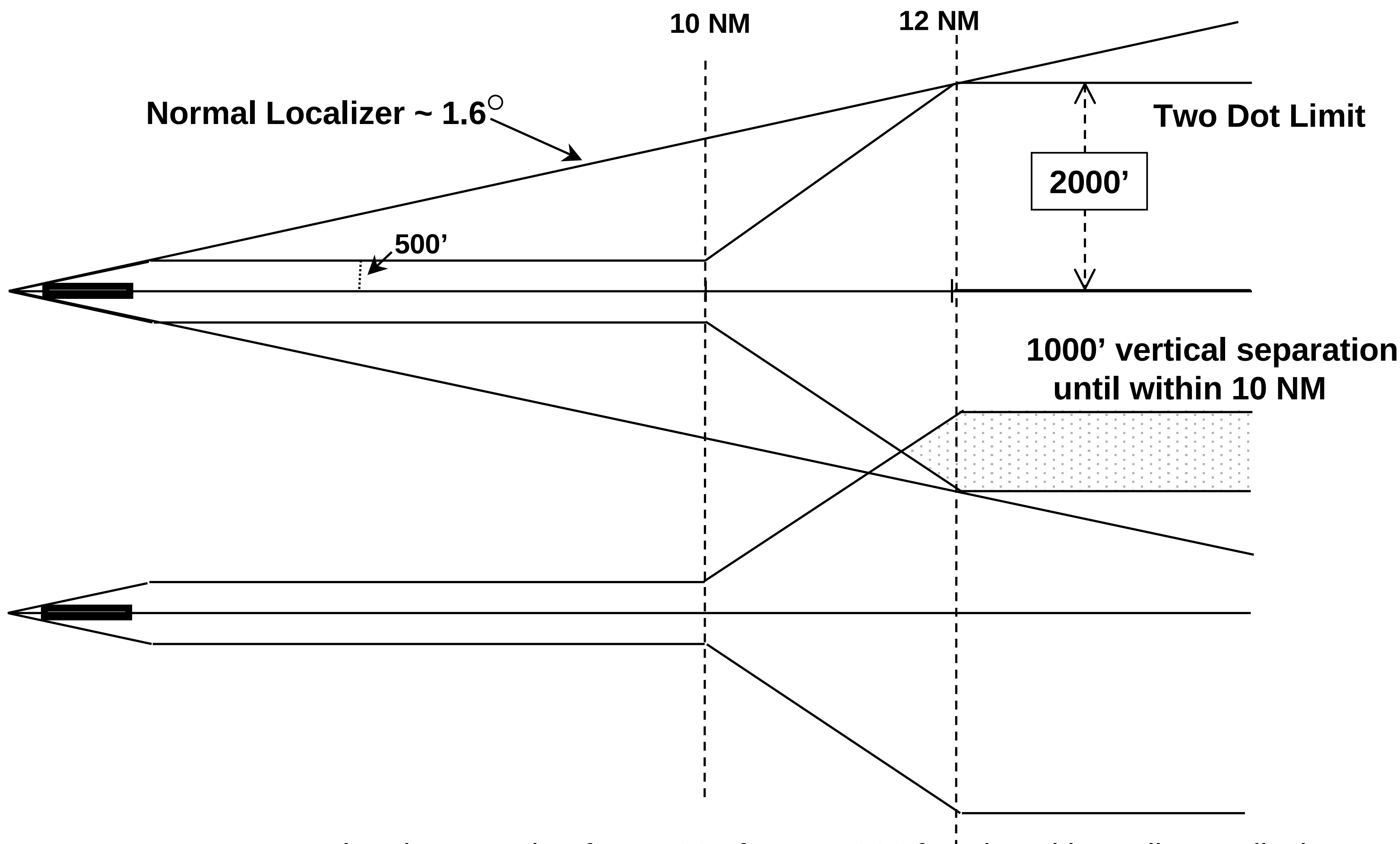
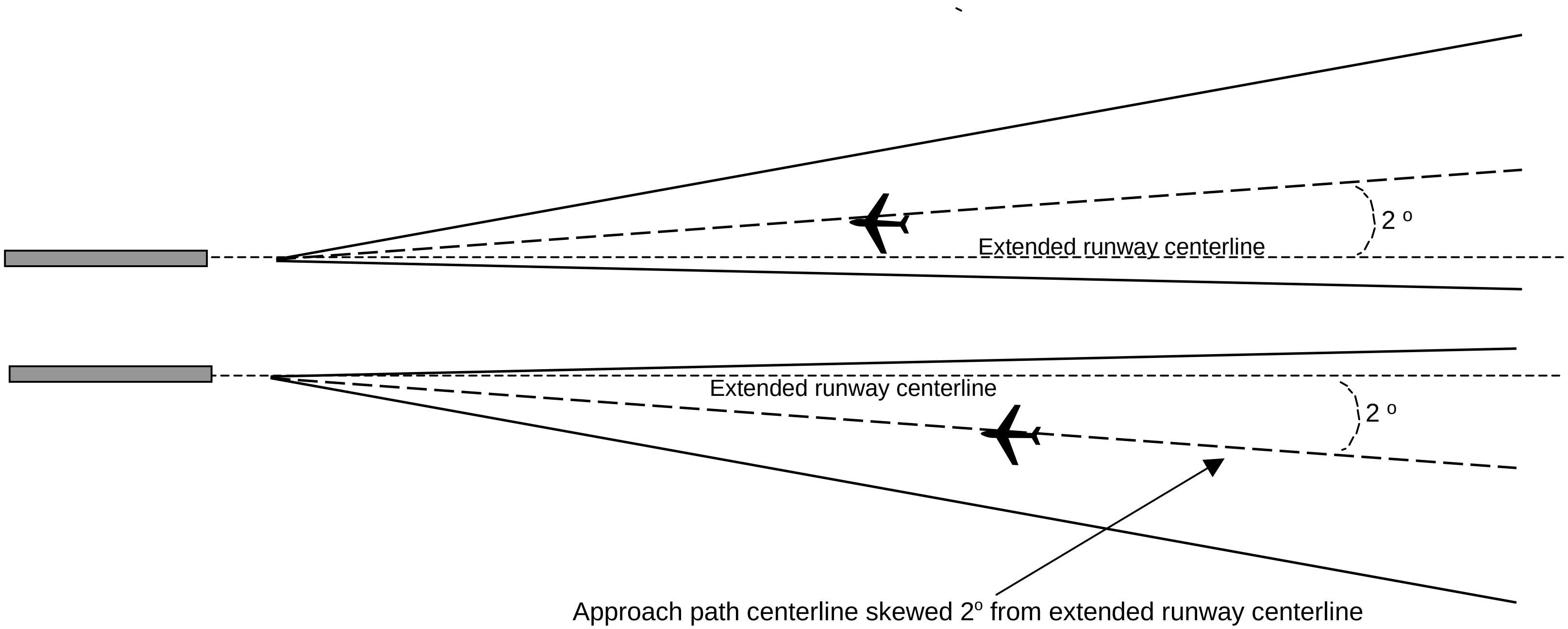


Figure 5. The AILS concept.



a. Lateral path tapered to from 4000 feet to 1000 feet (used in earlier studies)

Figure 6. Modified lateral path constraints (localizer) based on DGPS.



b. DGPS-based angular localizer look-alike skewed 2 degrees.

Figure 6. Concluded

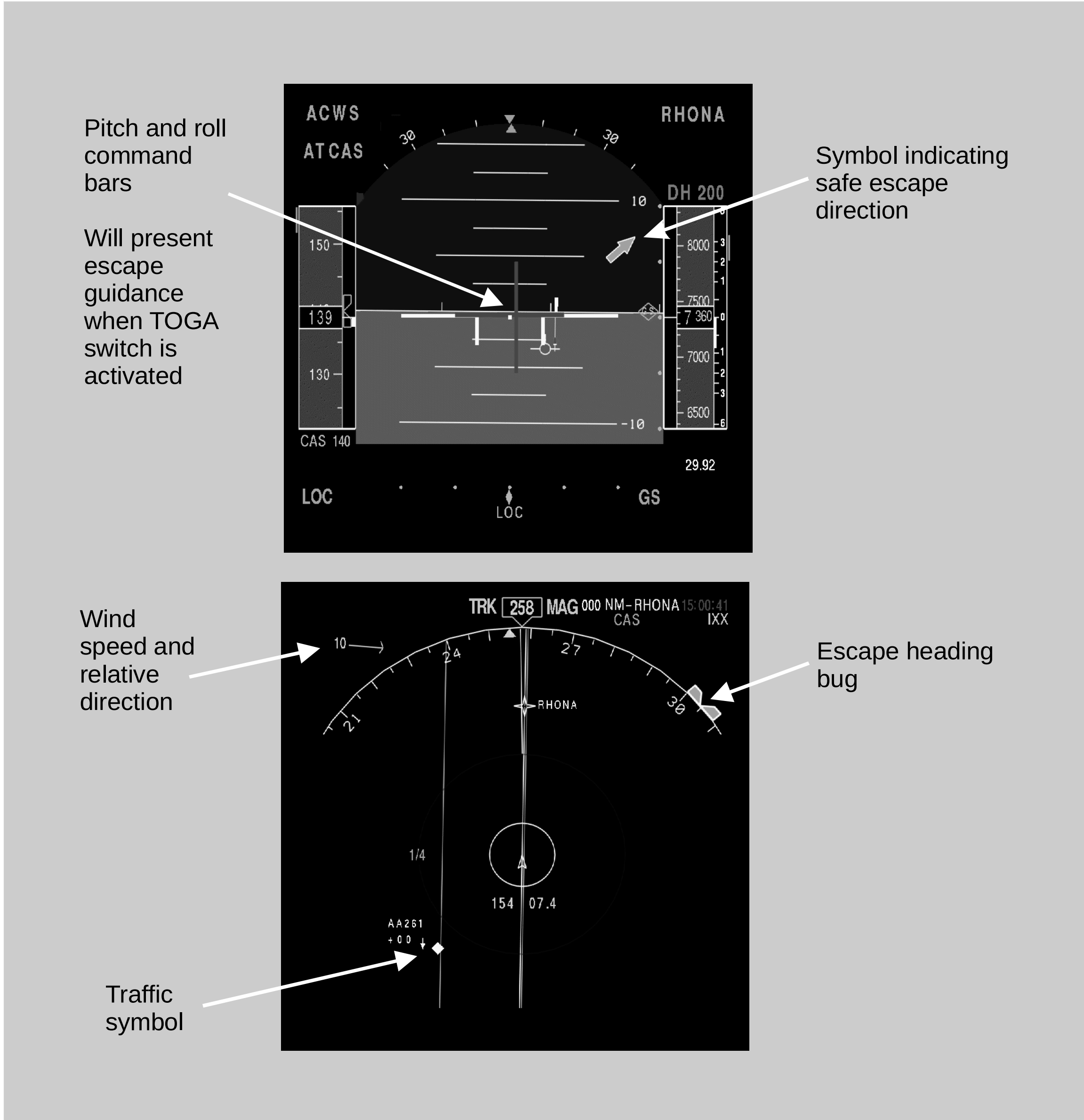


Figure 7. - AILS information presented in the PFD and ND (Nominal condition, no alert, AILS algorithms activated, one nautical mile display range).

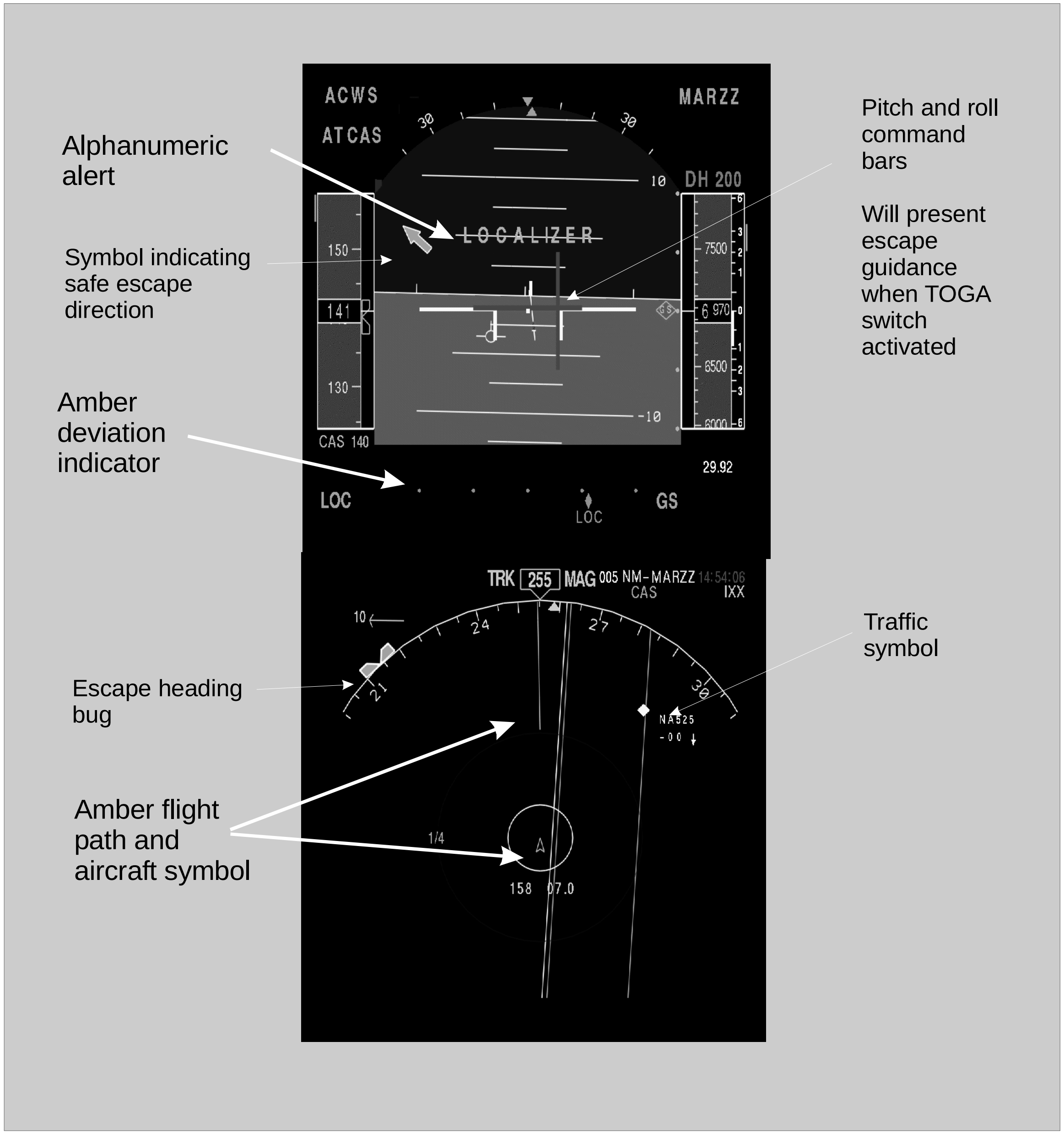


Figure 8. AILS information showing own airplane lateral deviation caution alert (Level two alert uses amber color coding).

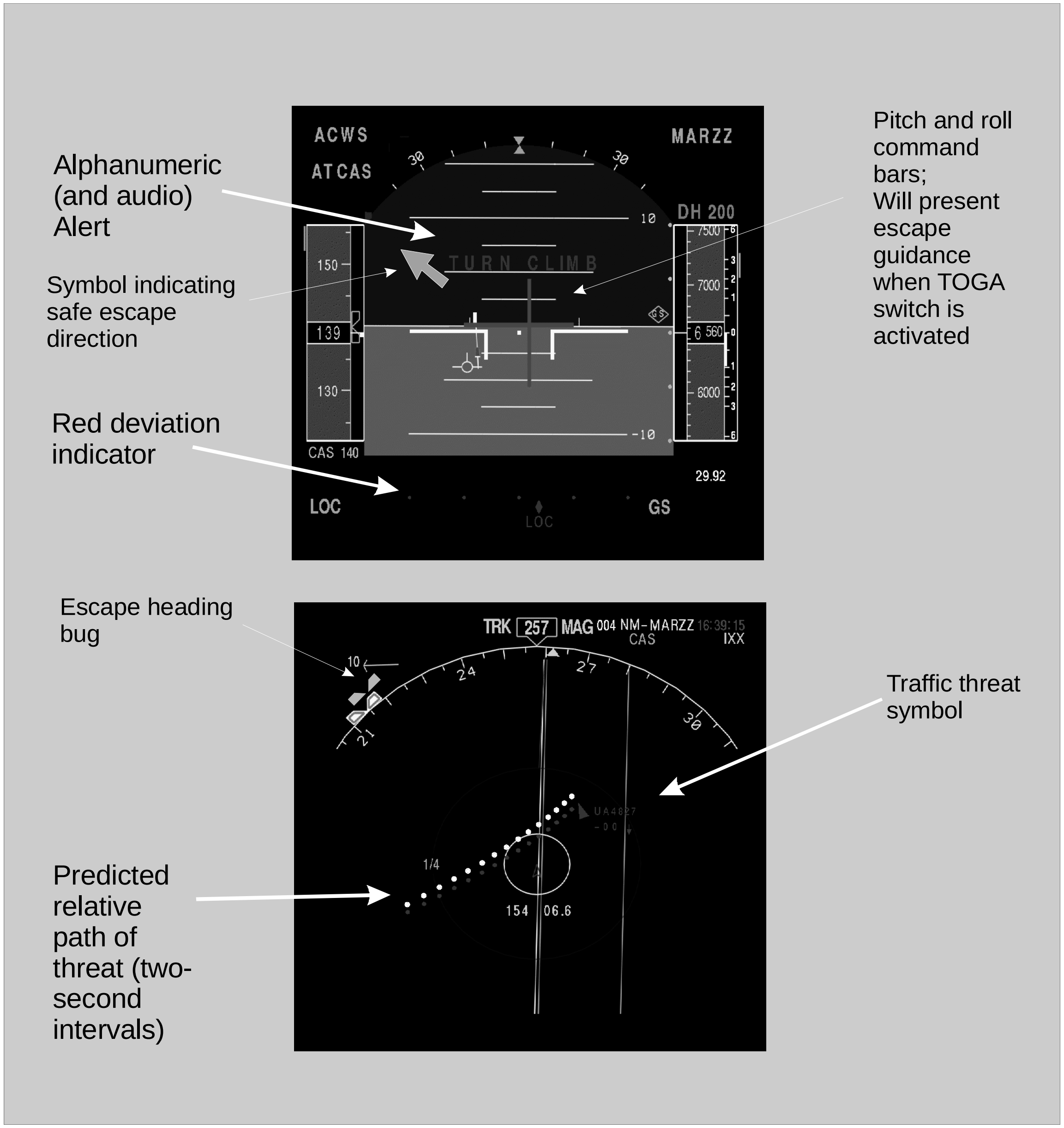


Figure 9. Traffic warning, level three alert (one nautical mile display range, red color coding for level three alert).

- Typically Tower Local Controllers use 15 NM range scaling

    10 to 40 NM available in 2NM increments

    2 NM range marks

    User preference with some variations

- Target Size on DBRITE display

    (Digital Bright Radar Indicator Tower Equipment)

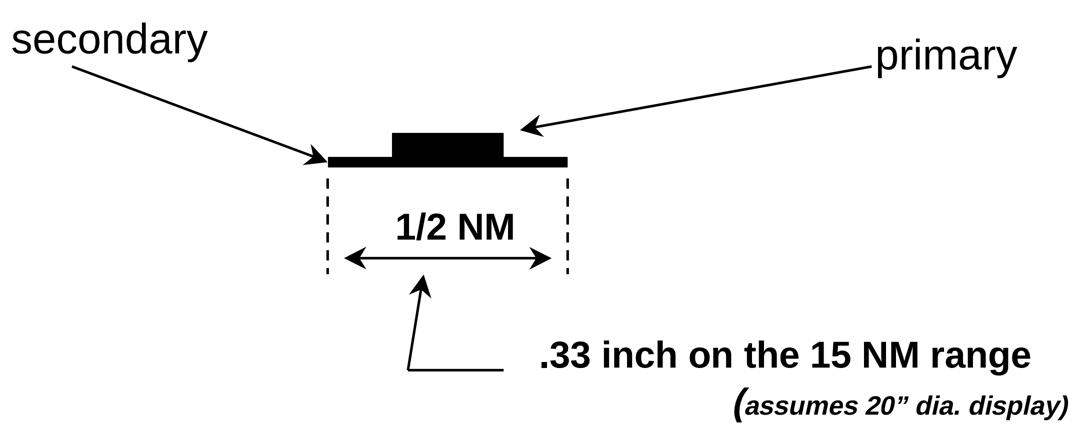
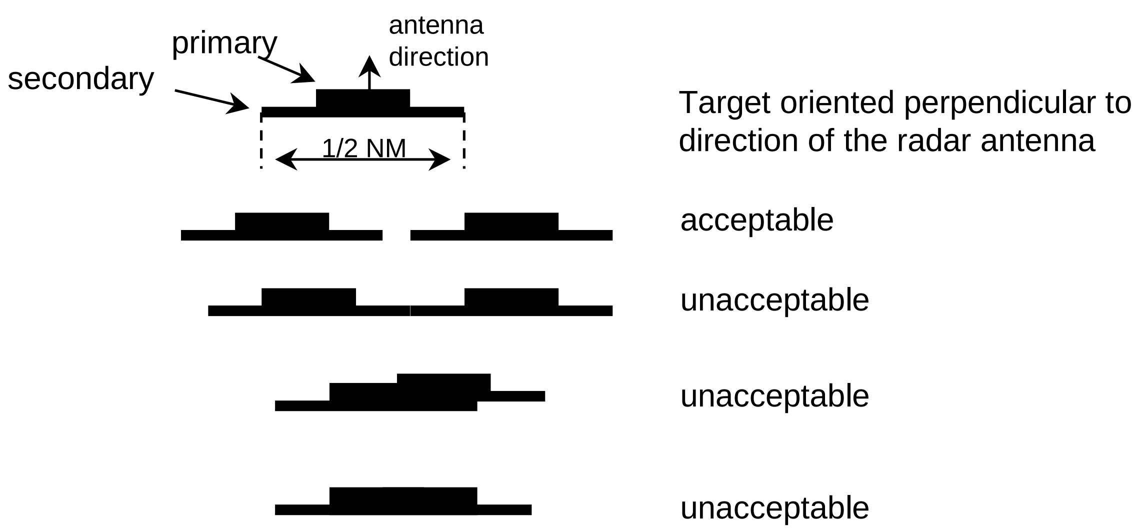


Figure 10. ARTS IIIA/E radar display scaling.



Rule of thumb: To accept control when altitude separation is less than 1000 ft., targets should be diverging with separation between targets.

Figure 11. Tower local controller radar display resolution.

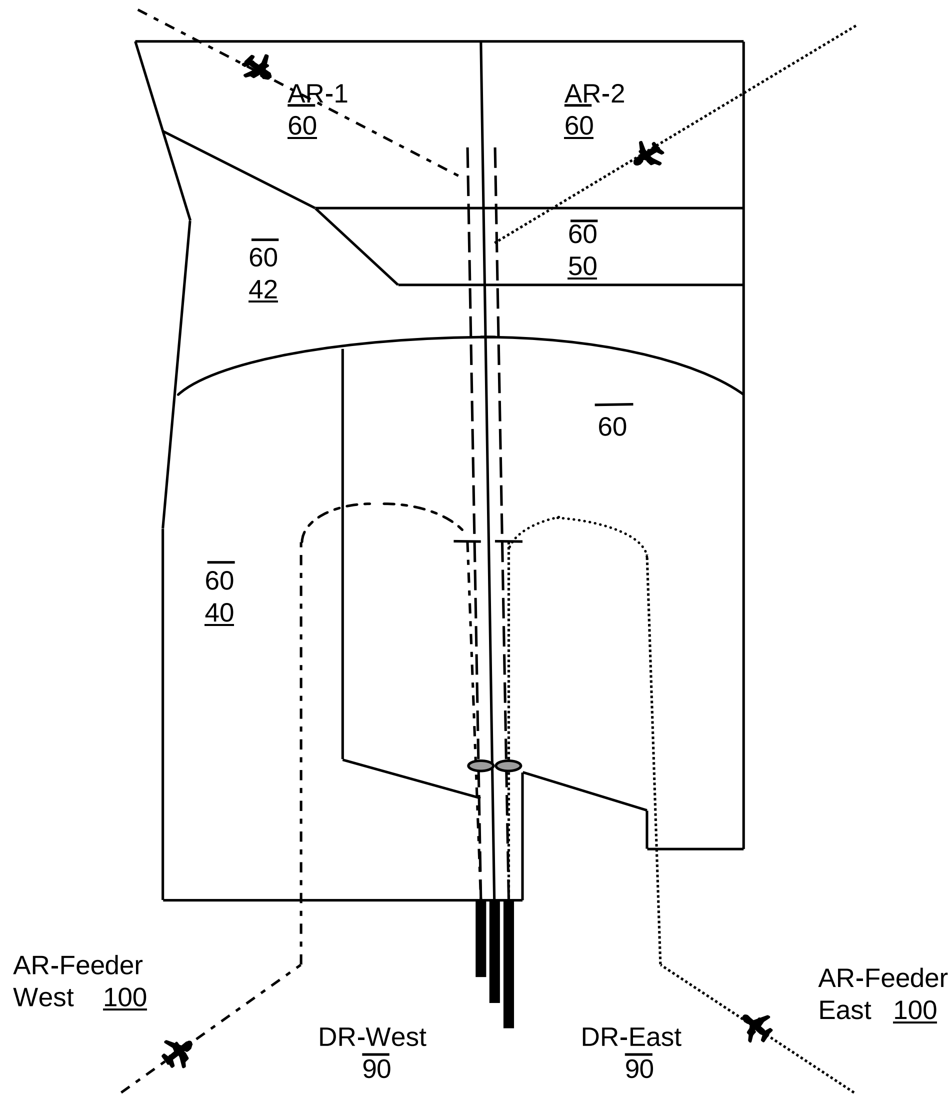


Figure 12. Nominal traffic pattern in the Seattle-Tacoma terminal area.

1. AR-Feeder East hands off Intruder aircraft to AR-2 descending to 6000'.
2. AR-2 descends Intruder to 3000' on downwind.
3. AR-2 turns Intruder approximately 12 mile final, descends aircraft to 2000', clears aircraft for AILS RWY 16L Straight-In Approach and contact LC-East approximately nine mile final.
4. AR-Feeder West hands off Evader aircraft to AR-1 descending to 6000'.
5. AR-1 descends Evader on downwind to 4000'.
6. AR-1 turns Evader approximately 12 mile final, descends aircraft to 3000', clears aircraft for AILS RWY 16R Straight In Approach and contact LC-West approximately nine mile final.
7. Prior to FAF the Intruder deviates 30 degrees right of course.
8. The Evader turns to a 205 deg. heading and climbs to 4000'.
9. The CI coordinates with AR-1/AR-Feeder West/DR-West. AR-1 approves downwind RWY 16R or both aircraft and 4000'
10. CI and CC coordinate transfer of control of both aircraft back to AR-1.
11. LC-West turns Evader to downwind climbing to 4000' and switches aircraft to AR-1.
12. LC-East turns Intruder to downwind climbing to 4000' and switches aircraft to AR-1.
13. Both aircraft are sequenced back into AR-1's traffic pattern.

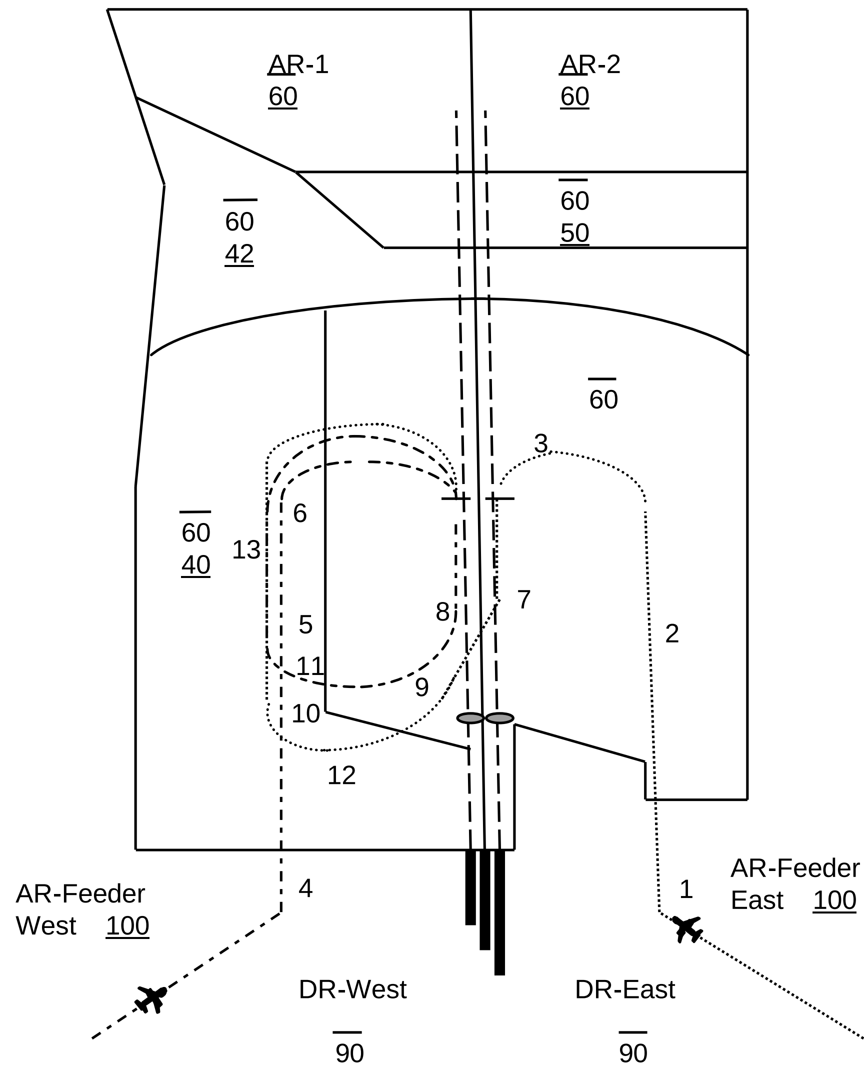


Figure 13. SEA incident scenario 1: RWY 16R straight-in approach, EEM right of course.

1. AR-Feeder West hands off Intruder aircraft to AR-1 descending to 6000'.
2. AR-1 descends Intruder to 4000' on downwind.
3. AR-1 turns Intruder approximately 12 mile final, descends aircraft to 3000', clears aircraft for AILS RWY 16R Straight-In Approach and contact LC-West approximately nine mile final.
4. AR-Feeder East hands off Evader aircraft to AR-2 descending to 6000'.
5. AR-2 descends Evader on downwind to 3000'.
6. AR-2 turns Evader approximately 12 mile final, descends aircraft to 2000' clears aircraft for AILS RWY 16L Straight-In Approach and contact LC-East approximately nine mile final.
7. Prior to FAF the Intruder deviates 30 degrees left of course.
8. The Evader turns to a 115 degree heading and climbs to 3000'.
9. The CI coordinates with AR-2/AR-Feeder East/ DR-East. AR-2 approves downwind RWY 16L for both aircraft climbing to 3000'.
10. CI and CC coordinate transfer of control of both aircraft back to AR-2.
11. LC-East turns Evader to downwind climbing to 3000' and switches aircraft to AR-2.
12. LC-West turns Intruder to downwind climbing to 3000' and switches aircraft to AR-2.
13. Both aircraft are sequenced back into AR-2's traffic pattern.

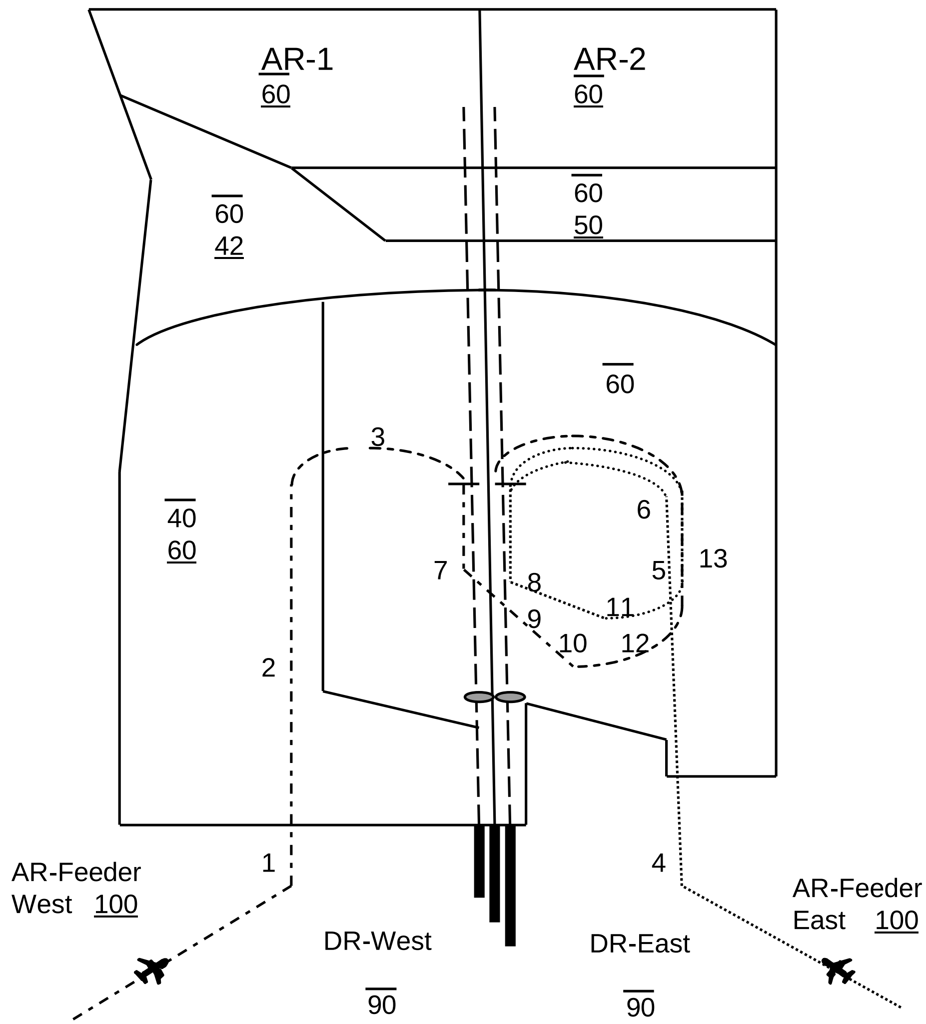


Figure 14. SEA incident scenario 2: RWY 16L straight-in approach, EEM left of course.

1. Both aircraft executing AILS RWY 16L/R straight-in approaches. On final, both aircraft are on their respective LC frequencies.
2. The aircraft on AILS RWY 16R approach executes a missed approach and climbs to 2000’ on the SEA R-158.
3. LC-West/CC coordinates with DR-East/West and AR-Feeder West for missed approach.
4. Aircraft told to switch to DR-West frequency for vectors to the approach pattern.

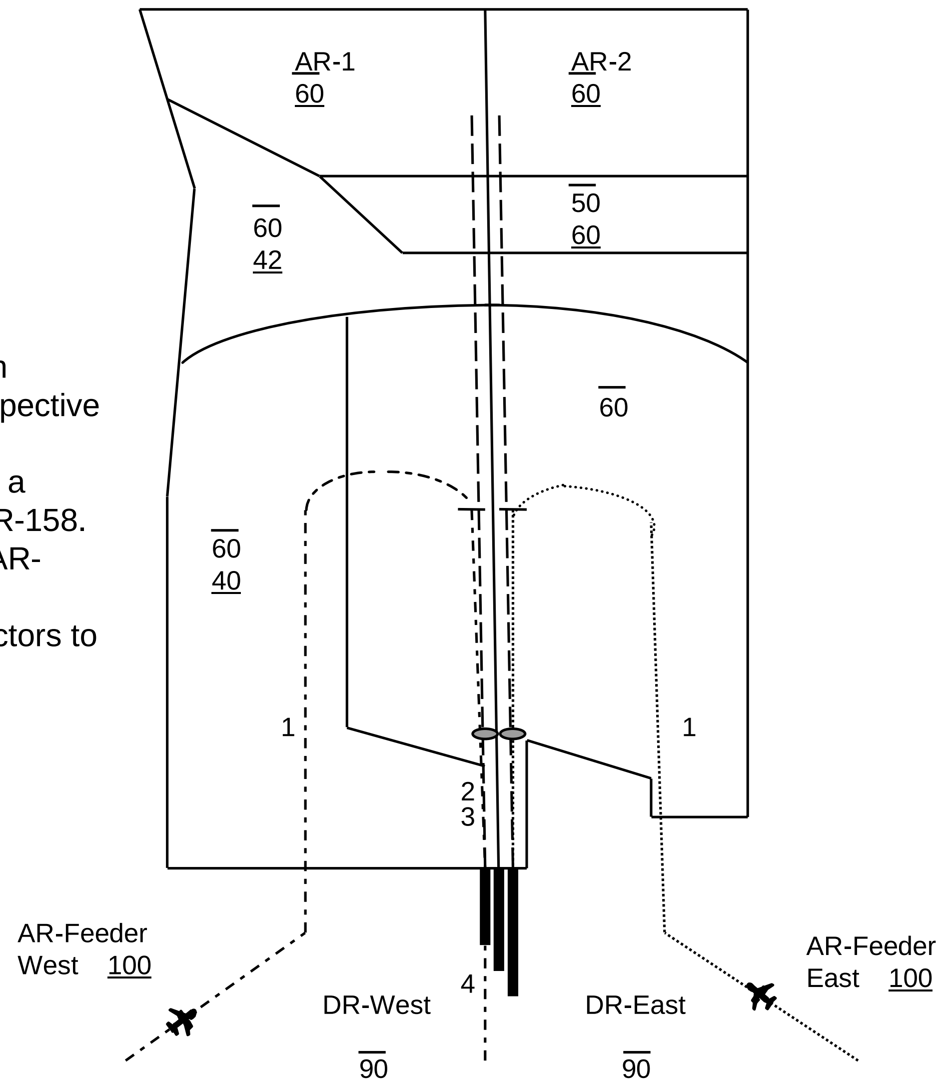


Figure 15. SEA incident scenario 3: straight-In approaches, missed approach on RWY 16R.

1. Aircraft making AILS RWY 16L/R approaches. On final, the Intruder is on LC-East frequency and the Evader is on LC-West frequency.
2. The Intruder drifts 30 degrees right of course.
3. The Evader executes an EEM.
4. CC coordinates with AR-1 for downwind turn.
5. CC points out traffic to DR-West and AR-Feeder West.
6. AR-1 instructs CC to turn aircraft on downwind climbing to 5000'.
7. LC-West turns Evader downwind RWY 16R climbing to 5000' and switches aircraft to AR-1 frequency.
8. LC-East turns Intruder downwind RWY 16R climbing to 5000' and switches aircraft to AR-1 frequency.
9. AR-1 climbs both aircraft to 6000' due to traffic going into BFI, and extends downwind to turn base-leg approximately 20 miles north.
10. AR-1 sequences traffic with BFI traffic and clears both aircraft for AILS RWY 16R approach.

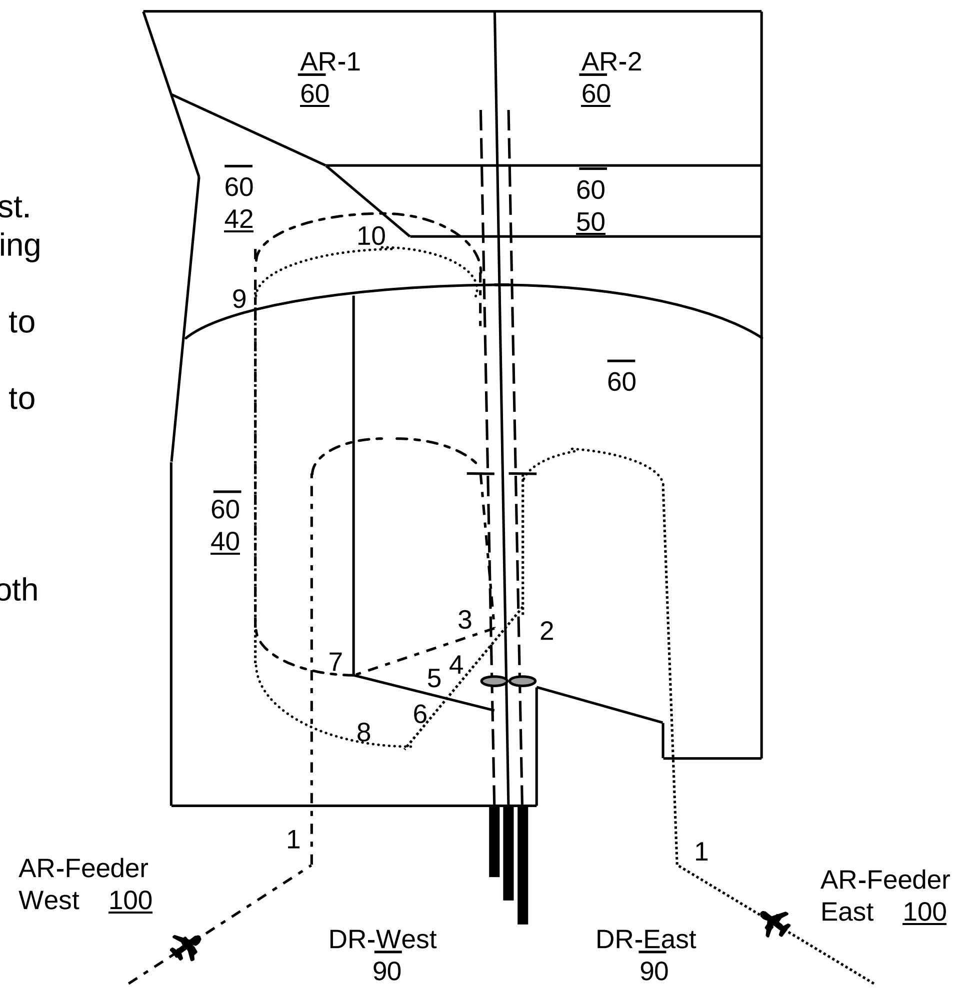
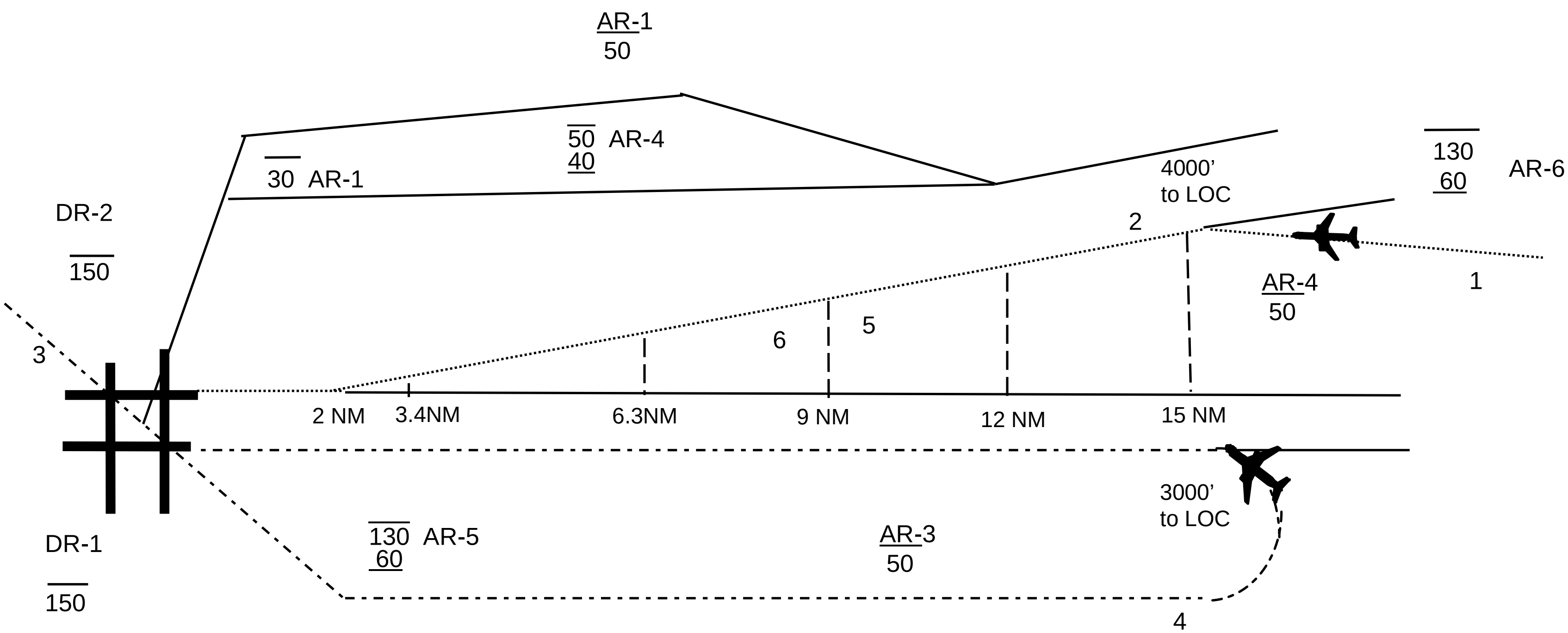
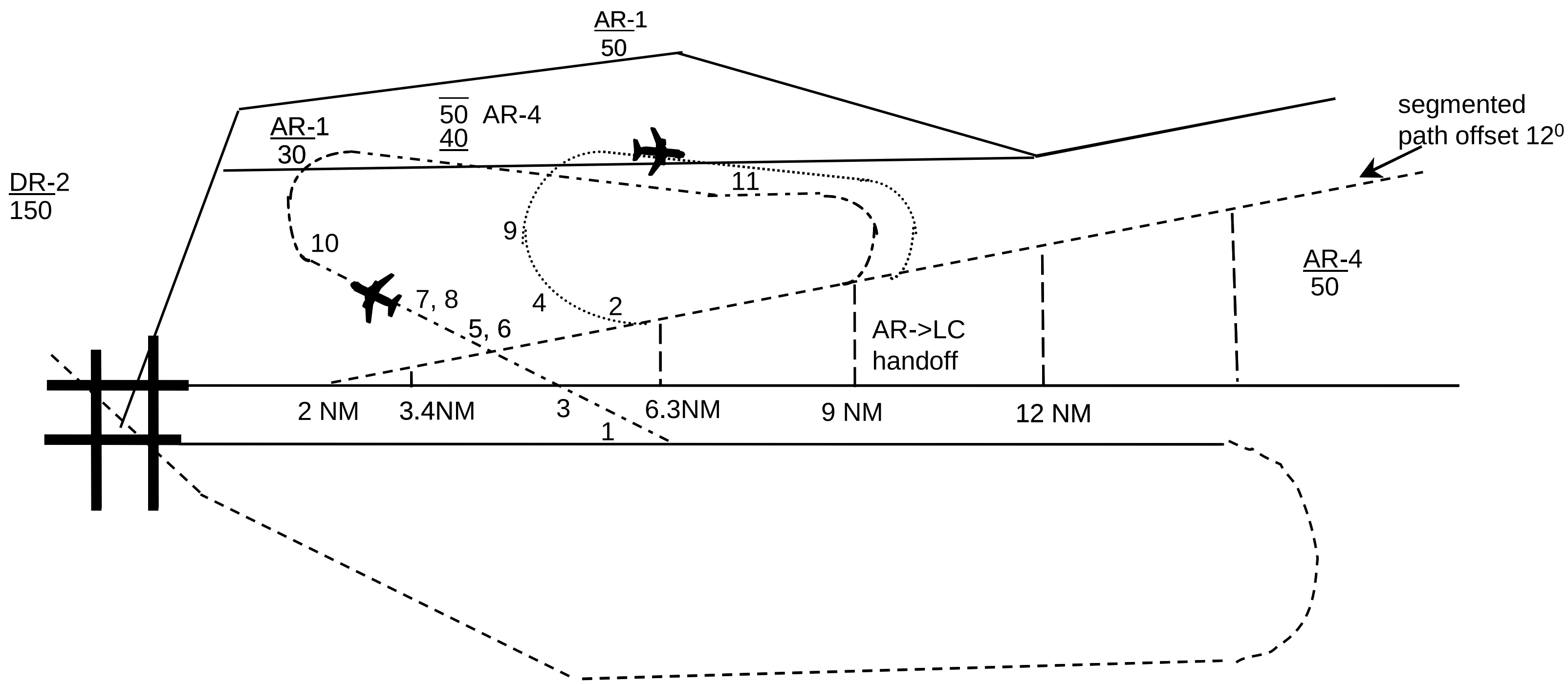


Figure 16. SEA incident scenario 4: RWY 16R straight-in approach; approaches to BFI in progress; EEM right of course.



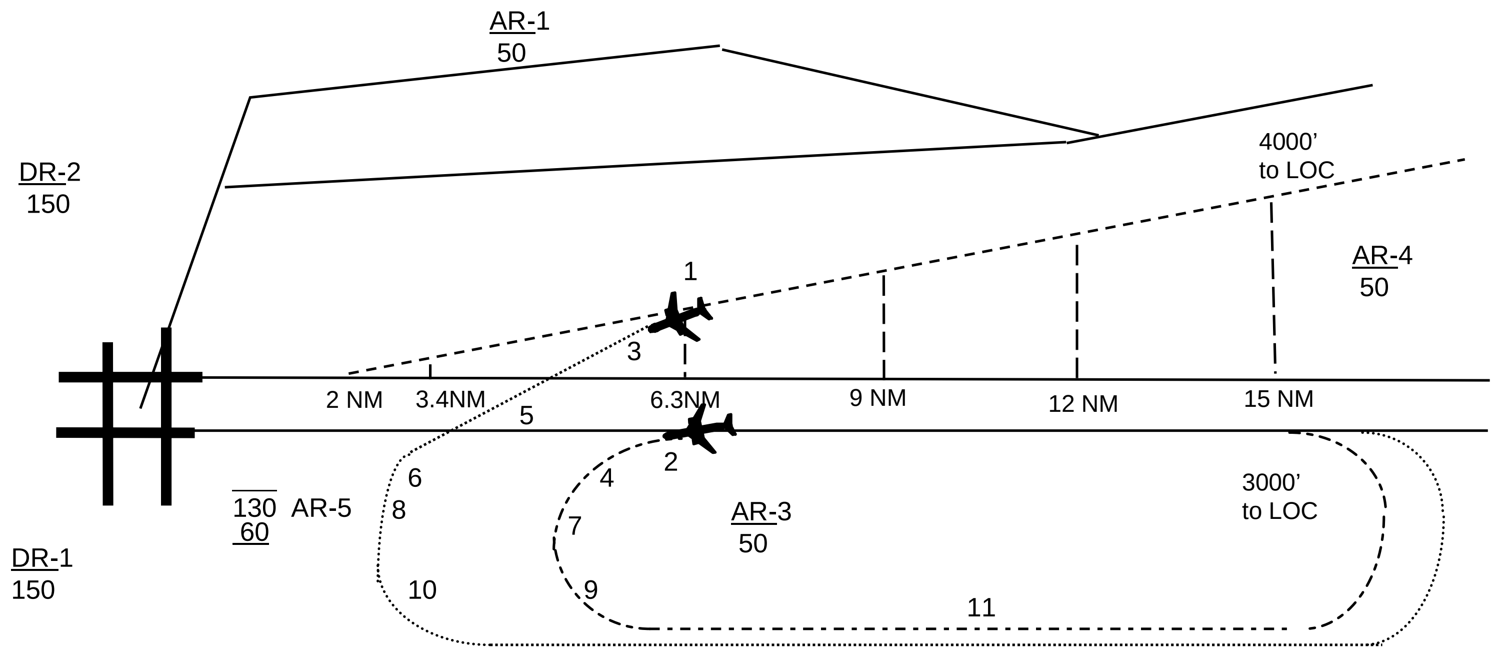
1. AR-6 hands off aircraft to AR-4 on a course parallel to RWY 28R, north of course to intercept the segmented approach course at approximately 15 NM, descending to 5000'.
2. AR-4 descends the aircraft to 4000' and clears it for the AILS RWY 28R Segmented Approach.
3. AR-5 hands off aircraft to AR-3 southeast bound from over the SFO airport descending to 5000'.
4. AR-3 descends the aircraft to turn final at 3000' at 15 NM and clears it for an AILS RWY 28L approach.
5. Both aircraft contact the tower LC and change to AILS Monitor frequency at approximately nine miles on final.
6. The tower LC clears the aircraft to land.

Figure 17. SFO nominal segmented approach.



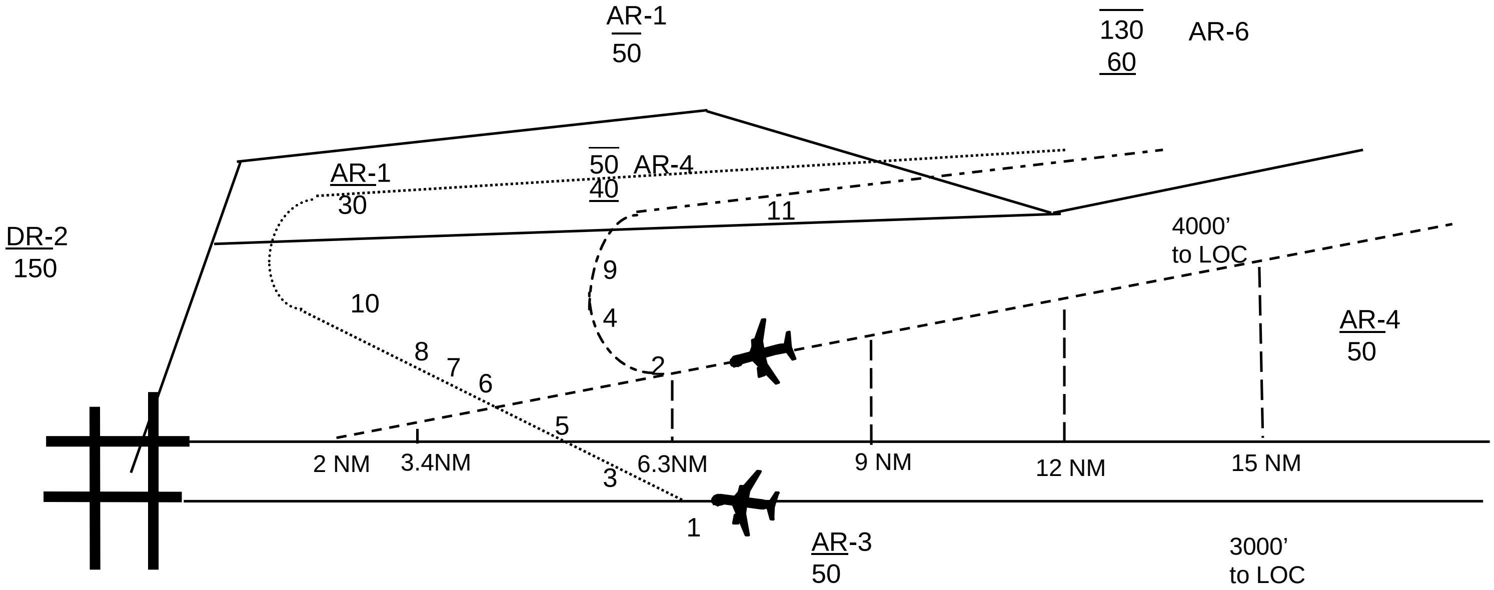
1. Intruder drifts right 30-degrees, aircraft targets converge.
2. Evader executes an EEM climbing right turn to 4000’ via heading 350-degree.
3. AR-1/4/DR-2 notified by CC through CI.
4. Targets radar identified.
5. Both targets are flashed to AR-4 for hand-off.
6. CC obtains clearance and 2000’ from CI through AR-1 “box” for both aircraft.
7. AILS Monitor (or CC/CI) request downwind for both aircraft from AR-4.
8. AR-4 approves downwind, 2000’ and accepts hand-off of both aircraft.
9. Evader turned to downwind heading, assigned 2000’ and switched frequency to AR-4.
10. Intruder turned to downwind heading, assigned 2000’ and switched frequency to AR-4.
11. AR-4 vectors both aircraft back into the approach sequence.

Figure 18. SFO incident scenario 1: RWY 28R segmented approach, EEM right of course.



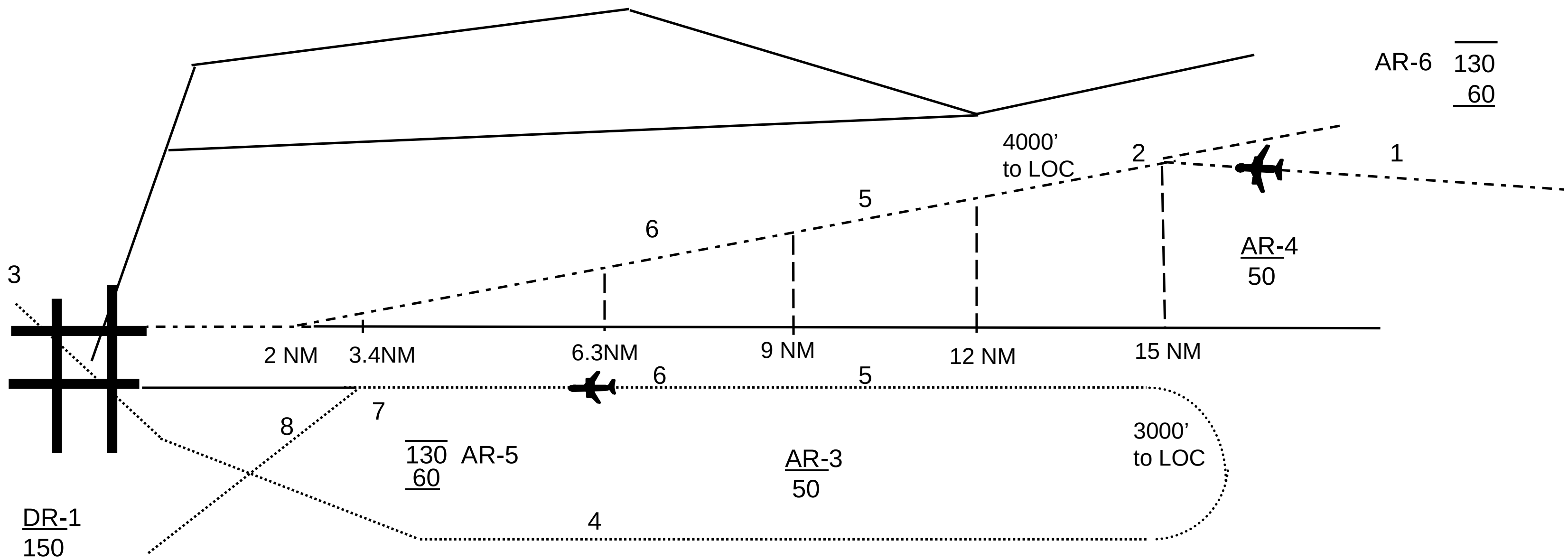
1. Intruder drifts left 30 degrees on approach to RWY 28R.
2. Evader executes EEM, climbing left turn to 4000' via 225 degrees.
3. AR-3/5/DR-1 notified by Coordinator (CI).
4. Targets radar identified.
5. Both targets are electronically flashed on the display at AR-3 for handoff.
6. CI obtains clearance to turn both aircraft downwind and climb to 4000'.
7. AILS Monitor requests downwind for both aircraft from AR-3.
8. AR-3 approves downwind, climb to 4000' and accepts handoff of both aircraft.
9. Evader turned to downwind heading, climbed to 4000' and switched to AR-3.
10. Intruder turned to downwind heading, climbed to 4000' and switched to AR-3.
11. AR-3 vectors both aircraft back into the approach queue.

Figure 19. SFO incident scenario 2: RWY 28L straight-in approach, EEM left of course.



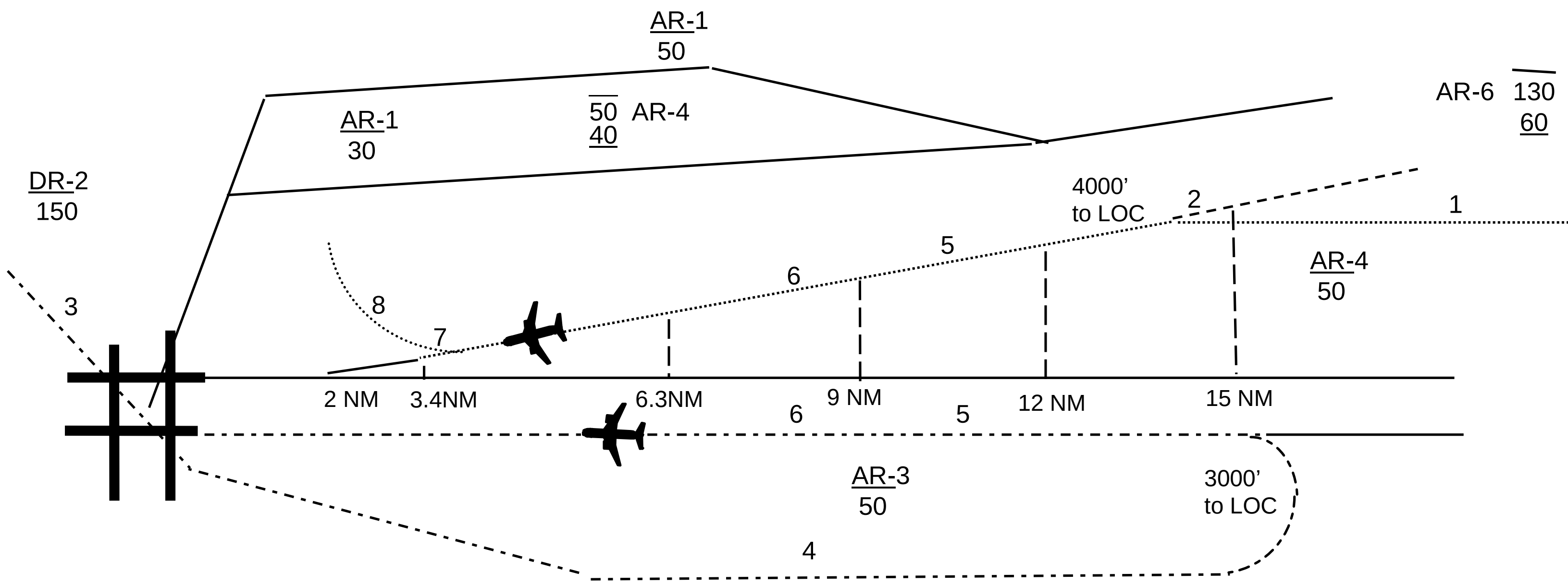
1. Intruder drifts right 30 degrees on approach to RWY 28L.
2. Evader executes EEM.
3. AR-4/1/DR-2 notified by Coordinator (CI).
4. Targets radar identified.
5. Both targets are electronically flashed on the display at AR-4 for handoff.
6. CI obtains clearance through AR-1 airspace for both aircraft.
7. AILS Monitor request downwind for both aircraft from AR-4.
8. AR-4 approves downwind , climb both aircraft to 5000’ and switched to AR-6.
9. Evader turned to downwind heading, climbed to 5000’ and switched to AR-6.
10. Intruder turned to downwind heading, climbed to 5000’ and switched to AR-6.
11. AR-6 climbs aircraft to 7000’ and sequences them with other traffic for AR-4/3.

Figure 20. SFO incident scenario 3: RWY 28R segmented approach, EEM right of course.



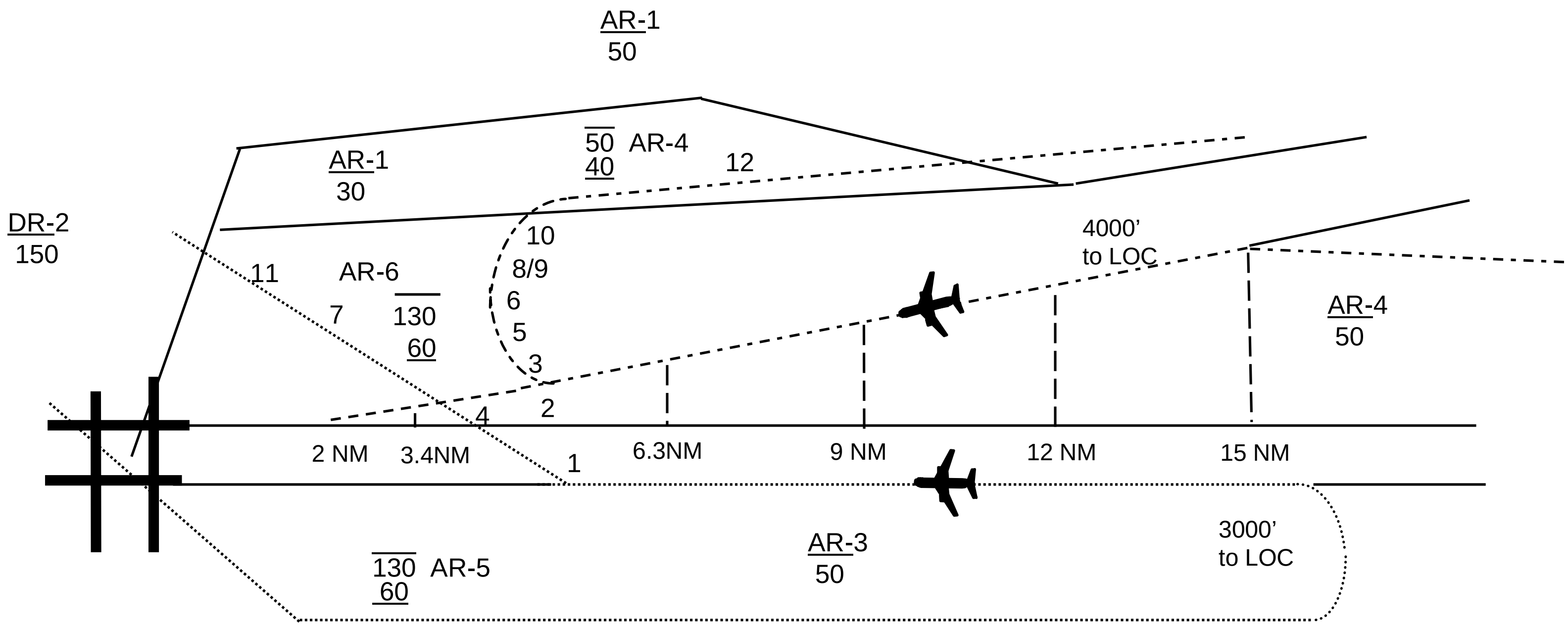
1. AR-6 hands off aircraft to AR-4 on a course parallel to RWY 28R, north of course, to intercept the segmented approach course at approximately 15 NM, descending to 5000'.
2. AR-4 descends the aircraft to 4000', clears the aircraft for an AILS RWY 28R Segmented approach.
3. AR-5 hands off aircraft to AR-3 southeast bound from over the SFO airport descending to 5000'.
4. AR-3 descends the aircraft to 3000' on base leg to final and clears the aircraft for an AILS RWY 28L approach.
5. Both aircraft contact tower LC and monitor AILS Monitor frequency at approximately nine miles on final.
6. The tower LC clears the aircraft to land.
7. The aircraft making the approach to RWY 28L executes a missed approach at the missed approach point, climbing left turn to 3000' via heading 235 degrees.
8. CI coordinates with AR-3/5/DR-1.

Figure 21. SFO incident scenario 4: RWY 28L segmented approach, missed approach.



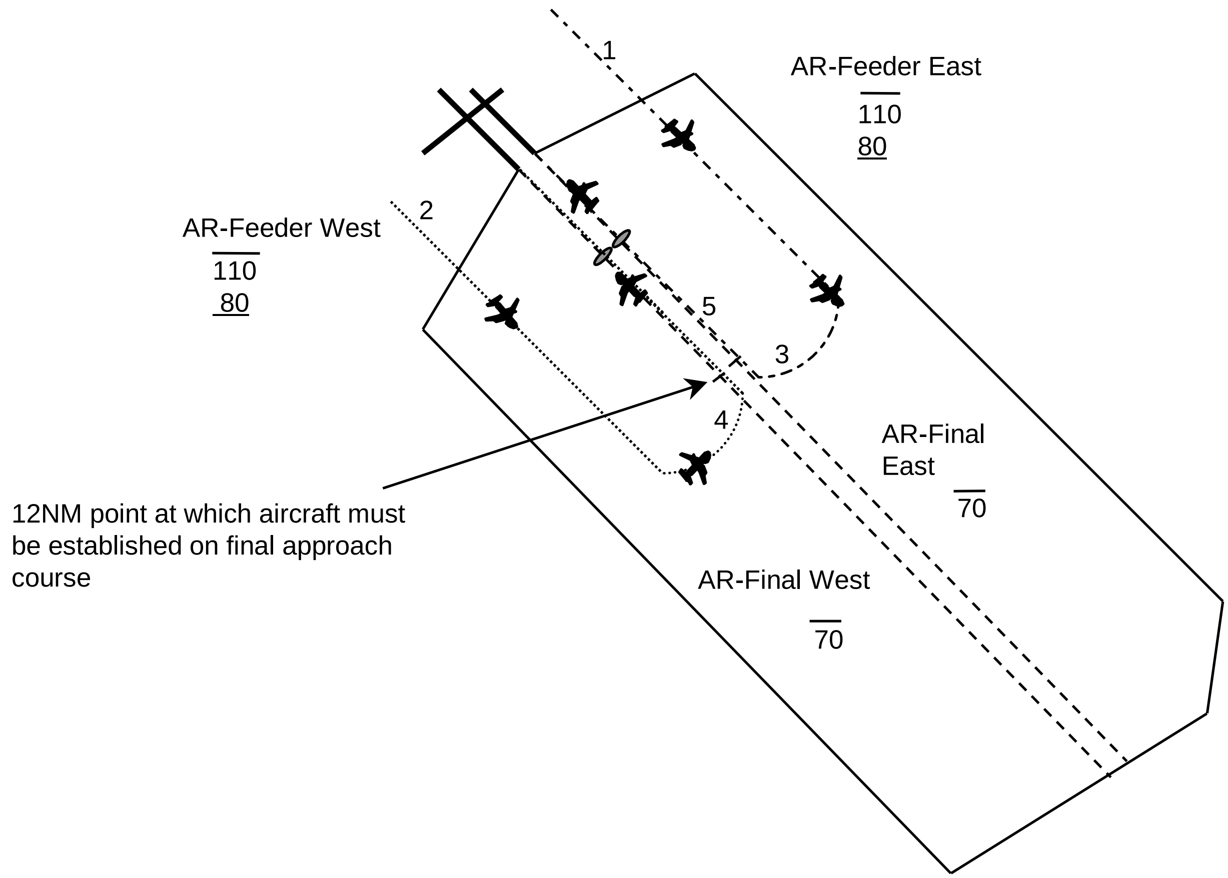
1. AR-6 hands off aircraft to AR-4 on a course parallel to RWY 28R, north of course to intercept the segmented approach course at approximately 15 NM, descending to 4000'.
2. When established on the localizer, AR-4 clears the aircraft for an AILS RWY 28R Segmented approach.
3. AR-5 hands off aircraft to AR-3 southeast bound from over the SFO airport descending to 5000'.
4. AR-3 descends the aircraft to 3000' on base leg and clears the aircraft for an AILS RWY 28L approach.
5. Both aircraft contact tower LC and monitor the AILS Monitor frequency at approximately nine miles on final.
6. The tower LC clears the aircraft to land.
7. The aircraft making the approach to RWY 28R executes a missed approach at the missed approach point, climbing right turn to 4000' via heading 350 degrees.
8. CI coordinates with AR-1/4/6.

Figure 22. SFO incident scenario 5: RWY 28R segmented approach, missed approach.



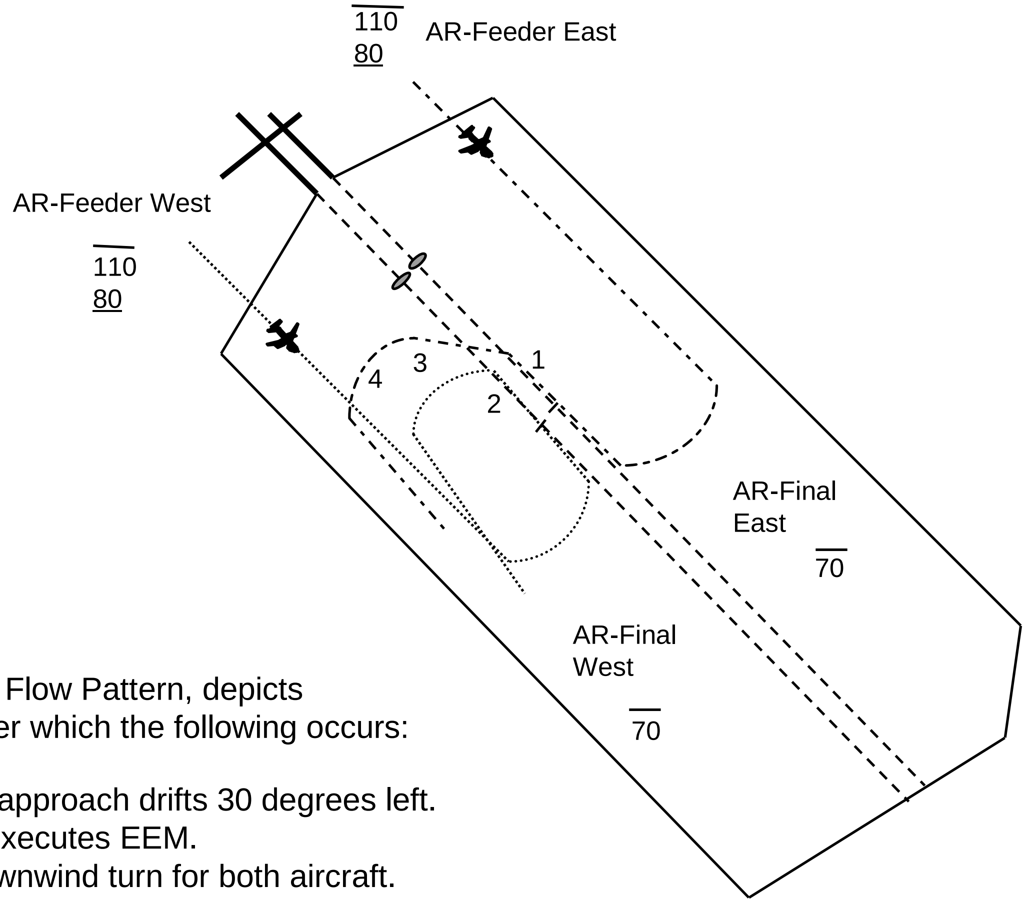
1. Intruder drifts right 30 degrees, aircraft targets merge.
2. Evader executes EEM, climbing right turn to 4000' via heading 350 degrees.
3. AR-1/4/6/DR-2 notified by CI.
4. Radio contact loss with Intruder aircraft flying northwest bound.
5. Evader aircraft radar identified and electronically flashed to AR-4 for handoff.
6. CI obtains clearance through AR-1 airspace.
7. CI points out Intruder aircraft to DR-2 and AR-6.
8. AILS Monitor request downwind for Evader aircraft from AR-4.
9. AR-4 approves downwind and climb to 5000' for Evader and switch to AR-6 frequency.
10. Evader turned to downwind heading, climbed to 5000' and switched to AR-6.
11. Intruder enters DR-2 airspace northwest bound.
12. AR-6 climbs Evader to 7000' and sequences it with other traffic for AR-4.

Figure 23. SFO Incident Scenario 6: Lost Radio Contact With the Intruder.



1. AR-Feeder East hands aircraft off to AR-Final East descending to 7000-8000’.
2. AR-Feeder West hands aircraft off to AR-Final West descending to 7000-8000’.
3. AR-Final East turns aircraft in for 12 mile final at 4000’ and clears aircraft for AILS approach.
4. AR-Final West turns aircraft in for 12 mile final at 3000’ and clears aircraft for AILS approach.
5. Aircraft are changed to tower Local Control frequency at approximately 9 miles for landing clearance.

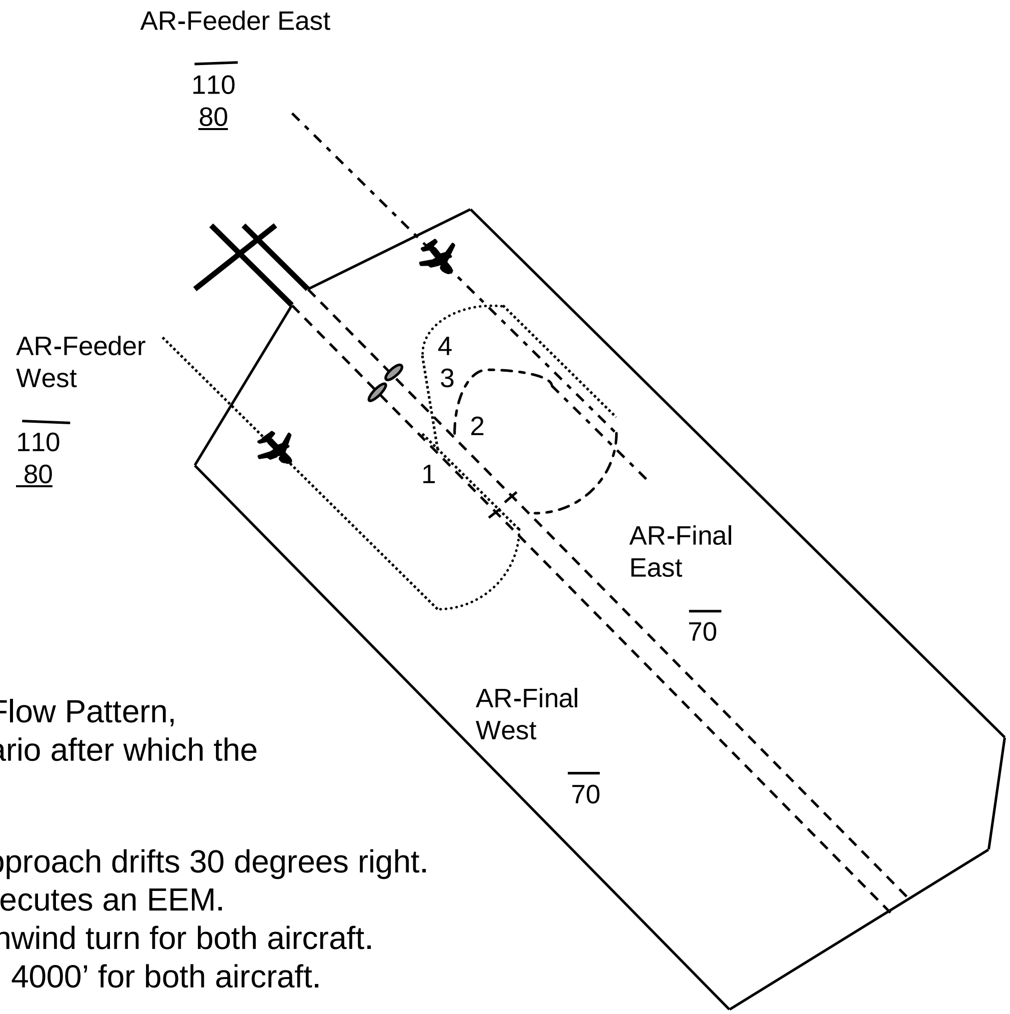
Figure 24. MSP terminal area, nominal traffic flow pattern.



Note: Figure 24, Nominal Traffic Flow Pattern, depicts the initial part of this scenario after which the following occurs:

1. Intruder aircraft on RWY 30R approach drifts 30 degrees left.
2. Evader aircraft on RWY 30L executes EEM.
3. CC coordinates with CI for downwind turn for both aircraft.
4. CI approves downwind turn and 4000’ for both aircraft.

Figure 25. MSP incident scenario 1: RWY 30L straight-in approach, EEM left of course.



Note: Figure 24, Nominal Traffic Flow Pattern, depicts the initial part of this scenario after which the following occurs:

1. Intruder aircraft on RWY 30L approach drifts 30 degrees right.
2. Evader aircraft on RWY 30R executes an EEM.
3. CC coordinates with CI for downwind turn for both aircraft.
4. CI approves downwind turn and 4000’ for both aircraft.

Figure 26. MSP incident scenario 2: RWY 30R straight-in approach, EEM right of course.

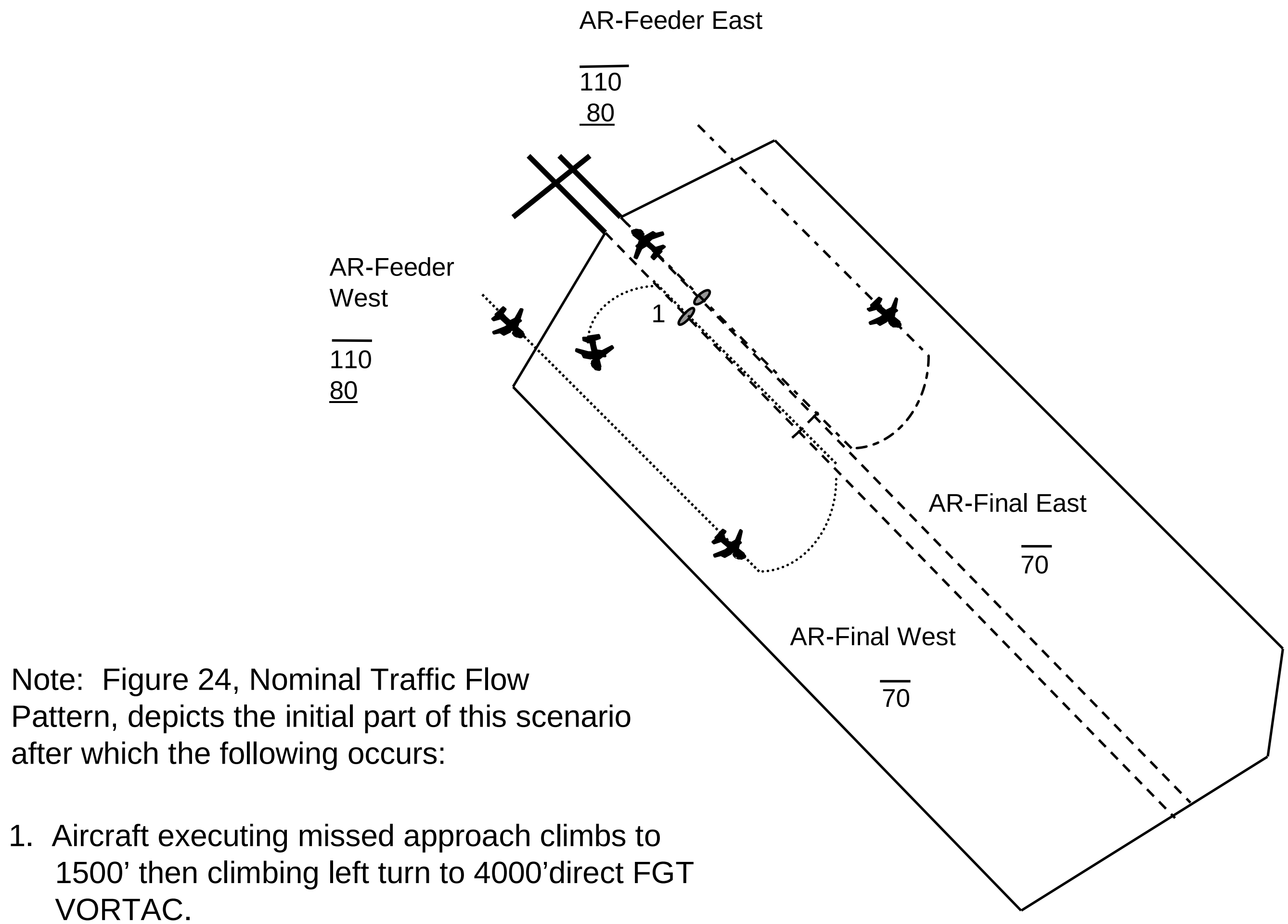
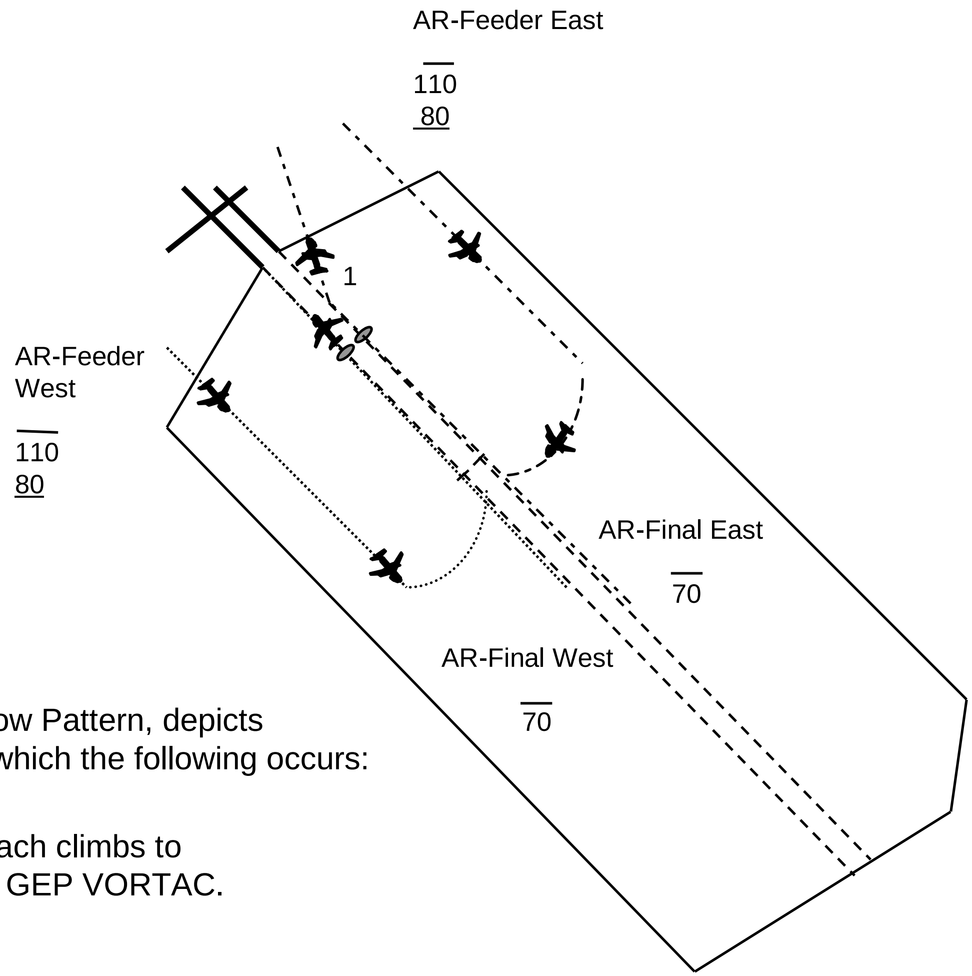


Figure 27. MSP incident scenario 3: RWY 30L Straight-In approach, missed approach to the left.



Note: Figure 24, Nominal Traffic Flow Pattern, depicts the initial part of this scenario after which the following occurs:

1. Aircraft executing missed approach climbs to 1500’ then right turn to 5000’ direct GEP VORTAC.

Figure 28. MSP incident scenario 4: RWY 30R straight-in approach, missed approach to the right.

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Airborne information for lateral spacing (AILS) is a concept for making approaches to closely spaced parallel runways in instrument meteorological conditions (IMC). Under the concept, each equipped aircraft will assume responsibility for accurately managing its flight path along the approach course and maintaining separation from aircraft on the parallel approach. This document presents the results of an analysis of the AILS concept from an Air Traffic Control (ATC) perspective. The process has been examined in a step by step manner to determine ATC system support necessary to safely conduct closely spaced parallel approaches using the AILS concept. The analysis resulted in recognizing a number of issues related to integrating the process into the airspace system and proposes operating procedures.

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