The ASLOTS Concept

An Interactive, Adaptive Decision Support Concept
for
Final Approach Spacing of Aircraft (FASA)

FAA-NASA JOINT UNIVERSITY PROGRAM

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This presentation outlines a concept for an adaptive, interactive decision support system to assist controllers at a busy airport in achieving efficient use of multiple runways. The concept is being implemented as a computer code called FASA (Final Approach Spacing for Aircraft), and will be tested and demonstrated in ATCSIM, a high fidelity simulation of terminal area airspace and airport surface operations.

Objectives

- PROVIDE AUTOMATED CUES TO ASSIST CONTROLLERS IN THE SEQUENCING AND SPACING OF LANDING AND TAKEOFF AIRCRAFT

- PROVIDE THE CONTROLLER WITH A LIMITED ABILITY TO MODIFY THE SEQUENCE AND SPACINGS BETWEEN AIRCRAFT, AND TO INSERT TAKEOFFS AND MISSED APPROACH AIRCRAFT IN THE LANDING FLOWS

- INCREASE SPACING ACCURACY USING MORE COMPLEX AND PRECISE SEPARATION CRITERIA WHILE REDUCING CONTROLLER WORKLOAD

- ACHIEVE HIGHER OPERATIONAL TAKEOFF AND LANDING RATES ON MULTIPLE RUNWAYS IN POOR VISIBILITY

Assumptions

1. A "metering " process is being applied to all arrivals for landing, and a Runway Operations Schedule (ROS) is being generated and updated continuously for landing and takeoff operations on each active runway.

2. Each landing aircraft has declared an IAS (Indicated Airspeed) for the final approach from the Outer Marker to the runway, and will be obligated to fly it. Each takeoff aircraft will declare itself ready for immediate takeoff as it approaches the runway.

3. A continuously updated estimate of the complete windspeed field in the terminal area is available.

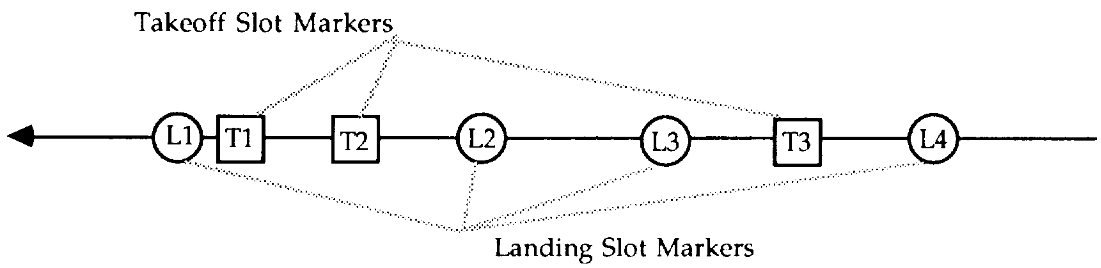
4. Radar surveillance provides data on the position of all aircraft and a tracking process estimates their current speed and direction.

5. Errors of known static and transient characteristics will occur in tracking and surveillance, in wind estimation, and in pilot and aircraft response to clearances for turns and speed reductions.

System Characteristics - Adaptive and Interactive

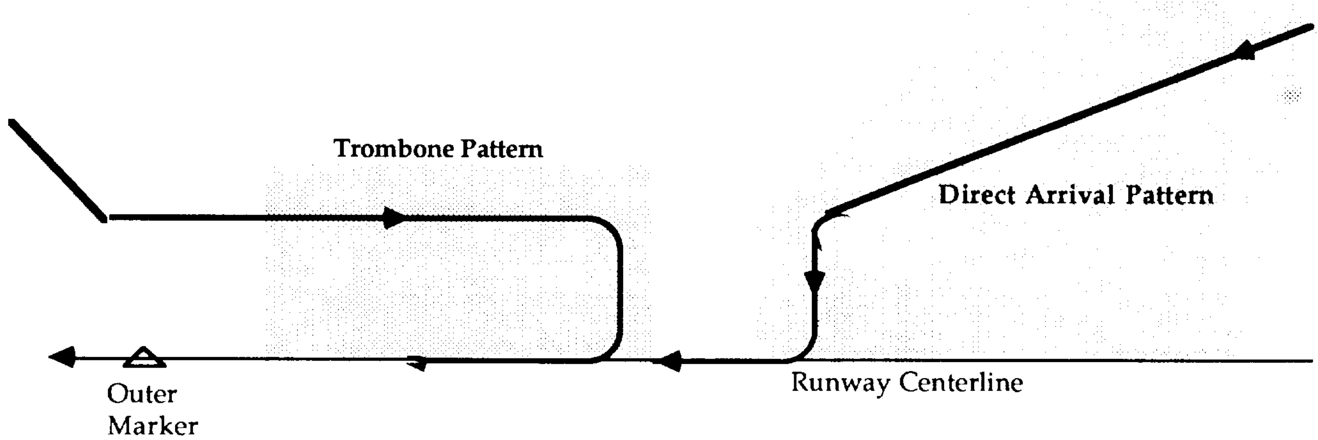
1. ASLOTS cues are " **adaptive** " to errors in measuring position and estimating speed by the radar and its tracking process, and from piloting errors in execution of commanded turns and speed reductions. Adaptation ensures that the planned spacing schedule is consistent with the actual traffic situation. Any inconsistency will be displayed to the controller for immediate correction.

2. The ASLOTS plans are " **interactive** " with the controllers, and are displayed to them by a sequence of "slot markers" which move along the extended runway centerline. Each aircraft using the runway has a slot marker which becomes visible to the controller as its scheduled operation time approaches. By manipulating the slot markers, controllers can change landing times, change the desired sequence of landings or takeoffs, change individual spacings, set a buffer on separation criteria between particular aircraft, locally modify the desired runway acceptance rate, insert a missed approach, and insert planned takeoffs between landings (which automatically modifies landing spacings).



Generic Arrival Patterns for Spacing

There are two generic patterns from which all landing paths are constructed. These arrival patterns are commonly used at major airports and can be adapted easily to any airport and terminal area. There is no fixed path to the runway, but instead each pattern consists of a fixed sequence of commanded turns and speed reductions (ie., "vectors"). The feasible area for patterns is constrained to maintain independence of arrival traffic streams.



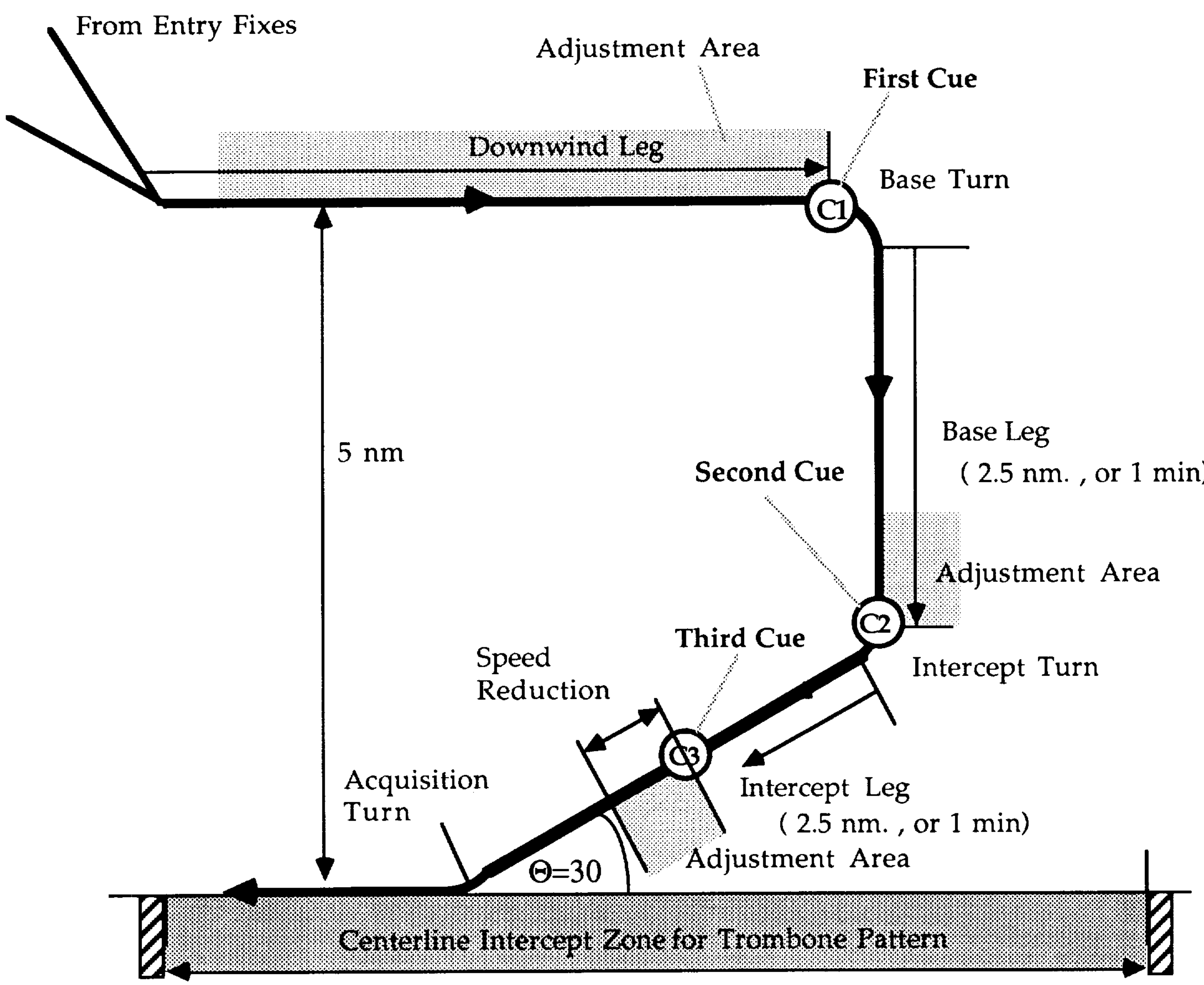
The Components of the Trombone Pattern

There are 8 Components:

1. Downwind Leg
2. Base Turn
3. Base Leg
4. Intercept Turn
5. Initial Intercept Leg
6. Reduce to Final Speed
7. Final Intercept Leg
8. Acquisition Turn

and 3 Adaptive Cues;

1. Turn to Base
2. Turn to Intercept
3. Reduce to Final Approach Speed



The Components of the Direct Arrival Pattern

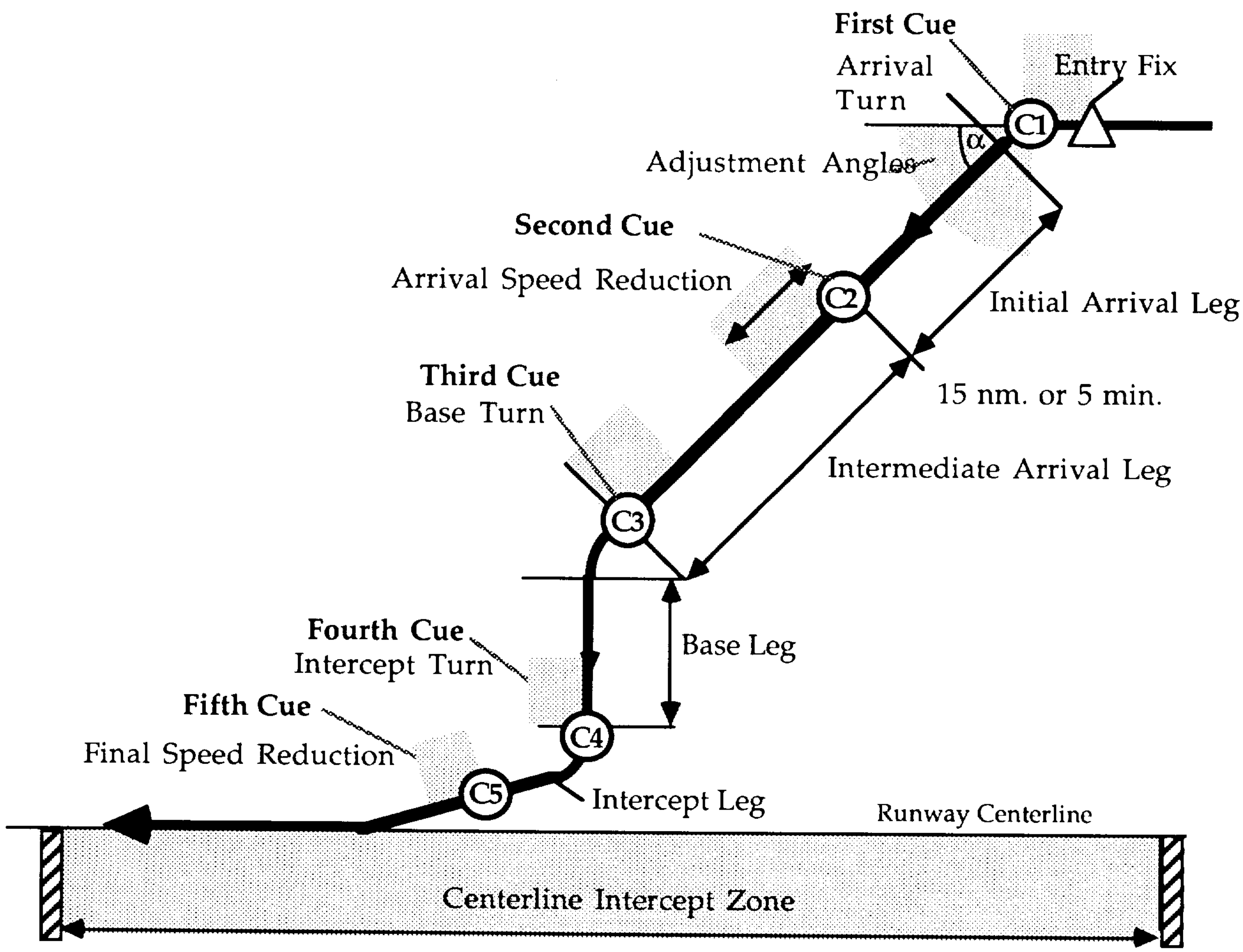
There are 11 Components:

1. Arrival Turn
2. Initial Arrival Leg
3. Arrival Speed Reduction
4. Intermediate Arrival Leg
5. Base Turn
6. Base Leg
7. Intercept Turn
8. Initial Intercept Leg
9. Final Speed Reduction
10. Final Intercept Leg
11. Acquisition Turn

and 5 Adaptive Cues:

1. Turn to Arrival direction
2. Reduce to Arrival Speed
3. Turn to Base
4. Turn to Intercept
5. Reduce to Final Approach Speed

(not all cues may be utilized on any approach)



Constrained Pattern Parameters (CPP)

There are a number of constraints on the paths flown in each pattern

Trombone Pattern

1. There is a minimum length specified for Base and Intercept Legs which ensures that radar tracking processes will be stabilized in estimating speed and direction

2. The intermediate airspeed on downwind, and angle of final intercept of the runway centerline can be specified within limits.

3. The geometries can be constructed to provide non-simultaneous cues for delivery to successive, closely spaced aircraft in a pattern

4. Minimum and Maximum slot acquisition points define a Trombone Intercept Zone on the runway centerline beyond the Outer Marker.

Direct Arrival Pattern

1. There is a range of angles and distances for the arrival leg from various entry points.

2. A common intermediate airspeed can be specified, or various intermediate airspeeds for different types of aircraft.

3. Minimum and Maximum slot acquisition points define a Direct Arrival Intercept Zone on the runway centerline beyond the maximum acquisition point of the Trombone Pattern

Adaptive Cues for Controller Actions

1. At some selectable warning time (eg., 10 seconds), the icon representing an aircraft position will turn yellow, and after some further period (eg., 5 seconds) begin to blink. At the desired time of the turn or speed reduction, the icon turns red indicating lateness in executing the cue. To stop the blinking, the controller must "mouse" the icon indicating his response.

2. It is not important that the cue be issued or executed exactly on time. The cueing logic is "adaptive" and will compute the next cue for this aircraft (and others) based on the **actual achieved position and ground speed** of aircraft after they complete the maneuver.

3. If the aircraft responds so poorly that it is not possible to make the current schedule, its slot marker will turn red indicating to the controller that a schedule change is necessary. This is done by mousing the slot marker and sliding it to a feasible position. This causes an adaptation in all other spacings.

The Spacing Schedule - Slot Markers

1. Along the runway centerline, a sequence of slot markers is displayed representing the desired schedule for landing and takeoff operations. They move at a groundspeed corresponding to final approach airspeed declared by each aircraft corrected for the current estimate of the wind on final approach. Eventually, the aircraft is directed to "intercept" its slot marker.

2. A landing sequence and schedule will be automatically generated, but controllers are able to modify both the sequence and schedule within certain limits by mousing and sliding slot markers within a safe and feasible range.

3. The spacings are computed to ensure safe separations at all points on the path to the runway. Since spacings are computed, the criteria for separation can be more efficiently determined and more complex than those used presently (eg., dependent on type of aircraft or actual weather). The controller is assured that only legal separations will be allowed on the display without having to remember them .

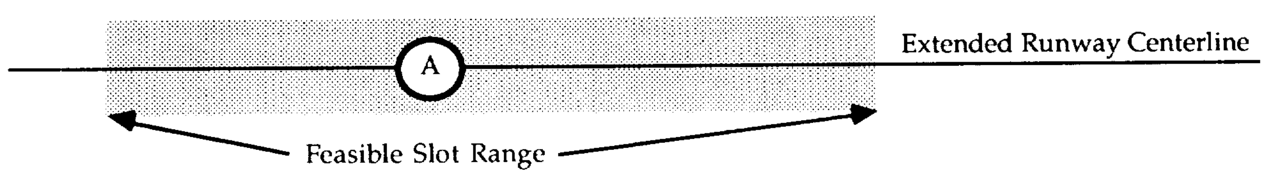
The Feasible Slot Range - (FSR)

1. The computations for the controller cues are used to compute a range of feasible positions along the extended runway centerline for each slot marker which depend on:

    a) the current position of its aircraft and its planned speeds

    b) its planned separations from other aircraft accounting for the fact that they can be shifted rearwards within their feasible ranges

2. When the controller "mouse" is a slot marker, the extent of the feasible range is displayed along the centerline. The slot marker may then be dragged to its desired position anywhere in that range. If it is dragged beyond its range, it snaps back to the limit of its range.



Automatic Rearward Shifting of Slots (ARS)

1. If a slot marker is shifted rearwards within its range, there may be an automatic adjustment of the positions of subsequent slot markers within their ranges. First any slack between successive aircraft is removed. The limit of rearward shifts is determined by one or more of the slot markers in the chain.

2. If a slot marker is shifted forward within its range, no other slot marker is affected. Each slot marker must be moved forward by the controller individually.

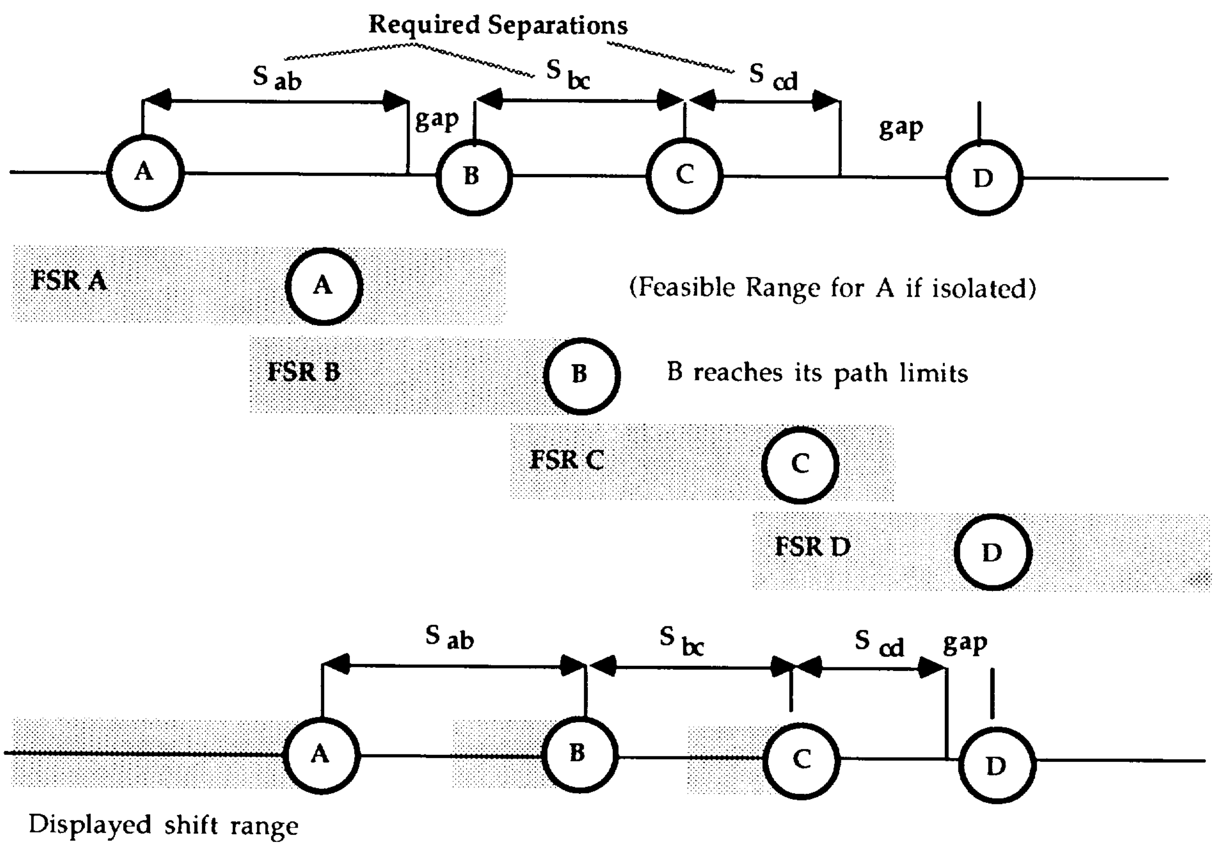
3. Having shifted a number of slot markers, there is an automatic adjustment of the cues. All cues are now based on the new positions of the slot markers.

4. By moving a slot marker rearward, space can be made for inserting a missed approach or one or more takeoff aircraft. When the controller tries to insert a new slot marker into the sequence, the new scheduled positions of subsequent slots are automatically displayed. A non-feasible insertion would be rejected, and the controller must then try a later insertion.

Automatic Rearward Shifting of Slots (ARS)

Example:

If an attempt is made to shift A rearwards, it cannot reach the limit of its feasible range because it must maintain a separation Sab from B; and when B reaches the limit of its range, A cannot be moved further and still maintain separation from B. As B moves rearward, C is also moved since it is tight in the original spacing, but when B reaches its limit, C stops moving rearward and since there still is excess spacing from D, it turns out that D does not have to be shifted. The shift range shown to the controller will instantly show how far each aircraft can be shifted in any situation so that the complexity of the shifting need not be known.

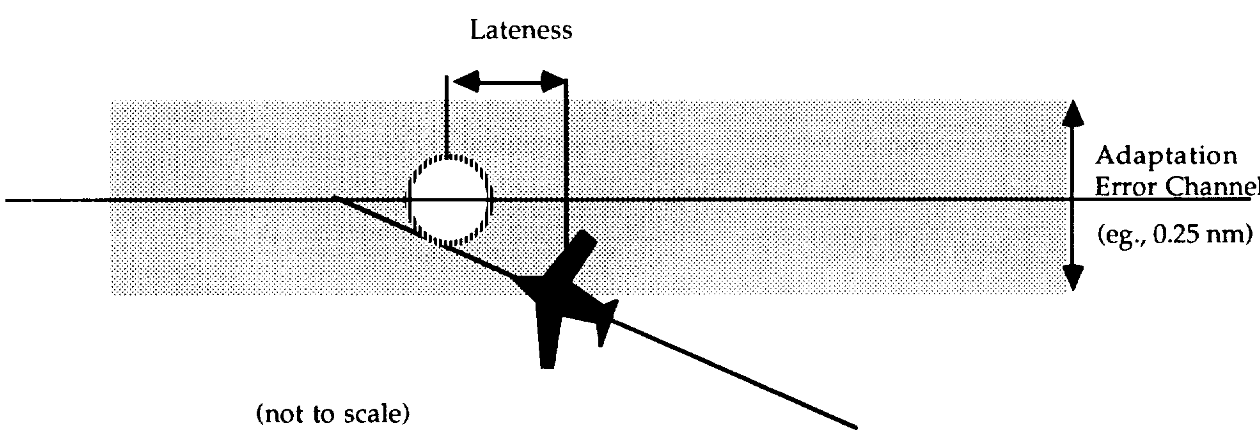


Centerline Adaptation - (CLA)

1. To prevent the actual situation from diverging from the planned situation, it is necessary to have a continuous feedback of the actual spacings achieved. This is done by **Centerline Adaptation**

2. As each aircraft approaches the runway centerline (and its slot marker), the slot marker disappears and its position is then replaced in the ASLOTS computations by the actual position of the aircraft along the centerline. Due to the operation of the Automatic Rearward Shifting, all slot markers for subsequent aircraft will then be shifted back if the aircraft is late. This maintains a safe spacing whenever an aircraft is late into its slot.

3. If the aircraft is early, it may be tight for spacing from the prior aircraft. If the earliness exceeds some buffer specified in time or distance, the aircraft icon will be turned red to advise the controller of the potential violation. Subsequent slot markers will not be moved forward. The controller can call a missed approach if it is warranted.

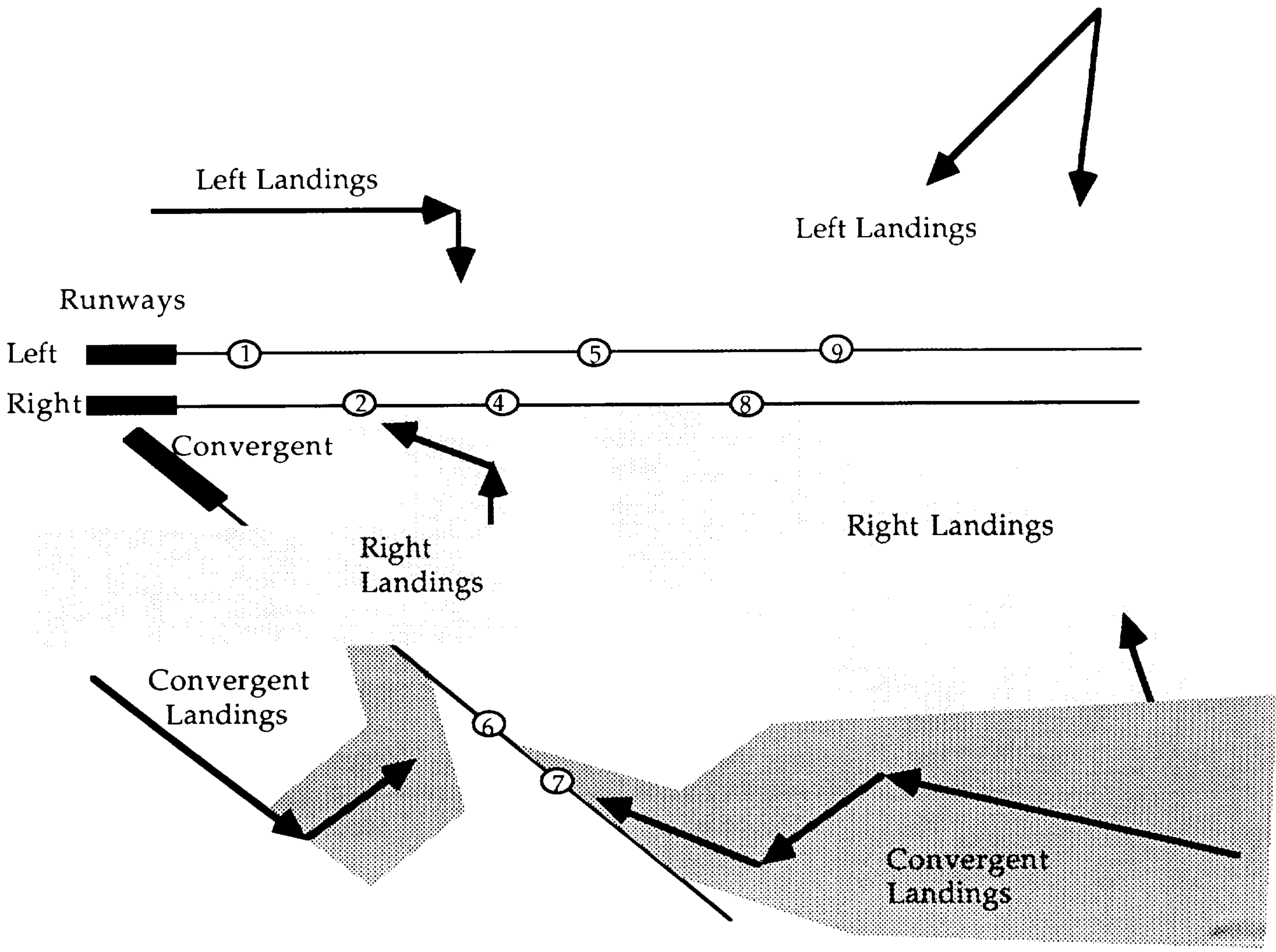


Spacing for Multiple Dependent Runways

Convergent and Parallel Runways

Dual runway operations are staggered and convergent runways are scheduled to assure safety if simultaneous missed approaches occur. Altitude Separation occurs in overlapping areas of the patterns for different runways.

The ASLOTS logic assists 3 Final Approach controllers in the situation below.



ASLOTS Research - Accomplishments

- research sponsored by FAA-NASA under the Joint-University Program has resulted in a recent S.M. Thesis at MIT/FTL.

  "A Graphic Simulation System for Adaptive Automated Final Approach Spacing", MIT/FTL Report 91-3, Z. Chi,

- a portable, desktop simulation for modern workstations has been created by writing the software in Standard C, and putting the graphics in X-Window. At FTL, it runs on an Apollo 4500, and an IBM RS-6000

Accomplishments to date

- the implementation of the following functions has been done:
  - Auto Rearward Shift (ARS)
  - Centerline Adaptation (CLA)
  - Constrained Pattern Parameters (CPP)
  - Feasible Slot Range (FSR)

Improvements in continuing research:

- the aircraft motion modeling needs improvement
- the effect of winds and a time varying wind model will be included
- the error modelling for radar and tracking is being incorporated
- the graphic representation of the cues for controller is primitive
- automated insertion of missed approaches and takeoffs will be achieved
- the system will be transferred to ATCSIM