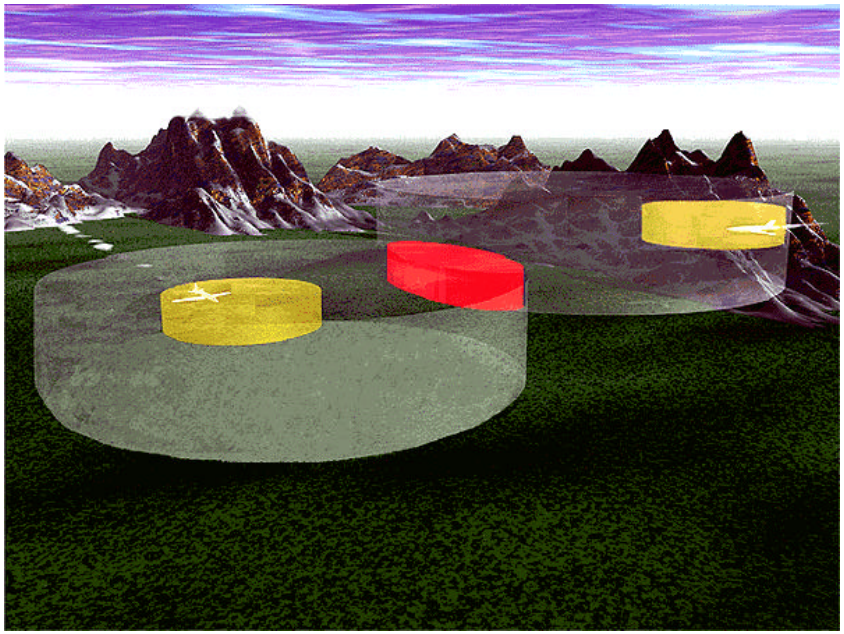
Closely-Spaced Parallel Approaches

An Operations Concept
"A Work in Progress"

- A "Living Document"
- Has been reviewed and commented on by representatives of the following organizations: FAA, ATA, NATCA, NASA, ALPA, RTCA, MITRE and others
- Will continue to be reviewed and refined
- Intended to be operationally rational and implementable

Vision Statement

- *Free Flight* is an Economically Driven Concept
- Procedural Flexibility in order to gain Operational Efficiency
- Paradigm Shift – Protect Aircraft not Airspace



Sources of Delay

Cause								
Weather	**67%**	**70%**	**57%**	**56%**	**65%**	**65%**	**72%**	**75%**
Terminal Volume	11%	9%	29%	35%	27%	27%	22%	19%
Center Volume	13%	12%	8%	2%	0%	0%	0%	0%
Closed Runways/Taxiways	4%	5%	3%	3%	3%	3%	3%	2%
NAS Equipment	4%	3%	2%	1%	2%	2%	2%	2%
Other	1%	1%	1%	4%	3%	3%	3%	2%
Total Operations Delayed (000s)	**356**	**338**	**394**	**393**	**298**	**281**	**276**	**248**
Previous Year	-15%	-5%	17%	0%	-24%	-6%	-2%	-10%

These 2 factors *significantly* reduce Airport Arrival Rates

Cited from: FAA's 1996 Aviation Capacity Enhancement (ACE) Plan

Statement of Need

- Current Airport Arrival Rates are Decreased in Cloudy Weather
  - (e.g., MSP Ceiling 3200ft and/or 8 miles visibility)
- Airlines Schedule Pushes which Exceed Airport Fair-Weather Capacity
- Airline Schedule Breakdown (Delay and/or Diversions) Reduces Profitability

Goal and Objective

- Use Technology to make Scheduled Operations Robust to Virtually All Weather Conditions
- Maintain Aggressive Airport Arrival Rates in order to satisfy economic goals associated with HUB operations
- Specific Application Opportunity at Airports with *Closely-Spaced Parallel Runways*

Cooperative Data Link Opportunity

- Capitalize on ADS-B
  - Primary Means of Surveillance
- No Reliance on Changes to Ground-Based Infrastructure
- The Question is “How to Integrate ADS-B based Surveillance and specialized Alerting Algorithm?”

Statement of General Principles

- TCAS II, as Currently Defined by DO-185A, Must Remain Functionally Independent as an Active Airborne Means of Collision Avoidance
- No Airborne Operations Shall be Undertaken Which use the Active Surveillance or Collision Avoidance Function of TCAS II as a Primary Means of Aircraft Separation

Airports with Closely-Spaced Parallel Runways

Fort Lauderdale	9L/9R	4000 ft
Detroit	3L/3C	3800 ft
Salt Lake City	16/17	3700 ft
Phoenix	8L/8R	3565 ft
Memphis	18L/18R	3400 ft
Raleigh-Durham	5L/5R	3400 ft
Minneapolis	30L/30R	3380 ft
Portland	10L/10R	3100 ft
Kennedy	4L/4R	3000 ft
Indianapolis	5L/5R	2525 ft
Detroit	3C/3R	2000 ft
Orlando	18L/18R	1600 ft
Boston	4L/4R	1500 ft
Philadelphia	9L/9R	1400 ft
St. Louis	12L/12R	1300 ft
Dallas-Ft. Worth	17L/17R 18L/18R	1200 ft
Pittsburgh	10C/10R	1200 ft
Atlanta	8L/8R 9L/9R	1000 ft
Houston	14L/14R	1000 ft
Las Vegas	7L/7R	1000 ft
Newark	4L/4R	900 ft
Seattle	16L/16R	800 ft
LAX	7L/7R	750 ft
SFO	1L/1R 28L/28R	750 ft

Wake Vortex Rules become an issue with below 2,500 ft separation*

****ATC Handbook 7110.65, Sec 10, 3-10-3***

Domestic Airports with Closely-Spaced Parallel Runways

Airline Hub Airports

UAL
- SEA
- SFO
- LAX
- JFK

AAL
- DFW
- SJC
- JFK

USAir
- PIT
- RDU
- MCO
- JFK

TWA
- STL
- LAX
- JFK

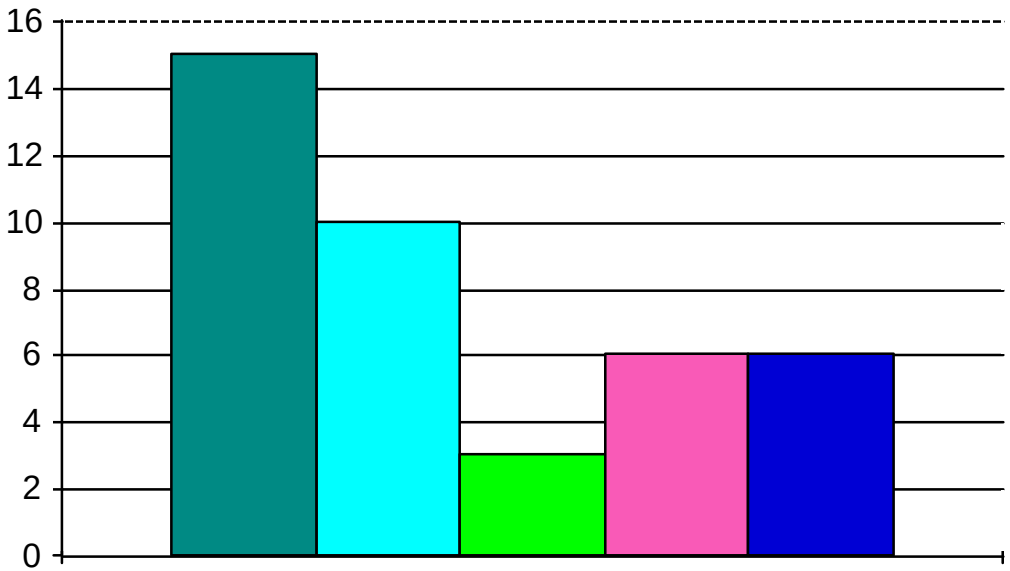
Airline Hub Airports

DAL
- ATL
- SLC
- JFK
- MCO

NWA
- MSP
- DTW
- MEM
- BOS

CAL
- IAH
- EWR
- LAX
- SLC

AWA
- PHX
- LAS



Newark (EWR)
Seattle (SEA)
Los Angeles (LAX)
San Francisco (SFO)
San Jose (SJC)
Las Vegas (LAS)

Atlanta (ATL)
Houston (IAH)
Dallas-Ft. Worth (DFW)
Pittsburgh (PIT)
St. Louis (STL)

Boston (BOS)
Detroit (DTW)
Orlando (MCO)

Minneapolis (MSP)
Memphis (MEM)
Kennedy (JFK)
Raleigh-Durham (RDU)

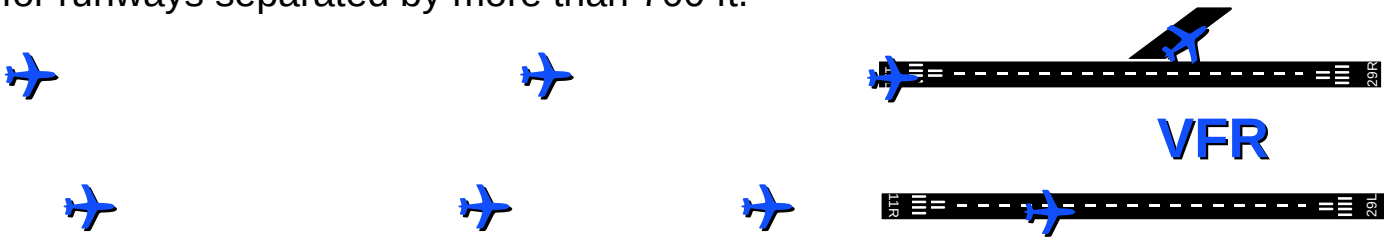
Detroit (DTW)
Salt Lake City (SLC)
Phoenix (PHX)
Tampa (TPA)

VFR vs. IFR
Separation Standards

VFR - Visual Flight Rules
IFR - Instrument Flight Rules

VFR
Final Approach Separation when Pilots are Responsible for Separation (Visual Approaches)

Longitudinal - Restriction on simultaneous occupancy of runway.
Lateral - Independent parallel operations possible for runways separated by more than 700 ft.

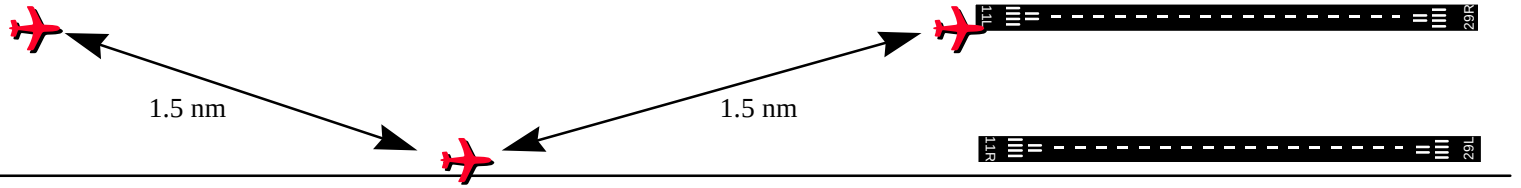


IFR
Final Approach Separation when Controllers are Responsible for Separation

Longitudinal - Pairwise spacing (nm) in table at right.
Lateral - Independent parallel operations possible for runways separated by more than 4,300 ft. or greater than 3,400 ft. with PRM. Dependent parallel approaches possible for runways between 2,500 ft. and 4,300 ft. Runways with less than 2,500 ft. treated as single runway with spacings according to table at right.

Following Aircraft	Leading Aircraft			
	Heavy	B757	Large	Small
Heavy	4	4	3	3
Large	5	4	3	3
Small	5 or 6*	5	3 or 4*	3

** Separation required when preceding aircraft is over landing threshold*



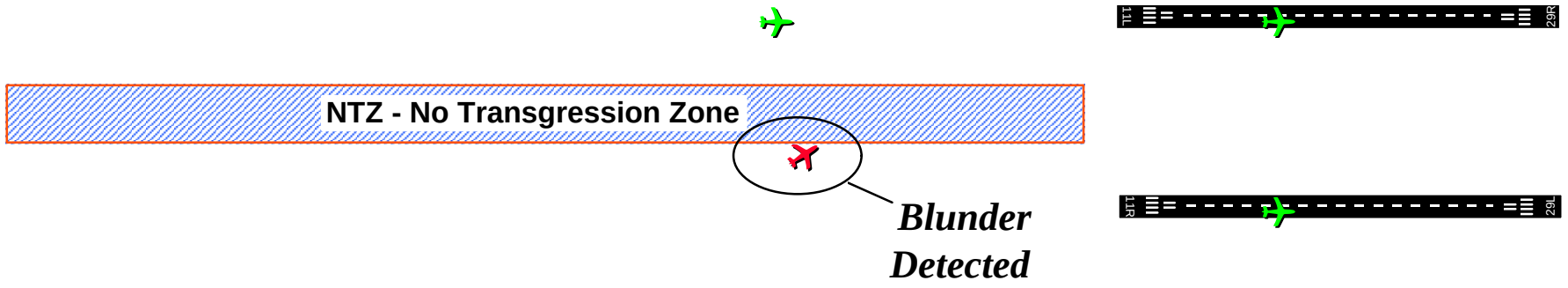
Available Options

- Ground-Based ATC – PRM
  - Business as usual
- Airborne Solution
  - Radical Free Flight
- Distributed Air-Ground Solution
  - ADS-B/Specialized CAS Algorithms to achieve “See & Avoid” and alerting capability that is separate from TCAS
  - Pilot and ATC alerted simultaneously
  - Procedural Escape Maneuver/Missed Approach Procedures (initial turn-climb)
  - ATC vectors to coordinate/guide aircraft that have executed initial MAP back into traffic flow

Ground-Based Solution

Goal – Independent Operations down to 3,400 ft

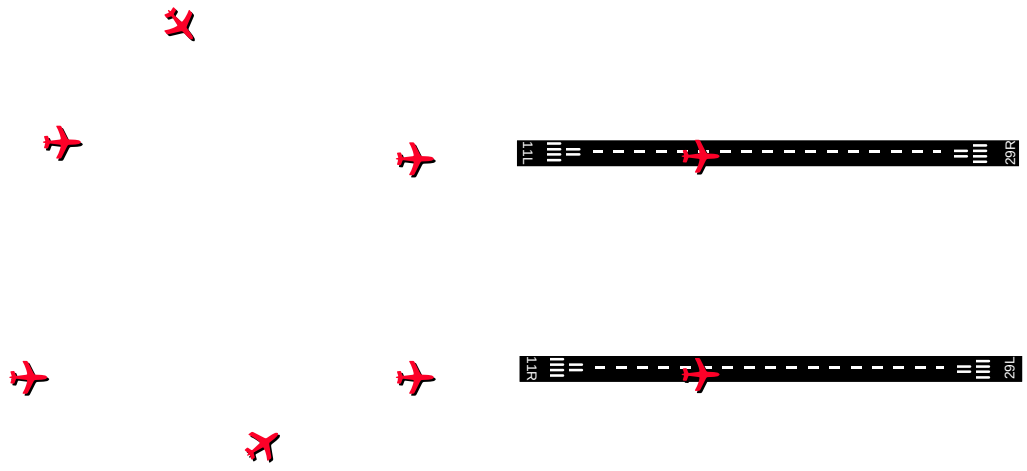
- Precision Runway Monitor – PRM
- High Update Surveillance: either E-Scan Radar or Mode S Multi-Lateration
- Two Final Monitor Controller Positions
- Two Frequencies: Active vs. Monitored
- TCAS Switched to TA Only



Radical Free Flight

Goal – It's my God-given right to fly anywhere I want

- Airborne Equipage to Satisfy Autonomous Separation Assurance Function
- Very Difficult to provide ATC-related Flow Management Function
- Longer Term Solution



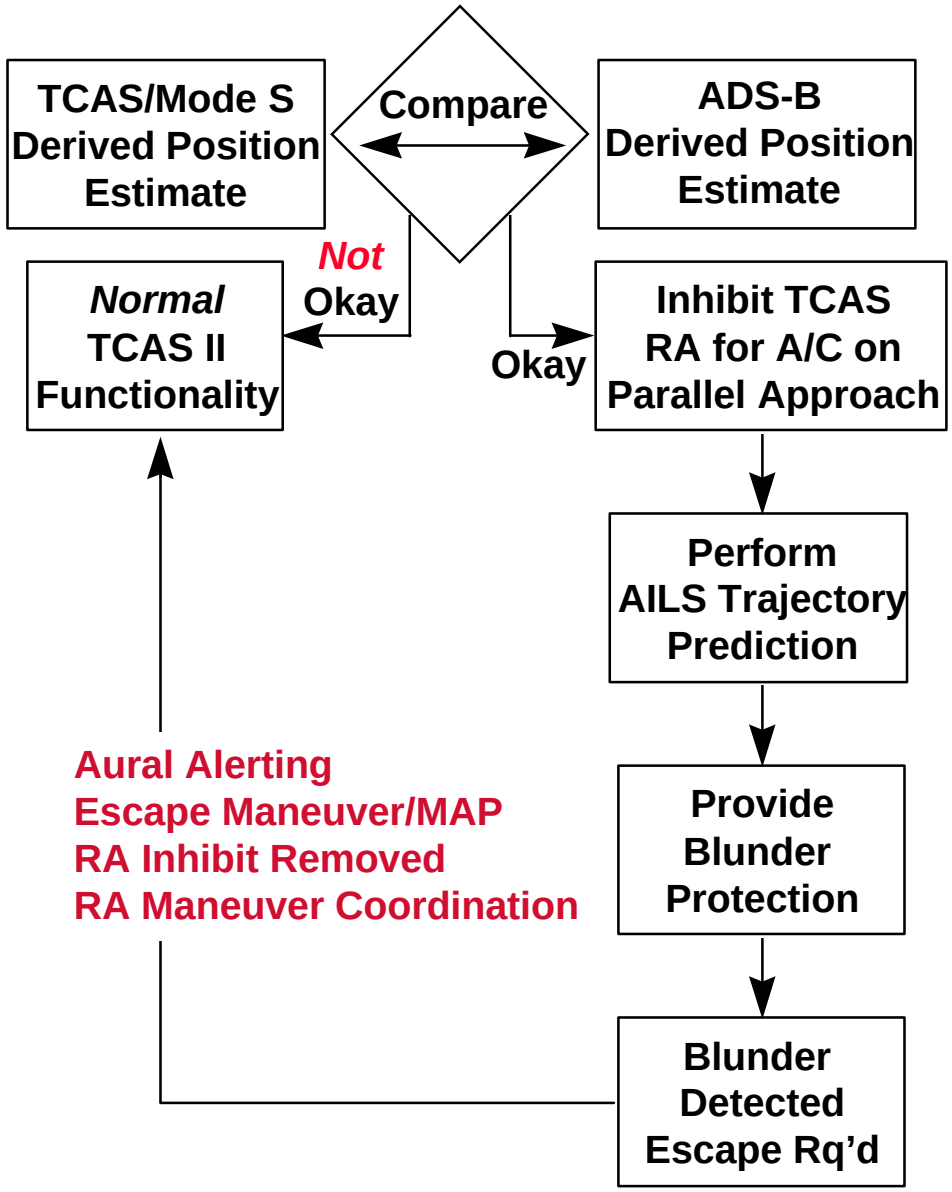
Distributed Air/Ground Concept

Goal – Independent Operations down to 2,500 ft AND BELOW

- Based on NASA-LaRC AILS Paradigm
- Requires DGPS Precision Navigation
- ADS-B Surveillance and AILS Alert Algorithm for both Pilot and Controller
  - TCAS II is *not* being used to Separate Aircraft
- Initial Escape Maneuver/Missed Approach in procedural (turn-climb)
- Controller guidance required for completion of Missed Approach

Interplay of TCAS II and ADS-B/AILS

- TCAS and ADS-B Continually Compare Position Estimates to Improve System Integrity
- If Position Estimates are Compatible, Then TCAS Defers Collision Avoidance of Parallel Aircraft to AILS Algorithm
- If AILS Alert is Required (Blunder Detected), Then Escape Maneuver/Missed Approach Procedure used to break-off approach
- TCAS Inhibit removed



The Foundation for a Free Flight Conflict Probe with Conflict Resolution

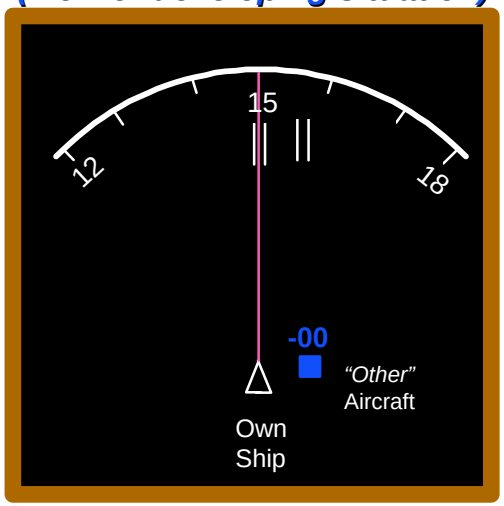
System Concept

Escape Maneuver (Turn & Climb)
BLUNDER DETECTED - ALERT ISSUED

Other Aircraft Position

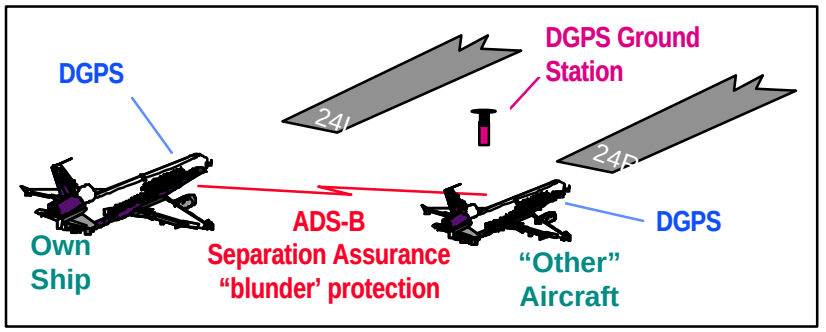
Cockpit Display of Traffic Information (CDTI) ← Airborne Information for Lateral Spacing (AILS) ← Mode S ADS-B ← DGPS ← **Landing NAV Signal**

Provides the pilot with a CDTI for situation awareness *(view of developing situation)*



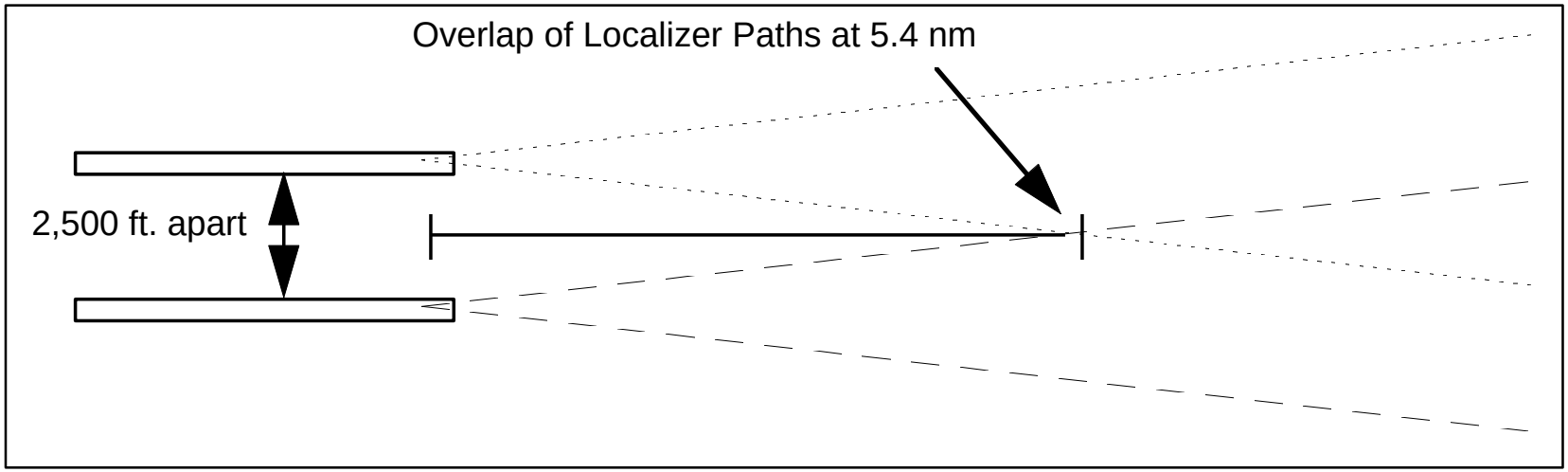
The Specific Thresholds for Alerting will change with specific applications

- **Closely-Spaced Parallel Approaches**
- **Over-taking in Oceanic Environment**
- **Runway Incursion**



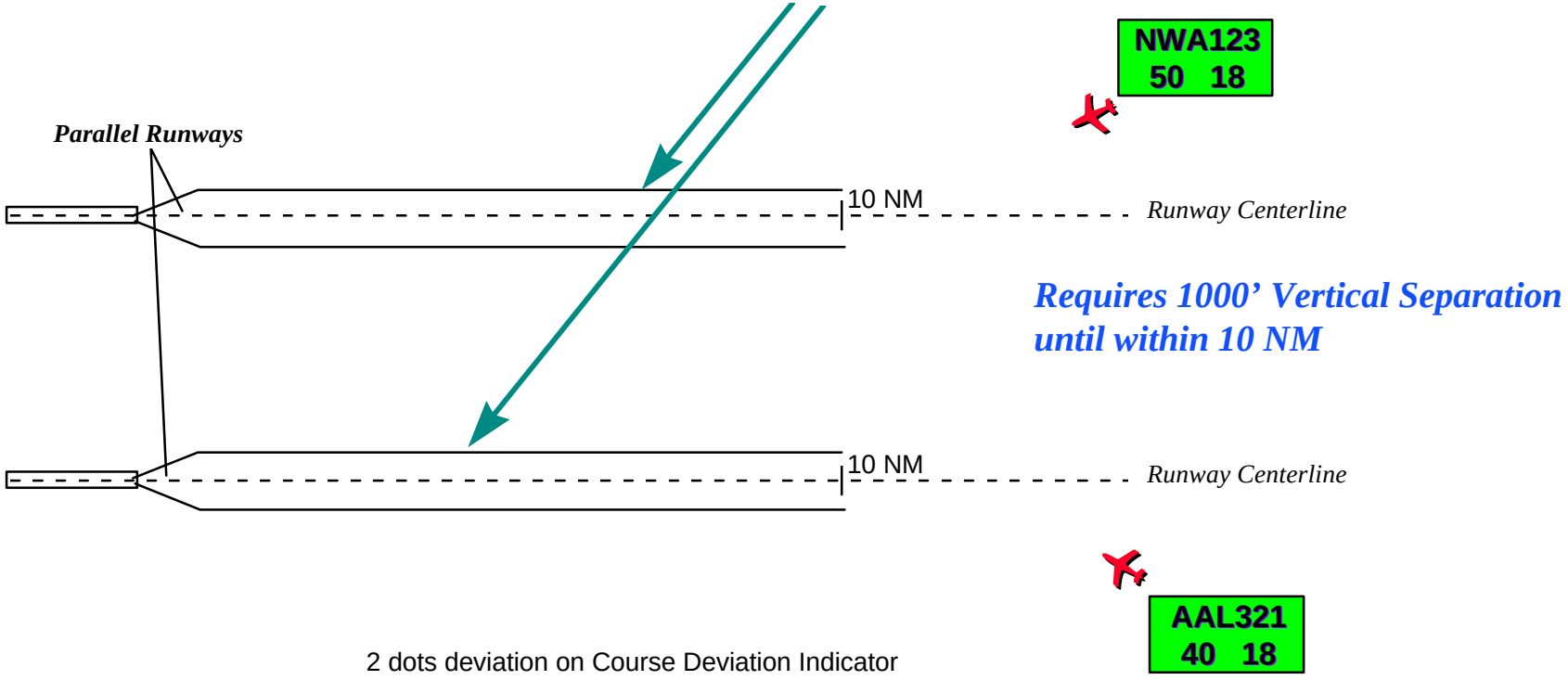
ILS Signal Inadequate

- Overlap of Splayed Localizer Signal won't Support Independent Approach Concept



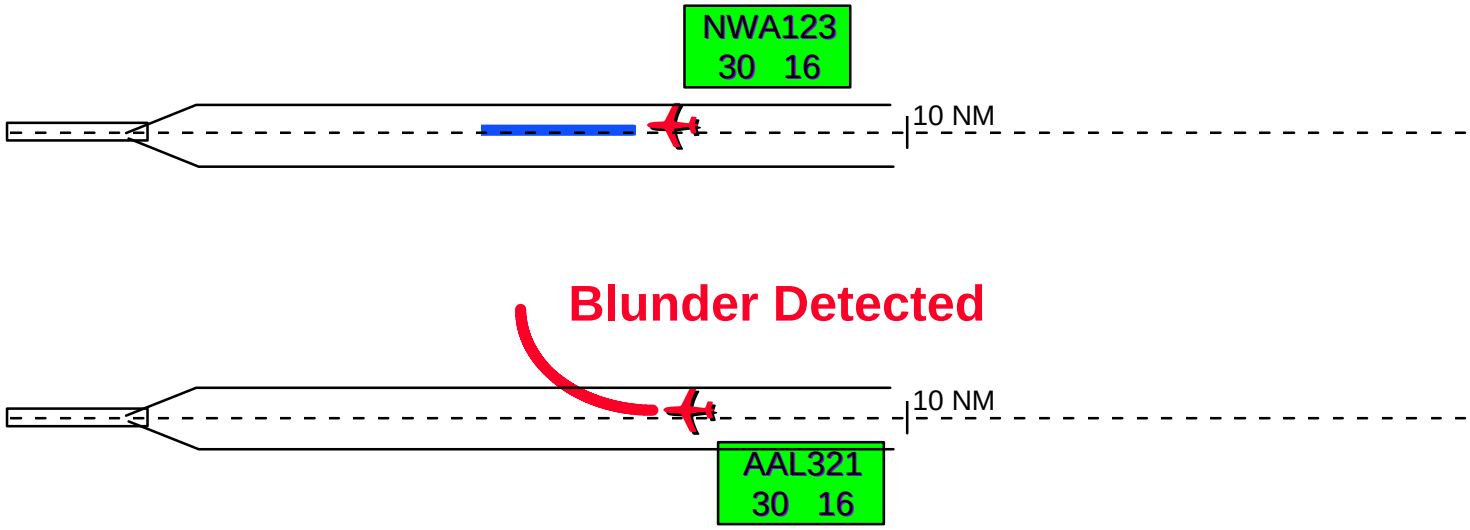
DGPS Navigation

- Maintain 1000 ft vertical separation until established on approach
- Narrow Lateral Path to TDZ



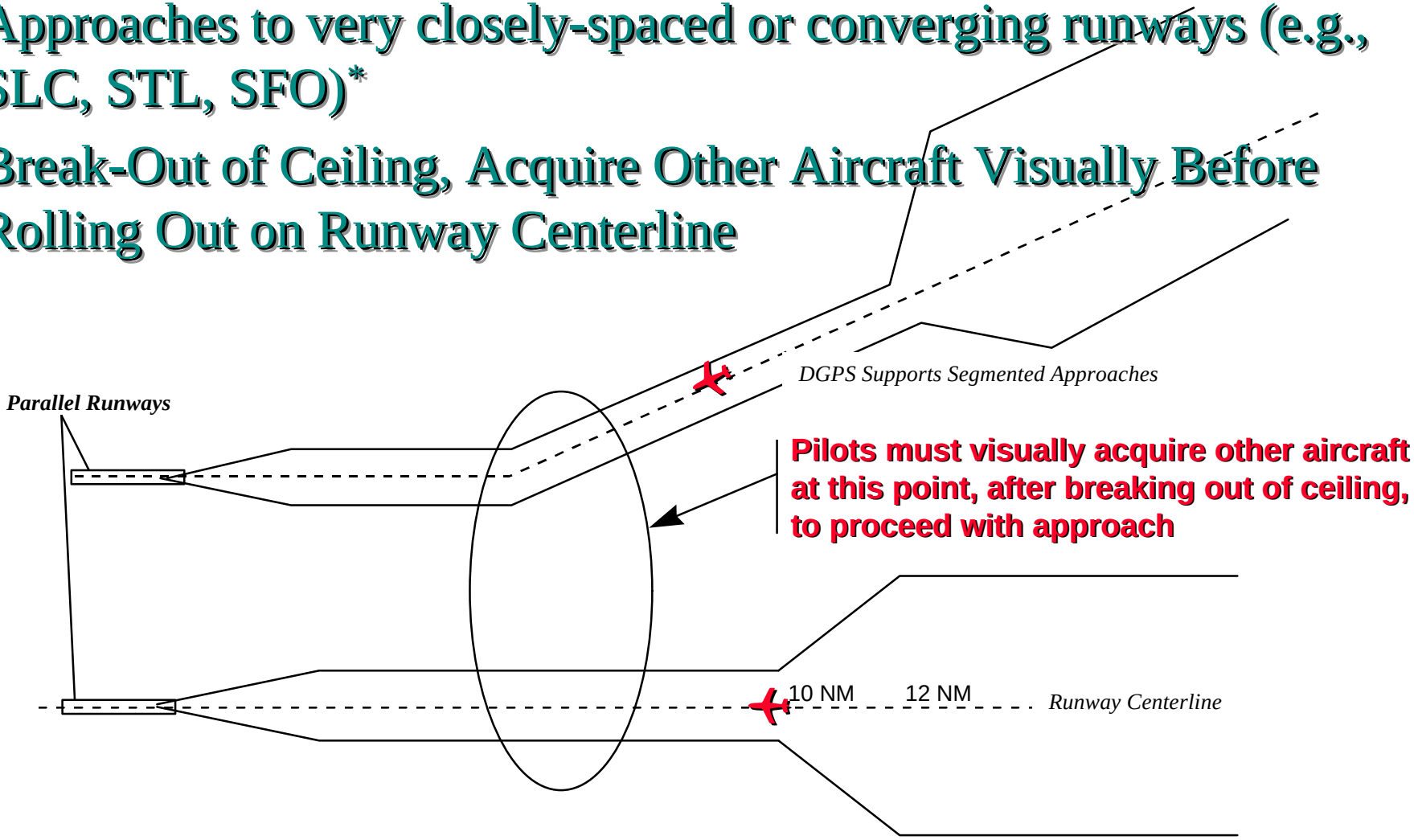
Tailored Alerting

- Predicting "other" Aircraft Trajectory is facilitated with ADS-B (ID, Position, Velocity)



Non-Parallel Initial Approaches

- Approaches to very closely-spaced or converging runways (e.g., SLC, STL, SFO)*
- Break-Out of Ceiling, Acquire Other Aircraft Visually Before Rolling Out on Runway Centerline

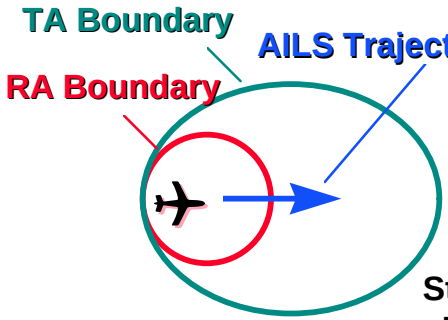


* Allows for Approaches to Runways that would otherwise be treated as a single runway

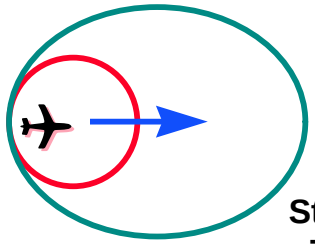
ATC Handbook 7110.65, Section 10, 3-10-3

Sequence of Events

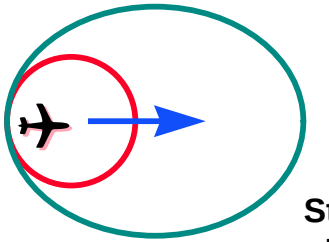
Including Coordinated Escape Maneuvering



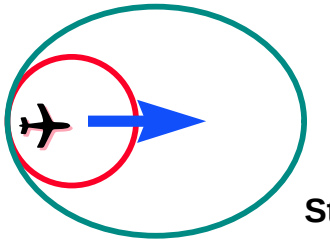
Step 1:
- **TCAS II & ADS-B Handshake**
- **Comparison of Position Est.**



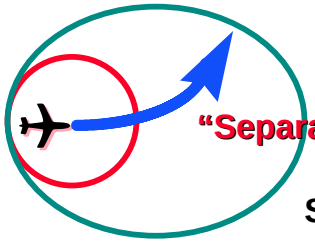
Step 2:
- **TCAS II RA is Inhibited for A/C on Parallel Approach**
- **AILS Algorithms are Activated**



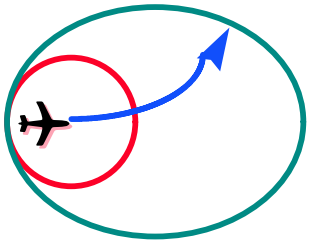
Step 3:
- **Blunder Begins**

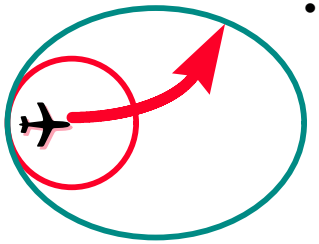


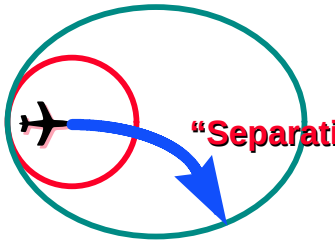
Step 4:
- **AILS Detects Blunder**
- **System Alert**
  Pilots & Controllers



Step 5:
- **Escape Maneuver**
  Turn & Climb

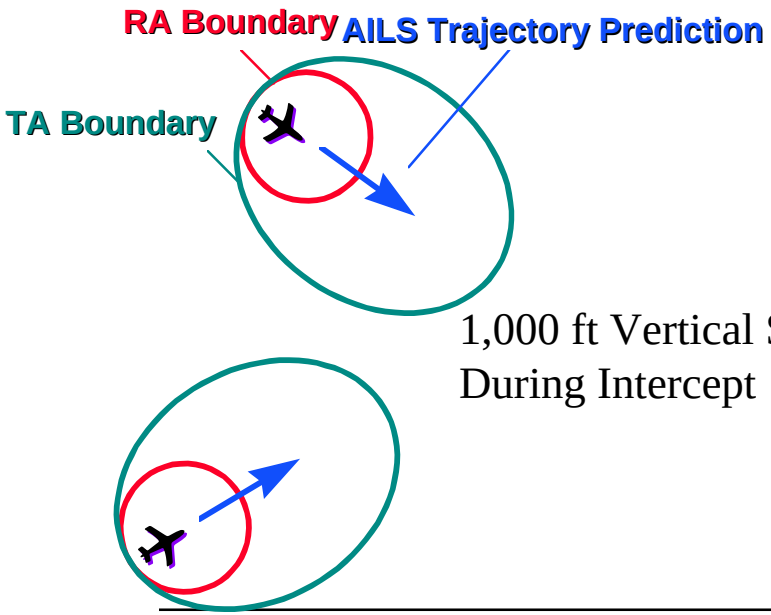






Intercept DGPS "Localizer" Guidance

- TCAS II & ADS-B Handshake
- Comparison of Position Estimate to determine ADS-B Integrity
- TCAS II shares trackfile information with AILS to determine proximate aircraft
- TCAS II continues to provide protection from other aircraft

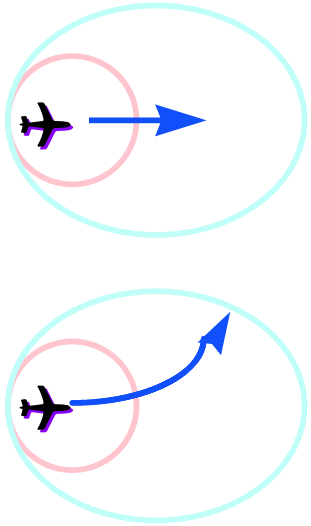


1,000 ft Vertical Separation
During Intercept

AILS Algorithm Active

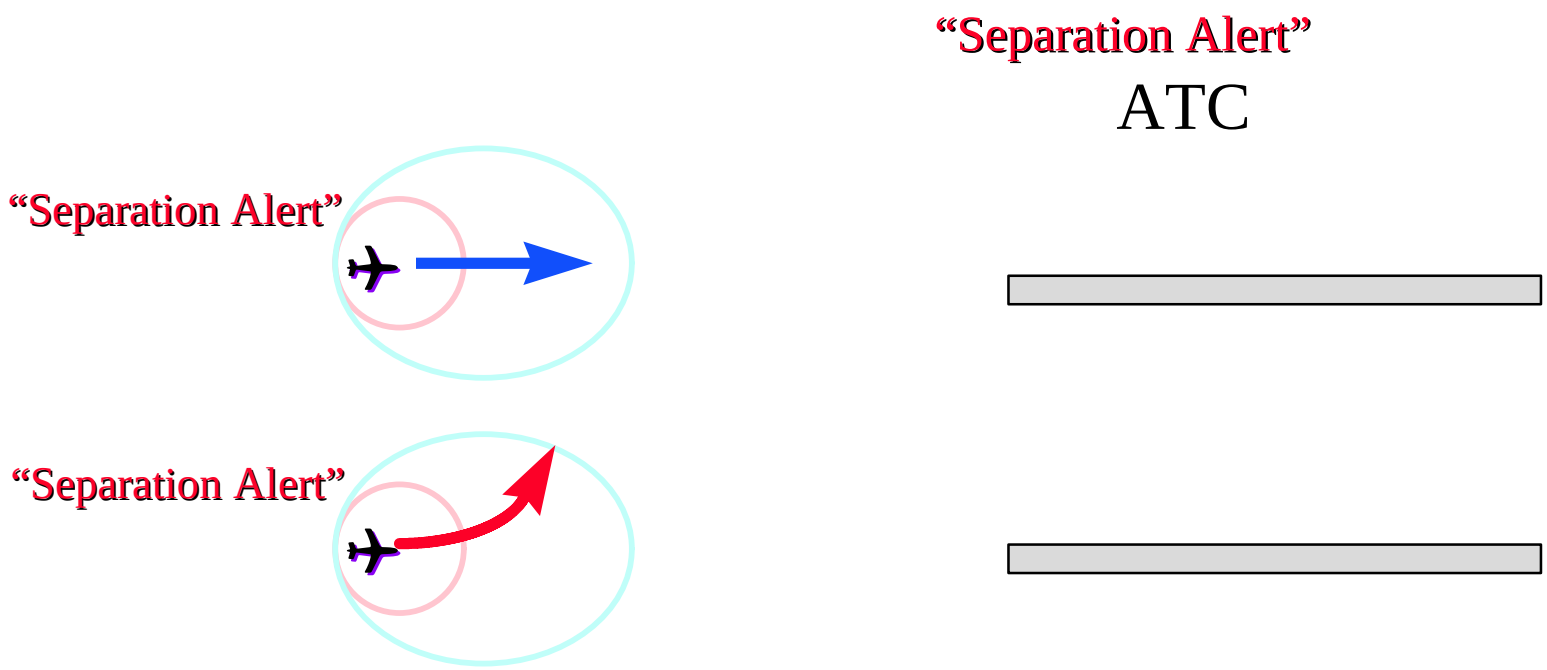
- Centerline of DGPS Localizer Captured
- TCAS II RA is Inhibited for A/C for near-proximity aircraft
- AILS Algorithms are used for Collision Avoidance

Blunder Begins



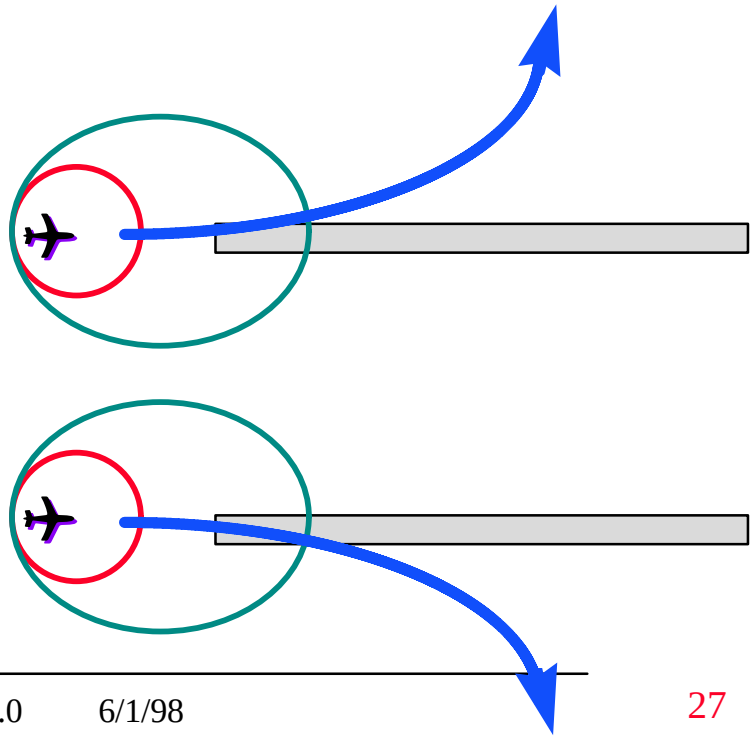
AILS Detects Blunder - Performs Alerting Function

Both Pilots and the Controller are Alerted to Blunder



Escape Maneuver/ Missed Approach

- Turn and Climb away from other aircraft
- ATC Notified
- ATC Vectors after initial Missed Approach Procedure initiated
- Blundering aircraft also contacted by ATC, given vectors
- TCAS Inhibit Removed



Benefits

- Robust Airport Arrival Rate
- Higher Quality of Surveillance
- Better position keeping on final

Benefits

- Higher Quality of Surveillance without fundamental change in current procedures
- Robust Airport Arrival Rate
  - Not Procedurally Intensive
    - Blend of Current Ops with Improved Surveillance
- Added Level of Safety in VMC
- Instantaneous Awareness for both Pilot and Controller of blundering aircraft

Issues

- Nature of Alert
- TCAS Behavior when “Inhibited”
- ADS-B/TCAS Track File Comparison Strategy
- How to Deal with Unequipped Aircraft
- Traffic display issues (e.g., scale, mode switching)

(Open List)

Point to Remember

Being Able to Meet The Challenge of *Independent* Approaches to Closely-Spaced Parallel Runways in IMC Will Provide The Vast Majority of ADS-B related Tools Required to Support a Free Flight Environment in All Flight Regimes

Future Activities

- NASA Simulation Activities
  - LaRC (March 99)
  - Ames (FY2000)
- NASA/Honeywell Flight Demonstration (July 99)
- SC-186 Activities
  - Acceptance of Operations Concept
  - Very closely-spaced, dependent approaches concept development

Questions?!?