Air Traffic Management

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Air Traffic Management

- **Objective: To review briefly some developments regarding ATC/ATM, primarily as they apply to airports**
- **Topics:**
  - General Comments
  - Traffic Flow Management
  - Increasing Airport Capacity
  - Advanced ATM Systems
  - Differences between US and Europe

ATM: Six fundamental components

1. Procedures and regulations; organization of airspace
2. Human air traffic controllers
3. Automation systems (computers, displays, decision support systems)
4. Communication systems (air, ground)
5. Surveillance systems (e.g., radar)
6. Navigation systems (e.g., VOR/DME, ILS, GPS)

Complex Requirements for ATM

- Exceptional levels of safety
- Accommodate growing numbers of diverse users in efficient traffic flows
- Mesh seamlessly humans and machines, including increasingly sophisticated automation aids
- Take advantage of new technology
- Evolve gradually without “discontinuities”
- Operate at reasonable cost to service providers and users

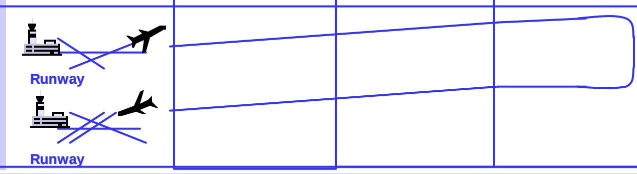
Generations of ATM Systems

- First: no (or little) radar coverage; ATC via communications only
- Second: analog radar coverage
- Third: digital (secondary) radar; upgraded ground-based CNS; automation of many data processing tasks
- Fourth: advanced automation aids; digital data links; satellite-based CNS

Status of Air Traffic Management

- Dramatic Differences Among Nations and Regions
- (Many) Developing Countries:
  - "first" generation ATC systems with limited (or no) radar coverage and few (often poorly maintained) navaids
- Advanced Industrial Countries:
  - mostly "third" generation systems with digital radar and significant automation
  - beginning to make transition to highly automated fourth generation systems

Schematic Representation of ATM System

Type of Facility	Terminal Area Facilities		En Route Facilities	
Controlling Facility	Airport Traffic Control Towers	Approach Control Facilities	Air Route Traffic Control Centers (ARTCCs)	
Type of Control	Ground Traffic Control Takeoff and Landing Control	Approach and Departure Control	ATC During Transition and Cruise	
Airspace	Airport Traffic Area Typically 5 nmi And 3,000 ft AGL	Approach Control (Tracon Area) Typically extending up to 40 nmi + 10,000 ft from the Airport	En Route Airspace Transitional Phase Typically 50-150 nmi From Airport	Cruise Phase Up to 60,000 ft
Typical Flight Time	Typical Ground Time 5 - 10 min	Typical Flight Time 10 - 20 min	Typical Flight Time 10 - 20 min	Typical Flight Time 20 min to several hrs
Flight Profile				

Cost to Users of ATM Constraints & Inefficiencies

- **Generators of Costs:**

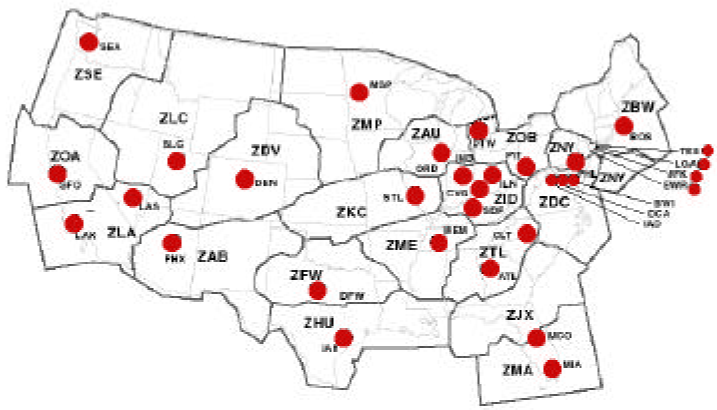
Delays	Missed Connections
Cancellations	Indirect Routing
Diversions	Sub-optimal Flight Paths

- **Uncertainty as to True User Costs**

- **Reasonable *Guess*:**

Cost to Airlines and Passengers ~ $4-6 billion/year, in Europe alone and in United States alone

“Major Problem” Airports (2010)



Alternatives for Addressing Airport and Terminal Airspace Capacity Problem

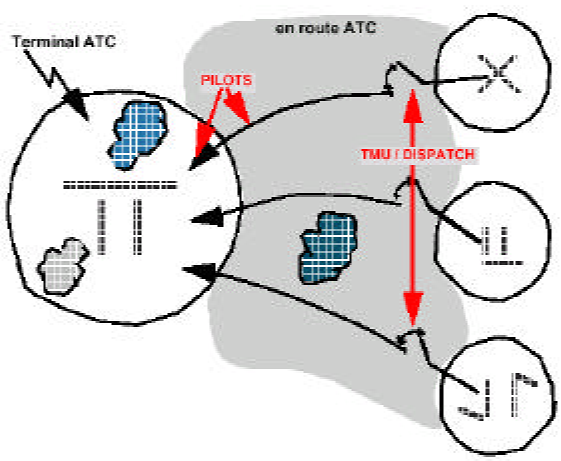
1. **Increased airport capacity**
   - **second, third, … airports**
   - **new, larger airports to replace older ones**
   - **more runways, etc. at existing ones**
   - ***improved ATM***
2. **Demand management**
   - **total operations**
   - **by time-of-day**
3. ***Flow management; reduce cost and impacts of unavoidable delays***
4. **Other modes of transportation; substitutes for transportation (communications)**

Definition and Fundamentals of ATFM

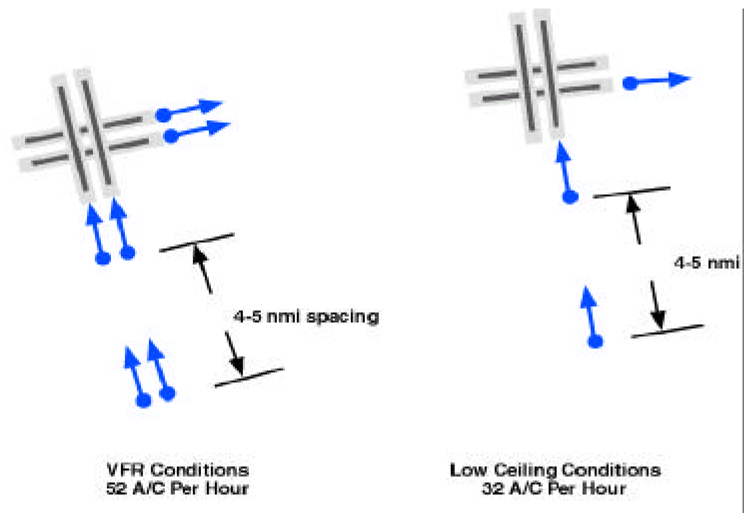
- **ATFM: Strategic planning and implementation of regional and national flows to best "match" demand with available capacity and minimize impact of congestion on users and operators of ATM system**
- **Now vital element of both European and US ATM systems**
- **Basic steps:**
  - **(1) Prediction of potential overloads**
  - **(2) Development of strategies**
  - **(3) Implementation of strategies**
- **The tools for accomplishing (2) and (3):**
  - **Ground-holding (more "strategic")**
  - **Re-routing, metering, speed control, sequencing**

Time horizon ranges from months to ~30 minutes

Strategic and Tactical ATFM Actions



Reduced Capacity at SFO Typically Leading to Initiation of a GDP



The Ground Delay Problem

- **Motivation: If long delays must be suffered, they would be better taken on the ground, prior to take-off**
  - **Safety, workload, fuel**
- **Must be solved in the presence of uncertainty regarding airport capacity**
  - "Type 1 Error"
    - **Demand higher (or capacity lower) than expected, leading to long <u>airborne</u> delays**
  - "Type 2 Error"
    - **Demand lower (or cap. higher) than expected, leading to unnecessary delays <u>on the ground</u>**
- **Highly dynamic environment**

GDP Until 1998

- **Prediction of Overload**
  - Compare Airport Acceptance Rate (AAR) for Arrivals to Scheduled Demand
- **Development of Strategy**
  - Calculate delay required of each flight, First-Scheduled, First-Served (FSFS), to meet AAR
- **Implementation of Strategy**
  - Issue Expected Departure Clearance Times (EDCT's) to aircraft
- **Could we improve on this?**

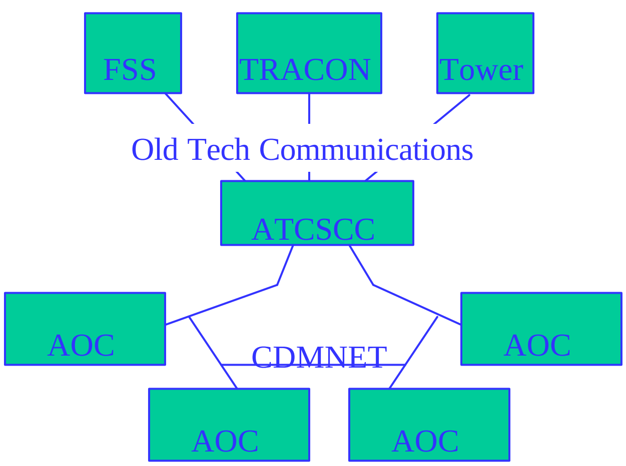
Concerns About "Old" GDPs: Motivation for CDM

- **Did not consider airline preferences regarding flight priorities, crew connections, "banks"/ "waves", etc.**
- **Was too conservative**
- **Did not deal well with uncertainty**
- **A "system-wide" viewpoint (instead of an individual user's): the ATFM system's operator (the FAA) effectively decided what is best for everyone ("global" objective function)**

Collaborative Decision-Making (CDM) in U.S.

- New approach to traffic flow management
- Airline Operations Centers (AOCs) and FAA share information on capacities, delays, cancellations, preferences, etc.
- First experiments with GDPs at SFO and EWR (1/98); adopted for all airports (9/98)
- Has already saved many $$ in delay costs
- Opportunity to work and make decisions in real time with a common data base
- Greatly expanded scope and objectives at this time

CDM Infrastructure



Dynamic Slot Assignment System under CDM

1. FAA estimates airport acceptance rate (AAR) at arrival airport
2. FAA assigns slots to airlines according to AAR on first-scheduled, first-served basis ("ration by schedule")
3. Each airline tells FAA how its own slots will be used (substitutions and cancellations)
4. After cancellations become known, "compression" is performed to take advantage of empty slots
5. FAA assigns controlled time of arrival (CTA) to each flight and an associated controlled time of departure (CTD)
6. (Future?) No CTDs: airline determines take-off time for each flight to meet that flight's CTA.

Example: Original Schedule and Initial GDP Schedule

Airline	Flight	ETA	CTA	Delay
A	1	0700	0700	0
A	2	0700	0710	10
B	3	0705	0720	15
B	4	0705	0730	25
B	5	0710	0740	30
B	6	0710	0750	40
A	7	0720	0800	40
C	8	0720	0810	50
B	9	0740	0820	40
C	10	0740	0830	50
A	11	0820	0840	20
B	12	0840	0850	10
Total A				70
Total B				160
Total C				100
Total D				330

Example continued: A GDP Scenario

- **Flight A1 is cancelled**
- **Airline B ranks flights B3-B6 in the order {B6, B4, B5, B3} in terms of priority**

Note: Under CDM rules airlines may freely substitute within their own flight schedule and can move any flight to a slot which is not earlier than that flight's ETA

Modified GDP: Cancellation of A1 and Swapping of B3 and B6 Slots

Airline	Flight	ETA	CTA	Delay
A	2	0700	0700	0
Void	Void	--	0710	--
B	6	0710	0720	10
B	4	0705	0730	25
B	5	0710	0740	30
B	3	0705	0750	45
A	7	0720	0800	40
C	8	0720	0810	50
B	9	0740	0820	40
C	10	0740	0830	50
A	11	0820	0840	20
B	12	0840	0850	10
Total A				60
Total B				160
Total C				100
Total D				320

Potential GDP if A Discloses Cancellation of A1 to FAA

Airline	Flight	ETA	CTA	Delay
A	2	0700	0700	0
B	6	0710	0710	0
B	4	0705	0720	15
B	5	0710	0730	20
B	3	0705	0740	35
A	7	0720	0750	30
C	8	0720	0800	40
B	9	0740	0810	30
C	10	0740	0820	40
A	11	0820	0830	10
B	12	0840	0840	0
Total A				40
Total B				100
Total C				80
Total D				220

Potential GDP if A Does Not Disclose Cancellation of A1

Airline	Flight	ETA	CTA	Delay
A	2	0700	0700	0
Void	Void	--	0710	--
B	6	0710	0720	10
B	4	0705	0730	25
B	5	0710	0740	30
B	3	0705	0750	45
A	7	0720	0800	40
C	8	0720	0810	50
B	9	0740	0820	40
C	10	0740	0830	50
A	11	0820	0840	20
B	12	0840	0850	10
Total A				60
Total B				160
Total C				100
Total D				320

CDM Rules for Cancelled Flights

- **CDM recognizes need to provide incentives to airlines to share information regarding flight cancellations and other changes in plans**

- ***CDM Rule: An airline that cancels a flight has the right to advance later flights to the first feasible slot which becomes available as a result of the cancellation.***

Substitutions under CDM Give Priority to Airline Which Cancelled Flight

Airline	Flight	ETA	CTA	Delay
A	2	0700	0700	0
B	6	0710	0710	0
Void	Void	--	0720	--
B	4	0705	0730	25
B	5	0710	0740	30
B	3	0705	0750	45
A	7	0720	0800	40
C	8	0720	0810	50
B	9	0740	0820	40
C	10	0740	0830	50
A	11	0820	0840	20
B	12	0840	0850	10
Total A				60
Total B				150
Total C				100
Total D				310

After Moving A7 Up….

Airline	Flight	ETA	CTA	Delay
A	2	0700	0700	0
B	6	0710	0710	0
A	7	0720	0720	0
B	4	0705	0730	25
B	5	0710	0740	30
B	3	0705	0750	45
Void	--	--	0800	--
C	8	0720	0810	50
B	9	0740	0820	40
C	10	0740	0830	50
A	11	0820	0840	20
B	12	0840	0850	10
Total A				20
Total B				140
Total C				100
Total D				260

Compression of Schedule

Airline	Flight	ETA	CTA	Delay
A	2	0700	0700	0
B	6	0710	0710	0
A	7	0720	0720	0
B	4	0705	0730	25
B	5	0710	0740	30
B	3	0705	0750	45
C	8	0720	0800	40
B	9	0740	0810	30
Void	--	--	0820	--
C	10	0740	0830	50
A	11	0820	0840	20
B	12	0840	0850	10
Total A				20
Total B				130
Total C				90
Total D				240

Final GDP under CDM after Substitutions and Compression

Airline	Flight	ETA	CTA	Delay
A	2	0700	0700	0
B	6	0710	0710	0
A	7	0720	0720	0
B	4	0705	0730	25
B	5	0710	0740	30
B	3	0705	0750	45
C	8	0720	0800	40
B	9	0740	0810	30
A	11	0820	0820	0
C	10	0740	0830	50
B	12	0840	0840	0
Total A				0
Total B				130
Total C				90
Total D				220

Potential GDP if A Discloses Cancellation of A1 to FAA

Airline	Flight	ETA	CTA	Delay
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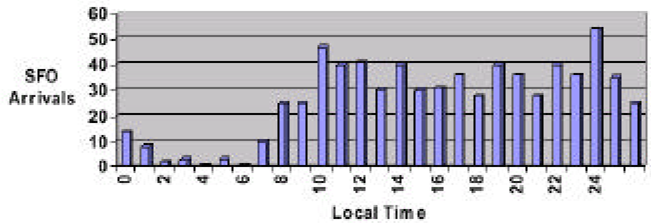
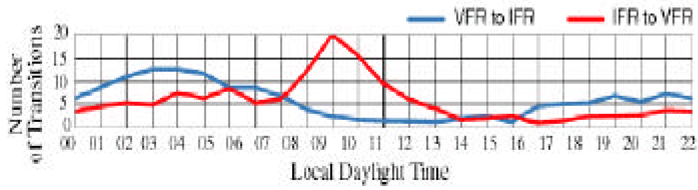
C	10	0740	0830	50
A	11	0820	0840	20
B	12	0840	0850	10
Total A				70
Total B				160
Total C				100
Total D				330

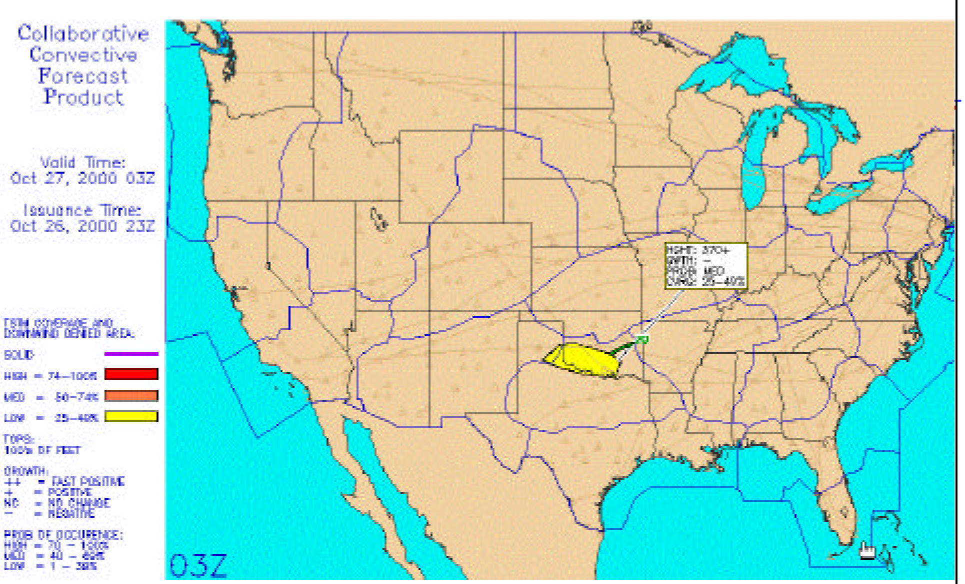
Some "Open" Problems in CDM

- Accurate forecasting of demand, capacity, delays
- Improvements to FSM software
- Airlines: how many and what flights to cancel during GDPs?
- Setting the "airport acceptance rate" (AAR)
- Considering trade-offs between allocating capacity to arrivals and departures
- GDP control strategies
- A real-time "slot exchange"?
- Collaborative routing

SFO Demand and Weather







Implications of CDM

- CDM represents a major change in ATM environment
- Opportunity to work and make decisions in real time with a common database
- Step toward decentralization and Free Flight
- Immediate impacts on GDPs and routing
- Longer-term impacts on entire spectrum of ATM operations
- Possibly unexpected developments

Examples of approaches to increasing airside capacity and/or improving efficiency

Terminal area ATC automation aids

- ✈ Tools for arrival scheduling, sequencing and spacing
- ✈ Convergent Runway Display Aid (CRDA)
- ✈ Surface traffic automation (TARMAC, SMA, A-SMCGS)
- ✈ Departure planning tools (EDP)

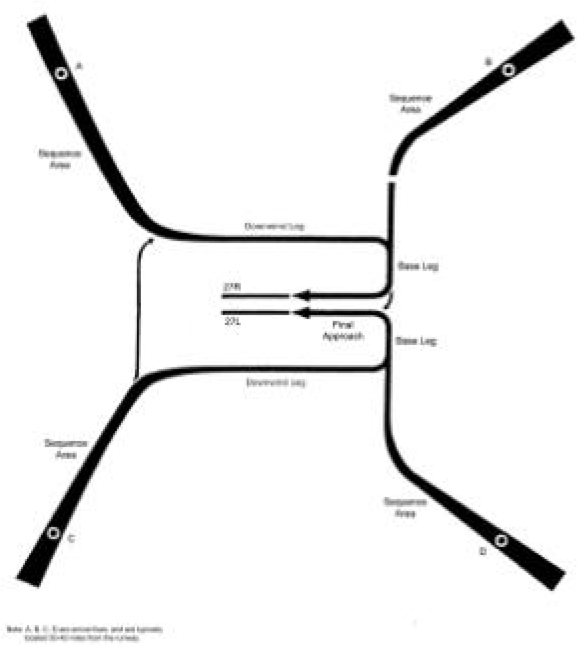
- **Wake-vortex separations**
- **Integrated terminal weather systems**
- **Precision runway monitor for closely-spaced parallel approaches**
- **Split approaches to close parallels; multiple runway IFR approaches**
- **ADS-B supported separations**
- **GPS-based precision approaches**

Advanced Terminal Area Automation Aids

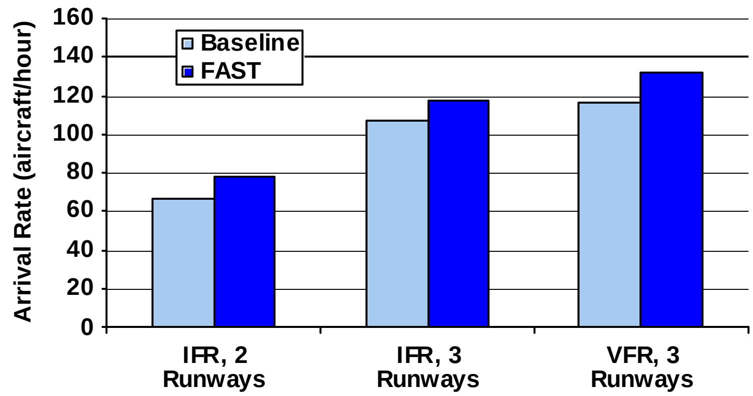
Decision support for arrival processing:
- CTAS (Center TRACON Automation System, U.S.)
- COMPAS (Frankfurt)
- MAESTRO (Paris)

Terminal area transitioning, scheduling, sequencing and spacing of airport arrivals: last ~40 minutes of flight

Several ongoing efforts to develop integrated arrival/departure/surface decision support systems

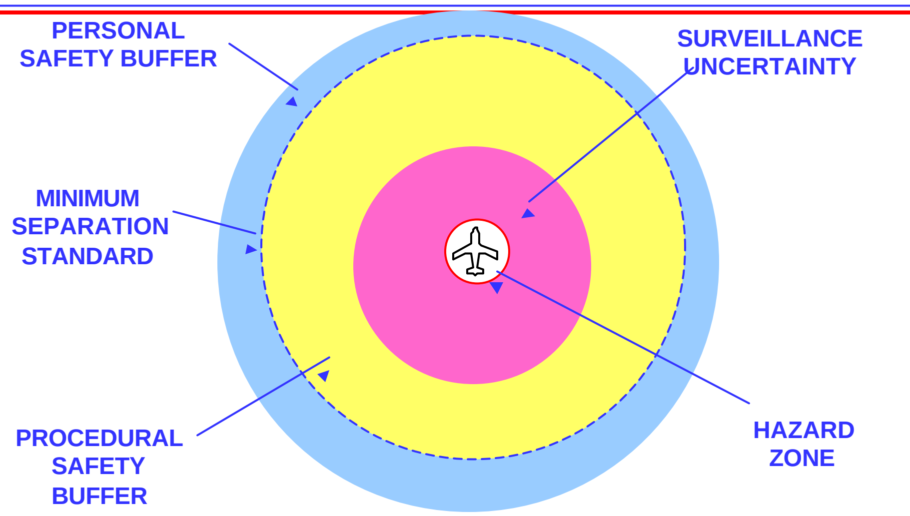


Impact of CTAS (p-FAST) on DFW Arrival Rates



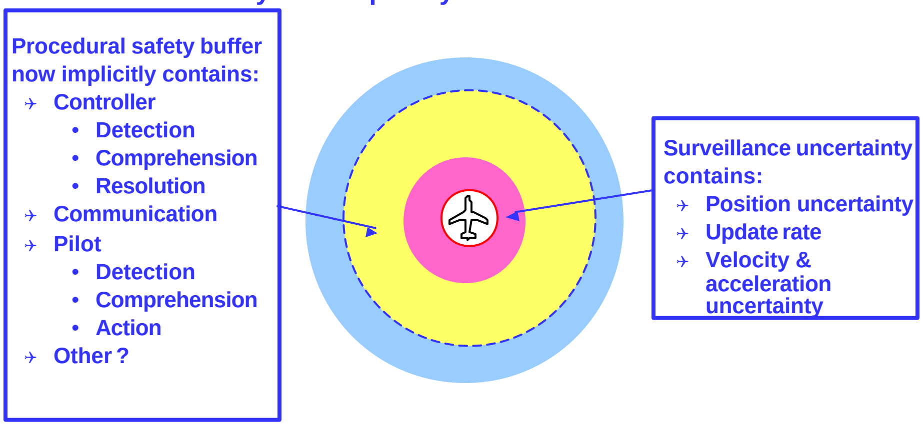
Mid-morning rush data (source: Mr. T. Davis, NASA Ames)

Separation Assurance Considerations

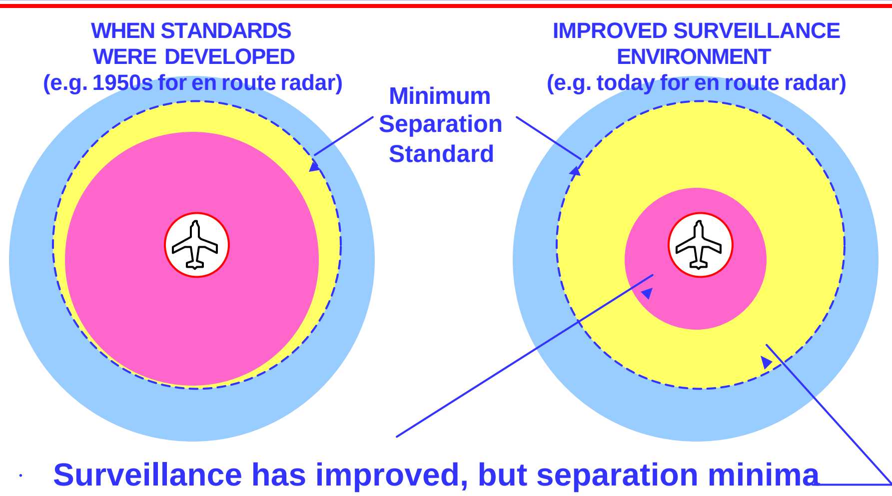


Surveillance & Procedural Safety Buffer Components

- Initial standards based primarily on surveillance uncertainty
- Hazard recovery now implicitly contained within standard?



Improved Surveillance Has Not Led To Significantly Reduced Separations



- Surveillance has improved, but separation minima have not changed: procedural safety buffer has implicitly increased

Trend to Less Centralized ATM

- New technologies and user concerns exert strong pressure toward some decentralization of ATM systems
- "Free Flight" concept is an example
- May mean significant departure from current approaches to ATM
- Fundamental issues need to be investigated

Free Flight

- *"A safe and efficient flight operating capability under IFR in which the operators have the freedom to select their path and speed in real time. Air traffic restrictions are only imposed to ensure separation, to preclude exceeding airport capacity, to prevent unauthorized flight through special use airspace and to ensure safety of flight. Restrictions are limited in extent and duration to correct the identified problem. Any activity which removes restrictions represents a move toward "free flight."*

Report of RTCA Board of Directors Select Committee on Free Flight (1/95)

Future of ATM Globally

- Essential components
  - Satellite-based communications, navigation, and surveillance (CNS)
  - Use of Global Navigation Satellite Systems such as GPS and GLONASS
  - Digital data links
  - Flight Management Systems
  - Conflict probes, collision avoidance systems
- Opportunity for countries with less developed ATM systems to “leapfrog”
- ATM in oceanic and remote areas will be first to benefit in important ways