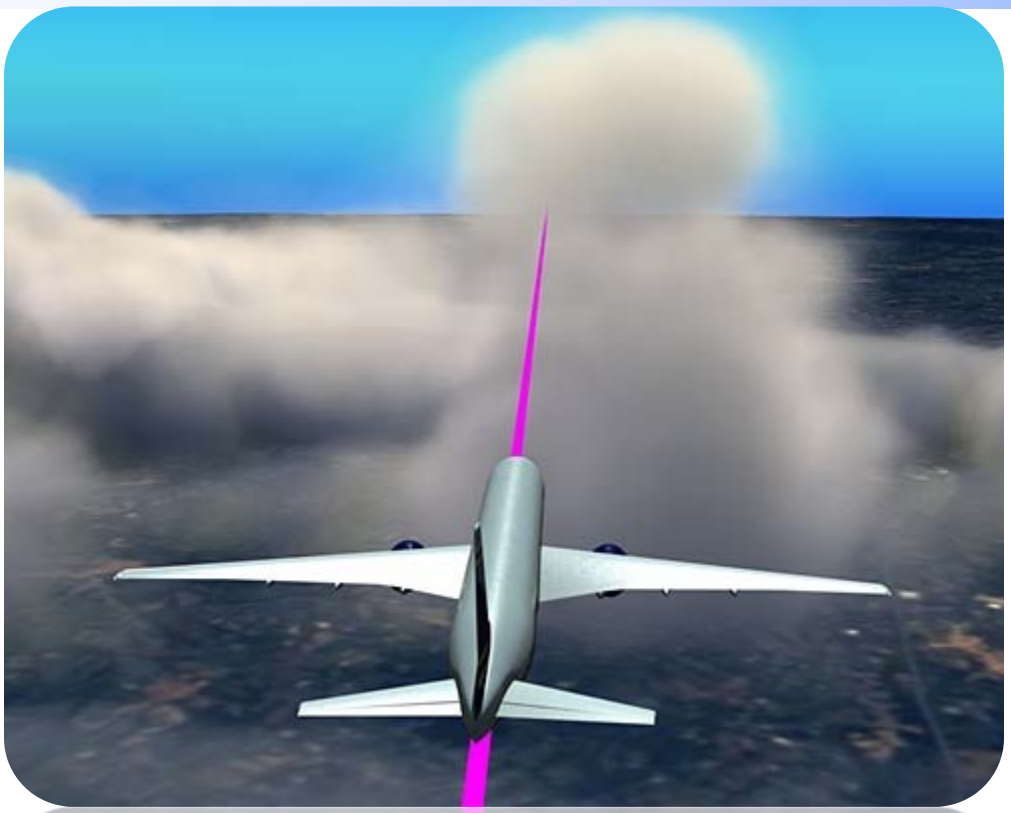
Concept for System Wide Trajectory Based Operations w/ Self-Separation



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Contents of Presentation

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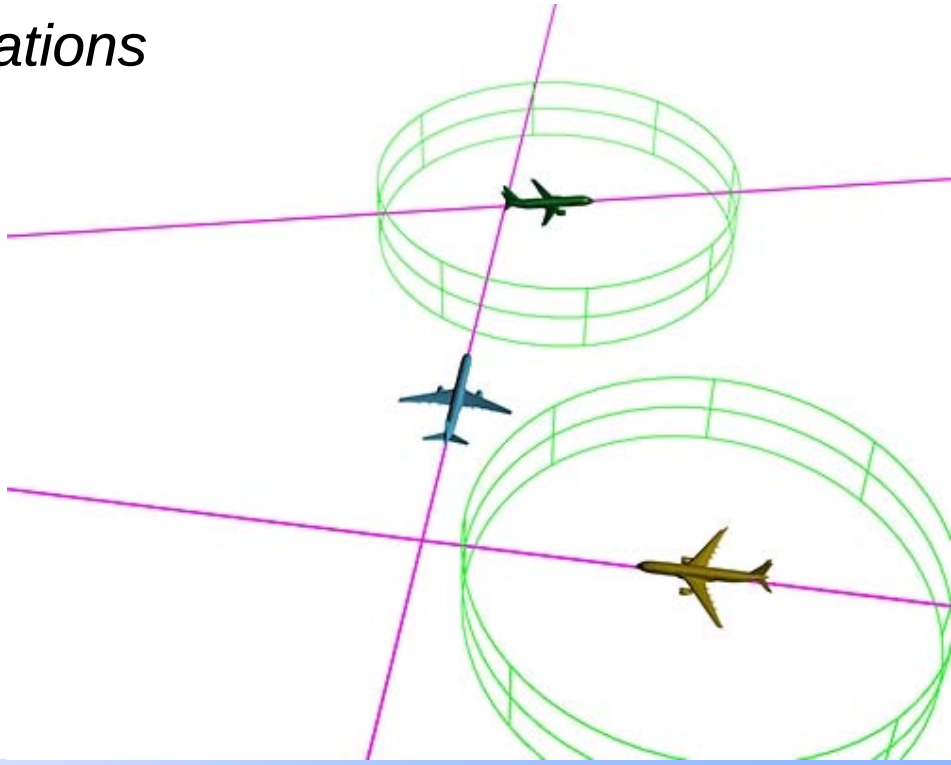
- *Operational domain and operating rules*
- *Details of the method proposed*
- *Internal and external requirements enabling the concept*
- *Safety assurance considerations*
- *Summary*



Objectives of the Concept

- *Improve **Flexibility** available for planning and operating flights*
  - Results in greatest efficiency of flight operations and reduced environmental impact
- *Maintain **Access** to greatest amount of airspace by all segments of airspace users*
  - Least amount of restrictions
- *Provide reliable **Transition** mechanism to ensure beneficial implementation/use of the concept*
- *Enable **Scaling** to many times more flight operations with wide diversity of vehicles and missions*
- ***Reduced Risk** of collision/mishap in all flight and ground operations*

Operational Overview

- *The business trajectory rules!*
  - For all operations, the optimization of each flight's performance measures and mission objectives is the beginning and the "end" of all aspects of the flight
  - The airspace itself has ample capacity to accommodate the needs of all users in this manner

- *Widespread application of "autonomous" operations*
  - Can be conducted in all "flyable" weather conditions
  - May be conducted in any class of airspace
    - Except access-limited Special Use Airspace
    - Restrictions in high-density terminal airspace

- *Air Traffic Management functions*
  - Separation: Accomplished on-board
  - Flow Management:
    - Airport related constraints only
    - Centrally organized: Required Time of Arrival (RTA)
    - Carried out on-board

Autonomous Flight Rules (AFR)

- *AFR is an additional flight option to VFR and IFR*
  - Operator has authority to manage and change the trajectory as needed
  - Operator has responsibility for separation from traffic
- *Aircraft capable of operating under AFR:*
  - Contain equipment certified for self separation (SSEP) functions
  - Are piloted by crews trained, checked and current for SSEP operations
  - Follow guidance generated by SSEP avionics to maintain safety in operations
- *AFR Right of Way rules:*
  - AFR to AFR: embodied in SSEP software, similar to VFR but more comprehensive
  - AFR to IFR: AFR gives right of way to IFR in conflicts, is merged with IFR near runway
  - AFR to VFR: follows VFR right of way rules
- *AFR aircraft participate in TFM initiatives that are airport related*
  - Meet constraints imposed through RTA assignment
- *Terminal airspace*
  - AFRs participate as IFR traffic in terminal environments where IFR services are provided

Mixed Operations – AFR, IFR, and VFR

Key element of the concept:
Simultaneous mixed operations in shared airspace.
No need for segregation by airspace.

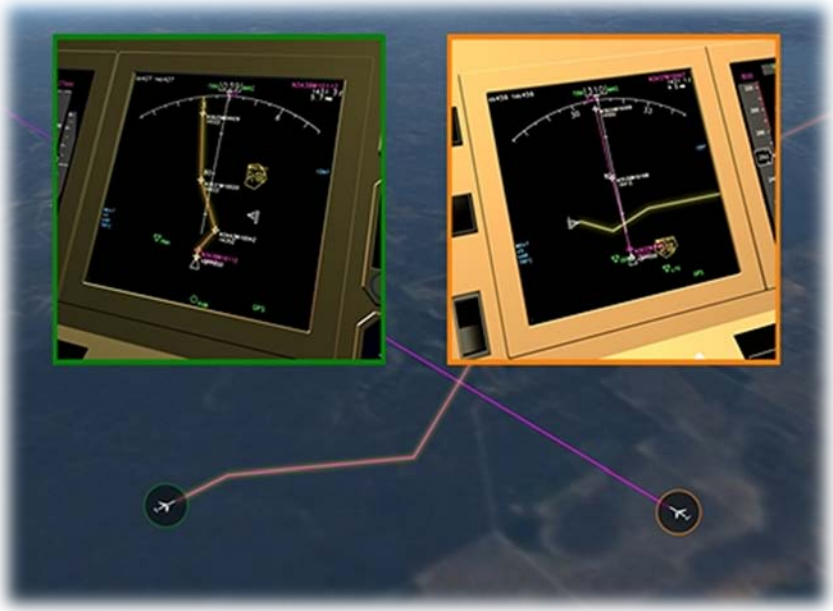
- *Made possible by AFR giving right of way to IFR (controller-based operations), ATC just separates IFR from IFR.*
- *AFR participates in IFR services on and near the airports, unburdening the ANSP between airports*
- *AFR adds safety to operations with VFR by providing automated conflict detection and resolution (CD&R) in the visual environment*

Conflict Management

- *Many good CD & R algorithms have been tested or postulated. All use some degree of trajectory prediction, from the state vector to a fully described trajectory.*
- *Strategic intent-based CD&R uses traffic and ownship intent (when available)*
  - Facilitates flying with the FMS
  - Longer horizon supports planning for multiple constraints and more optimum business trajectory planning
- *Tactical intent-based CD&R uses traffic intent when available, ownship "target state"*
  - More flexible than full-route resolutions (reconnect solution saved for later)
  - Not limited by FMS restrictions
- *Tactical state-based CD&R uses only state vectors for ownship and traffic*
  - Immune to intent errors and non-conformance
  - Used for blunder protection and short-time alerts
  - Reactive but nimble in highly constrained environments

Coordination of Maneuvers

- *Conflict resolution*
  - During the period of the resolution, the behavior of the reference aircraft is implied by intent and controlled through “implicit” coordination
  - Nominal coordination
    - Right of way determines the burdened aircraft, i.e. who gets alerted first
  - Short-term coordination
    - Common state-based CR algorithm coordinates turn direction, etc.
  - “Explicit” coordination is “hand-shaking” of resolution maneuver
    - Not proposed for this concept
    - Used only in TCAS-TCAS resolutions
- *Maneuvering without conflict*
  - Involves checking for conflict on altered plan before executing it
  - Selecting new trajectory or an FMS route amendment triggers check for conflicts before execution
  - May be indicated to pilot even before altered trajectory is programmed, e.g. conflict prevention bands



Traffic Flow Management

- *TFM: the equitable metering of traffic through a scarce resource*
- *For self-separation airplanes, the only common resource is the runway*
- *AFR aircraft participate in runway-constraint Traffic Management Initiatives (TMIs)*
- *Mechanism for compliance normally by RTA at merge point*
  - Ranges from terminal airspace boundary to approach fix, depending on airport
  - Centralized TMIs to accomplish equitable metering of traffic to runways does not yet exist

Integration with IFR in Terminal Areas

- *AFR Departure: Simplest form is to depart with other IFRs until "released" to AFR by Departure Control*
- *AFR Arrivals: "Hand off" to Approach Control upon entering the Terminal Area*
- *Several compatible "airborne separation" concepts to take advantage of self-separation capability could be adopted locally:*
  - Delegated separation:
    - On departure or arrival, the ANSP could delegate separation responsibility to an AFR-capable aircraft in "pairwise" fashion
    - Analogous to use of visual separation in the US as a part of an IFR clearance
  - Merging and Spacing of arrival traffic, integrated with Optimized Profile Descent
  - "In-Trail Following" at designated time interval from final approach to the runway, or after takeoff.

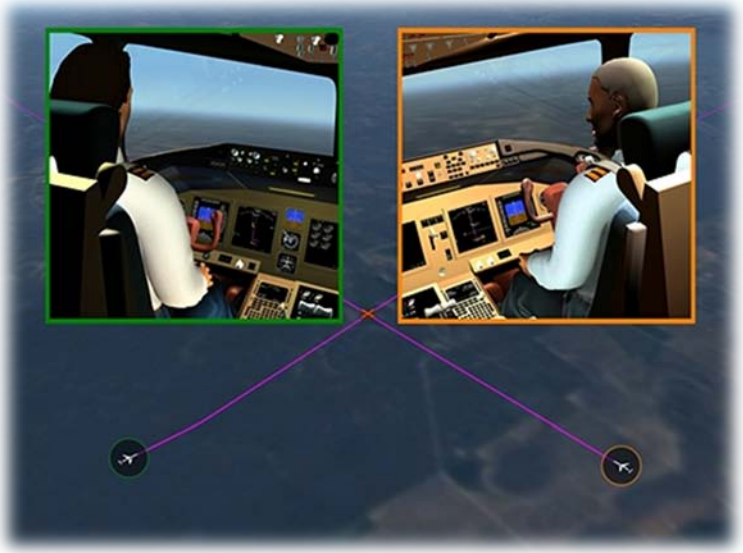
Infrastructure Requirements

- *Communications*
  - Primary: Dual thread data communications
  - Air-Air and Air-Ground voice back up for non-routine coordination
- *Navigation*
  - Primary: GNSS
  - Alternate means: DME/DME, ground surveillance (e.g. multilateration) sent to aircraft for use in navigation
- *Surveillance*
  - Primary: ADS-B (cooperative)
  - Alternate means: Traffic information service based on radar, multilateration (non-cooperative)
- *Ground-based Air Traffic Management*
  - Traditional IFR services available for unequipped aircraft
  - Centralized metering service to runways must be developed to accomplish equitable time-based merging of all traffic

Safety Considerations

- *Failure Nodes*
  - Communications, navigation and surveillance (CNS) aircraft systems
  - CD&R software
  - Guidance and Display
  - Human performance

- *Mitigations*
  - Alternate means for C, N and S as part of system design
  - Redundant equipment in aircraft, dual thread, independent source, information flows
  - Software test, V&V using best techniques
  - Separation of AFRs ensured by both aircraft in conflict
  - ANSP backup in AFR/IFR conflict
  - Well designed cockpit system monitoring and alerting backed up by effective crew training



Summary of Capability

- *Purpose is to provide the maximum flexibility for performance optimization of the business trajectory*
- *Benefits available to the first aircraft equipped to perform SSEP applications*
- *Mixed operations provides transition path in domestic airspace, benefitting early adopters without penalizing the unequipped*