ATM Concept Integrating Trajectory-Orientation and Airborne Separation Assistance in the Presence of Time-based Traffic Flow Management

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Contents

Introduction

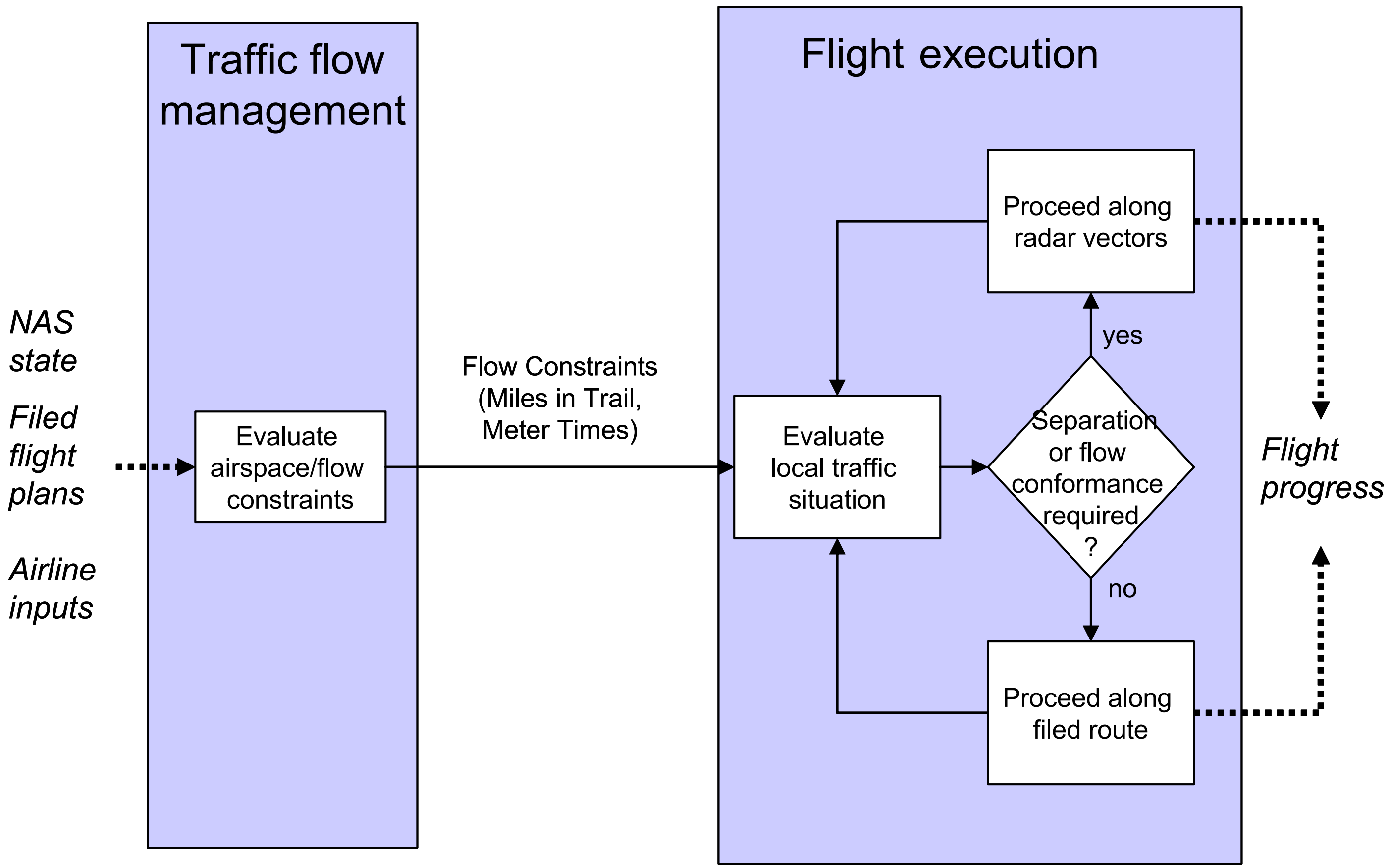
- Today's tactical "sector-oriented" air traffic control:
  - Safe
  - Can cause inefficiencies
  - Limited by controller workload and frequency congestion

- Different approaches to address the inefficiencies and limitations
  - 4D Trajectory-based approaches (strategic)
  - Use of Airborne Separation Assistance Systems (ASAS) (tactical)

- Proposal:
  - Combine both approaches to achieve "the best of both worlds"*

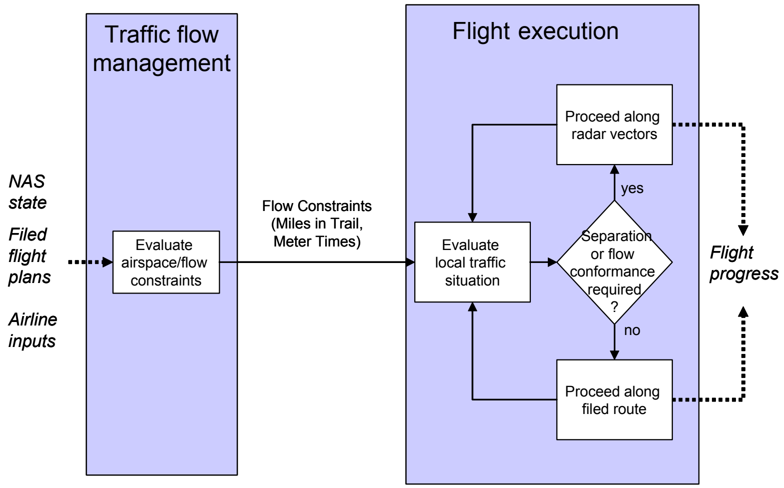
*Graham, R., E. Hoffmann, C. Pusch, and K. Zeghal, 2002, *Absolute versus Relative Navigation: Theoretical Considerations from an ATM Perspective*, e.g. ATM 2003

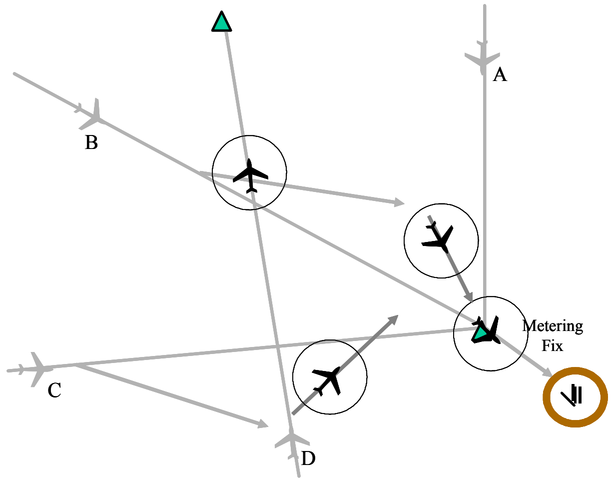
Today's Tactical Air Traffic System



Today's tactical air traffic system is focused on separation management. Traffic flow management provides flow constraints to the flight execution (i. e. air traffic control) layer.

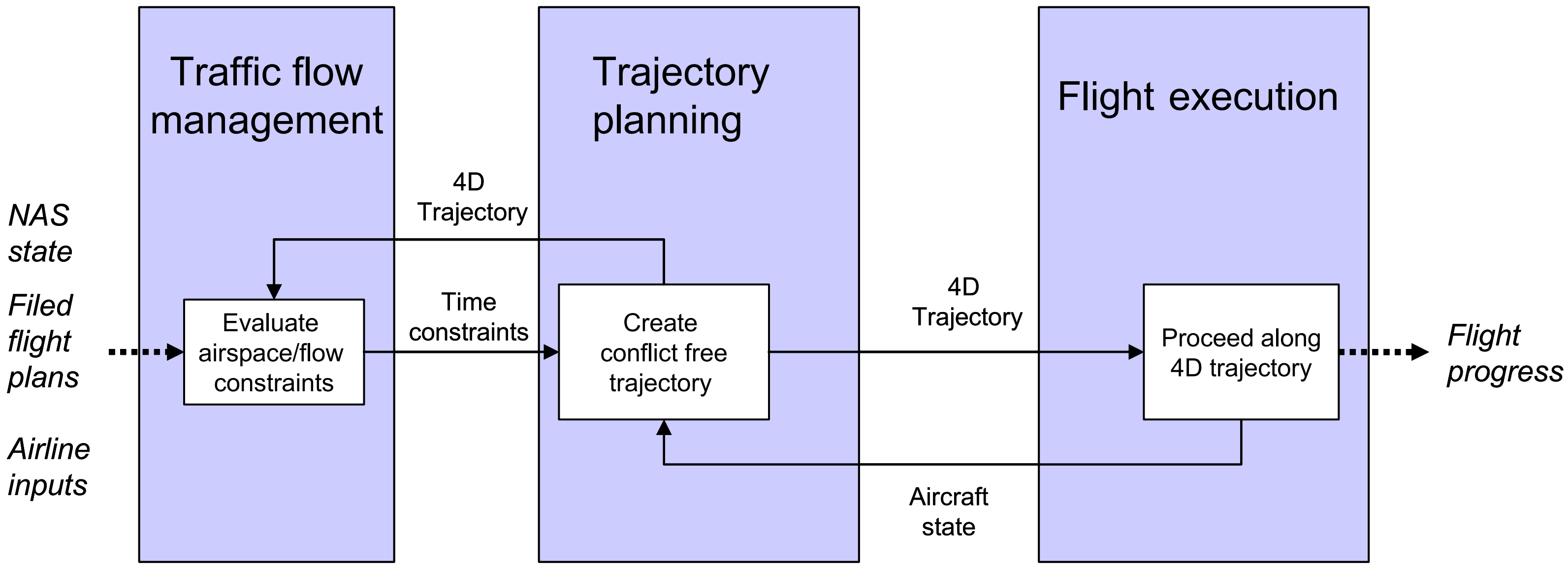
Today's Tactical Air Traffic System





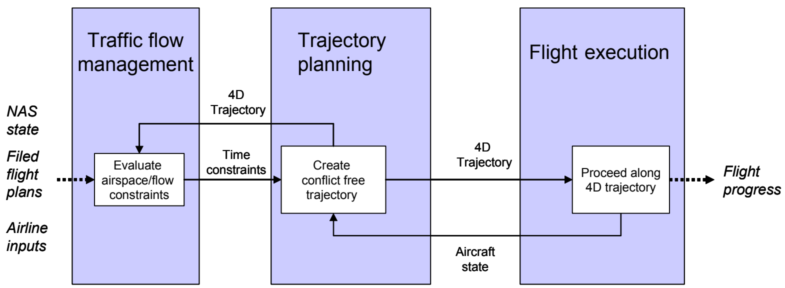
- Relies heavily on the skills of air traffic controllers and traffic flow managers
- Requires little automation (simple algorithms in the host computer)
- Separation management is primary objective
- Safe, but not as efficient as it could be

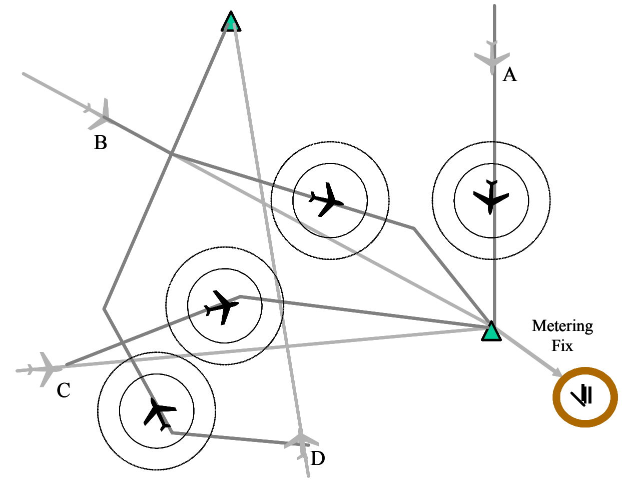
Strategic trajectory-based system



In a pure trajectory-based system, aircraft should always fly along up to date 4D trajectories that need to be conflict-free and conform to TFM constraints.

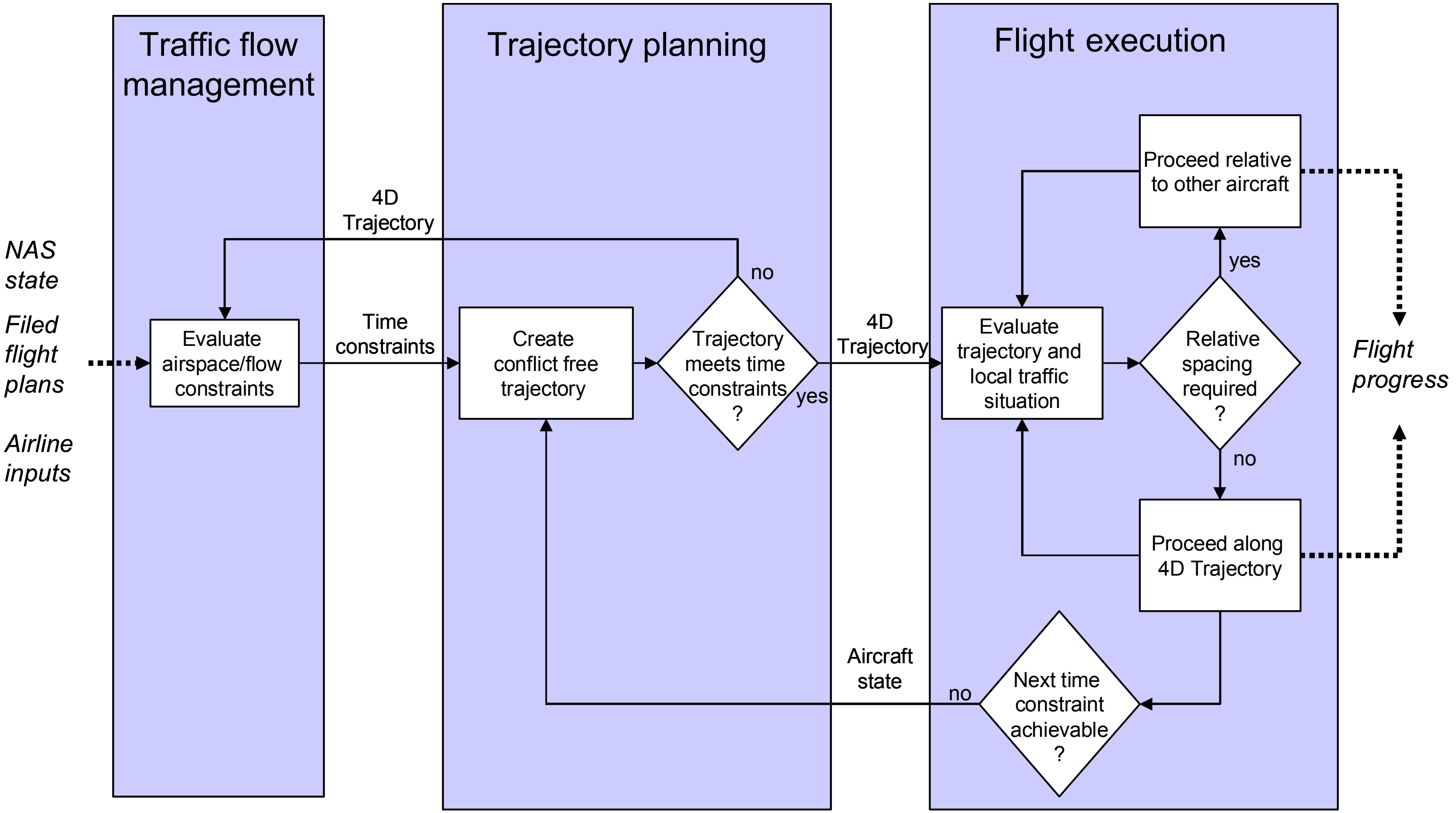
Strategic trajectory-based system





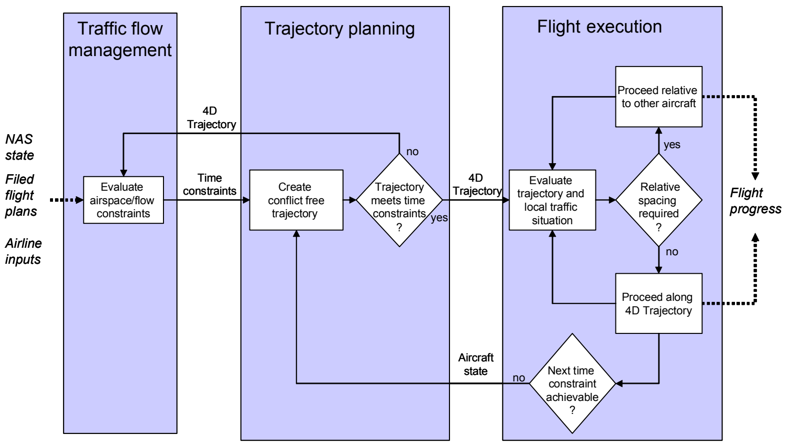
- Benefits in terms of flight predictability, efficiency, and workload
- Faces challenges in the areas of trajectory de-confliction and tool capability
- High requirements on automation capabilities and CNS infrastructure
- Can cause problems for controllers and pilots who have to evaluate, manipulate and communicate the trajectories
- In a purely trajectory-based system, controllers and pilots would have to *adjust trajectories* for local problems that could otherwise be handled by *one or two tactical instructions*.

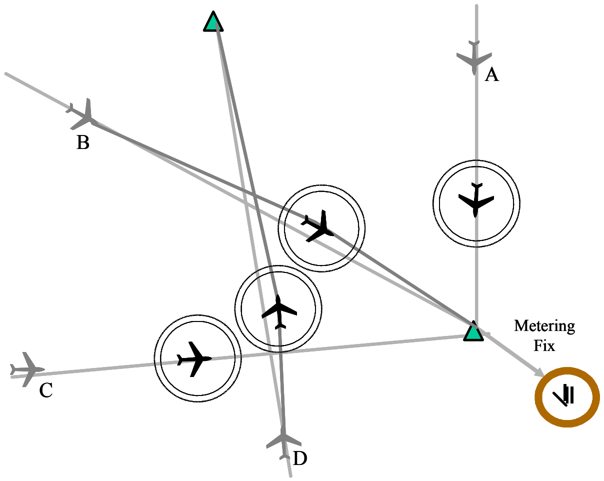
Integrating Trajectory-Orientation and ASAS



Proposed system: time-based traffic flow management and trajectory-orientation are augmented by a tactical relative spacing loop. Feedback between the layers is event-driven and not continuous.

Integrating Trajectory-Orientation and ASAS





- Time-based traffic flow management on a NAS-wide and local level assures that local airspace areas are not overloaded at any given time
- Trajectory-based operations are used to plan and execute conflict free flight paths for upcoming flight segments.
- Together, these operations put flight crews in a position to utilize Airborne Separation Assistance Systems (ASAS) to deal with local separation issues, if instructed or permitted by the controller to do so

Concept

- *Use trajectory-based operations to create efficient, nominally conflict-free trajectories that conform to traffic management constraints and,*

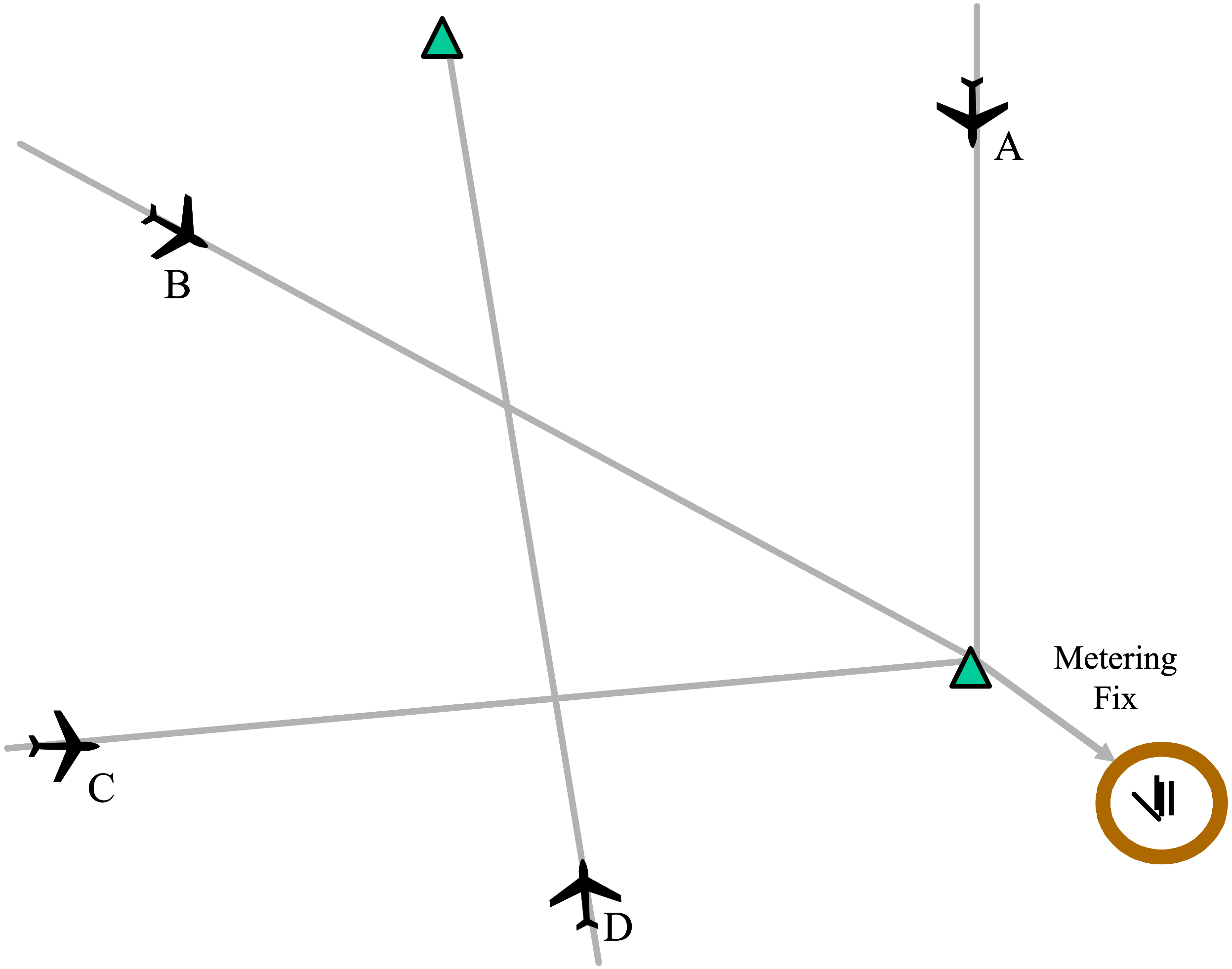
- *maintain local spacing between aircraft with airborne separation assistance*

Envisioned Benefits

It is intended that the concept:

- Takes full advantage of the traffic flow management benefits of the trajectory-oriented approach
- Reduce to a minimum any additional conflict resolution buffers arising out of prediction uncertainty
- Reduces controller workload → increases controller availability
- Minimally impacts flight crew workload.
- Has a positive effect on controller and flight crew traffic awareness
- Limits the deviations from the 4D path to short-term deviations mostly due to speed changes, thereby minimizing the medium to long-term prediction uncertainty
- Minimizes lateral route and/or altitude changes for local separation assurance

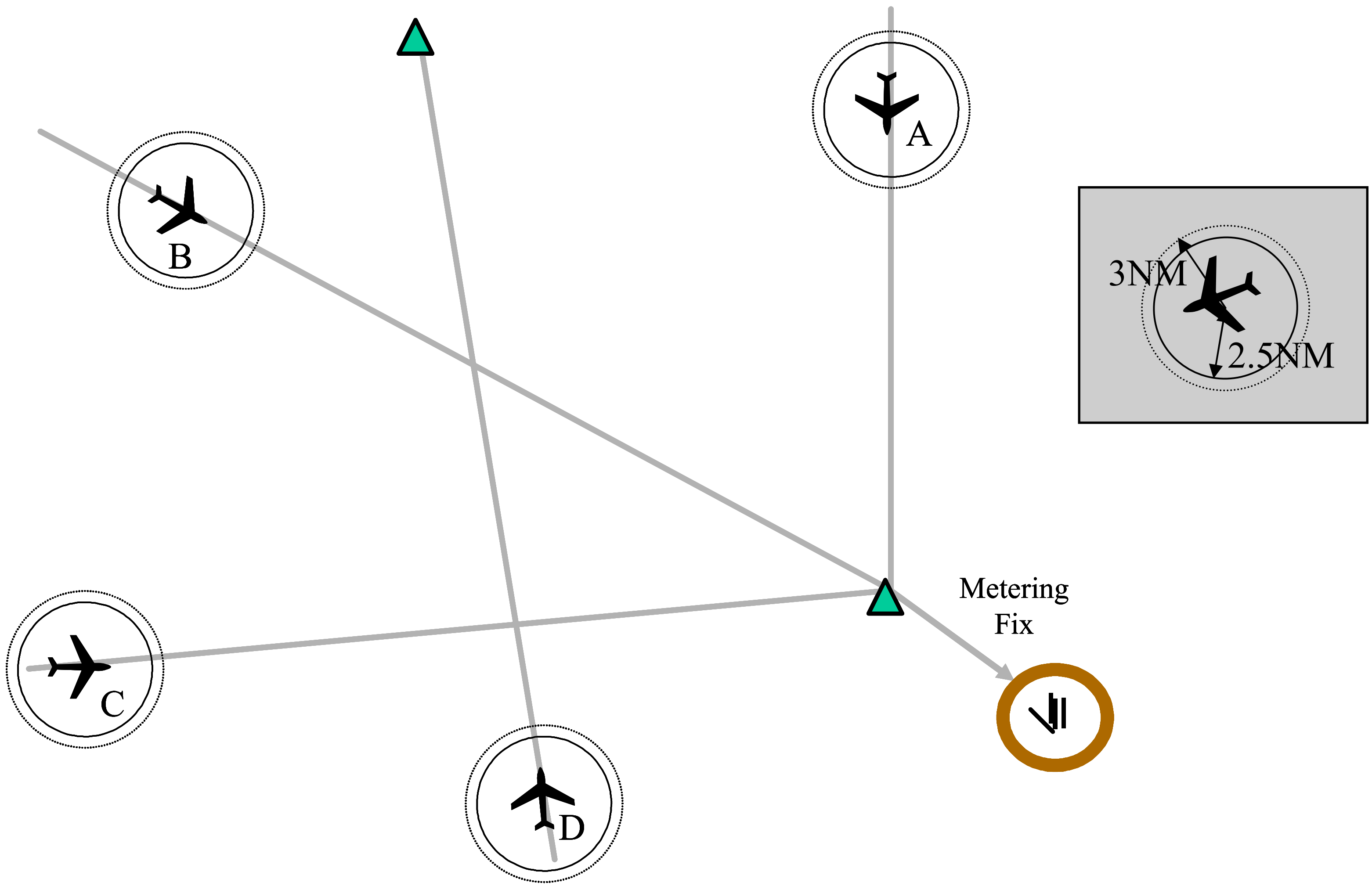
Example Traffic Problem



The three arrivals A, B, and C merge at a metering fix, the over flight D crosses the path of arrival B and C

Assume lateral separation has to be achieved

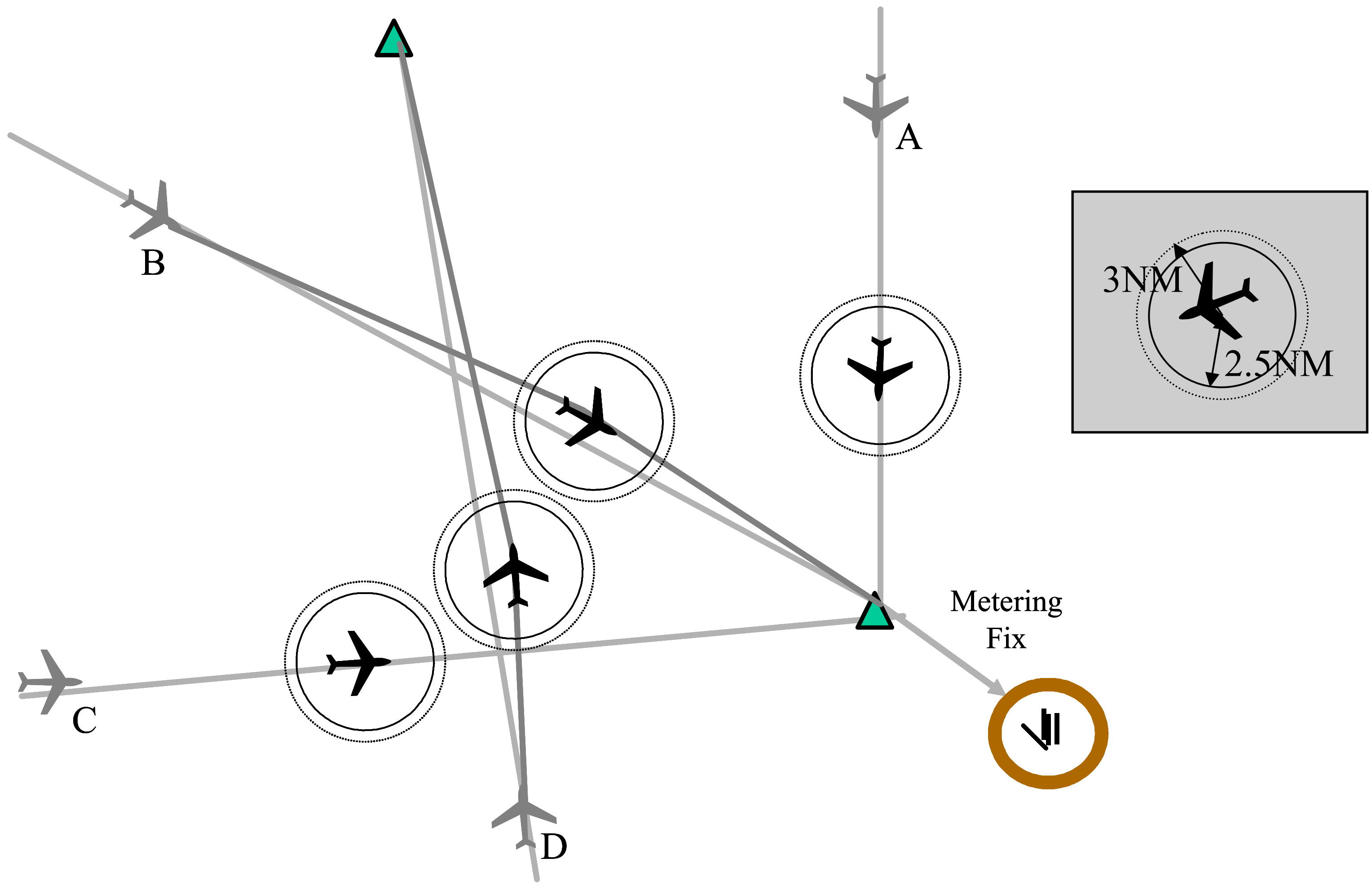
Trajectory Oriented Operations with Limited Delegation



Strategy:

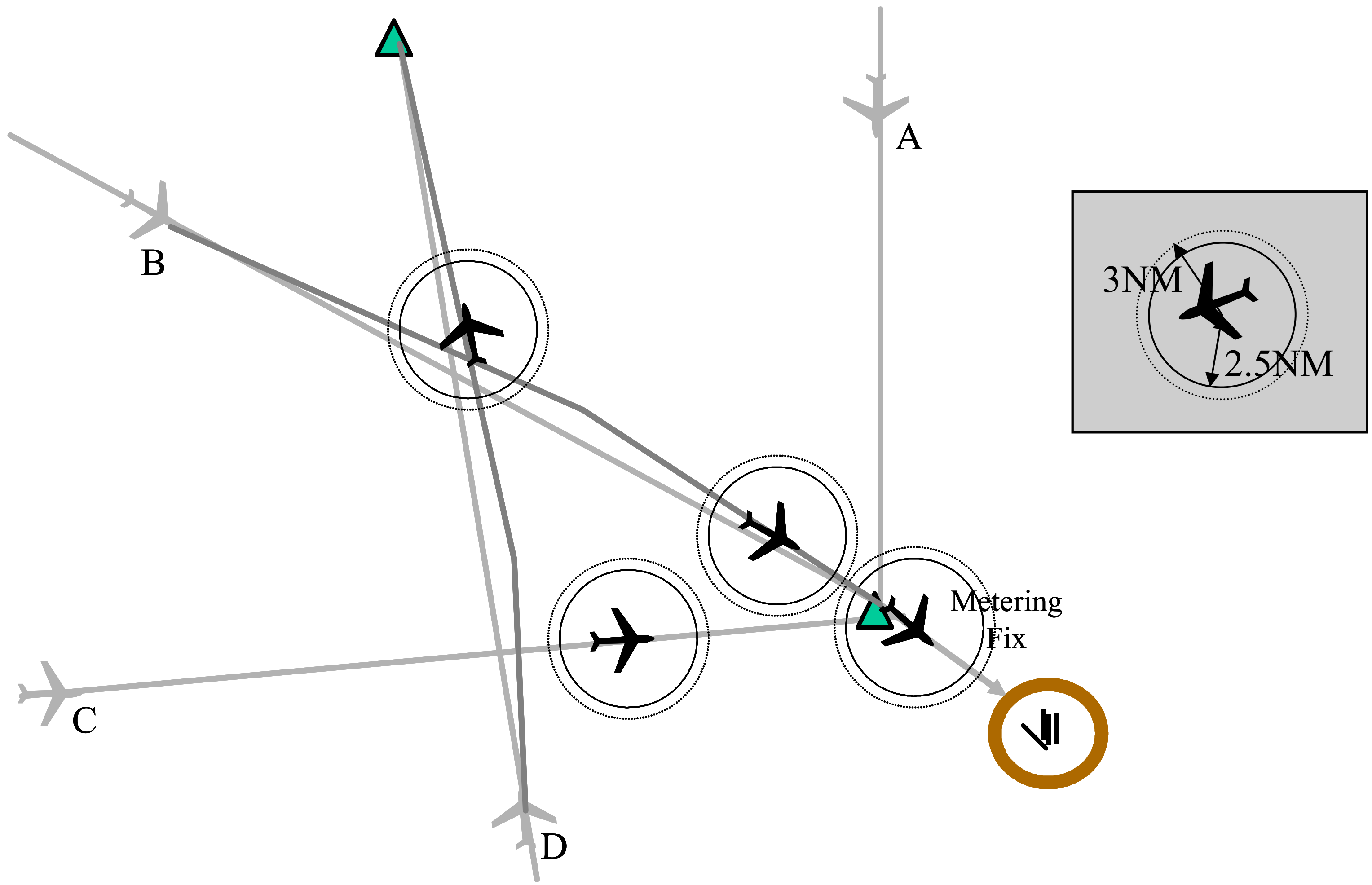
Generate a set of conflict free trajectories with small buffers for flight deck based spacing inaccuracies that meet the metering constraints, communicate the trajectory change points to the flight crew and delegate the spacing tasks to the flight crew.

Trajectory Oriented Operations with Limited Delegation



The trajectories can be designed with minimal buffers to precondition the aircraft properly and meet the metering constraints precisely. The spacing will be fine-tuned by the flight crew dynamically.

Trajectory Oriented Operations with Limited Delegation



The metering constraints can be defined with minimal separation buffers and the aircraft handle the merge and follow each other into the next airspace (e.g. TRACON)

Concept Implementation

- Near-term:
  - Ground-side:
    - Trajectory tools
    - Conflict detection tools
    - Could use standard trajectories (airways, STARs, approach transitions)
    - Simple spacing assignment and monitoring function
  - Air-side
    - Improved surveillance e.g. ADS-B
    - Traffic display
    - Simple state-based spacing algorithm

- Medium to Far-term
  - Ground-side:
    - CD&R tools
    - Trajectory negotiation capabilities (e.g. integrated CPDLC)
    - Support for autonomous operations
  - Air-side
    - Trajectory tools
    - CDTI with CD&R capabilities
    - Trajectory negotiation capabilities (e.g. integrated CPDLC)
    - Advanced self spacing capabilities (local free maneuvering)
    - Autonomous Operations

Near-Term Implementation

Ground-based trajectory planning and limited delegation of spacing task to properly equipped aircraft

- Ground-side
  - Utilize existing ground-based trajectory tools like CTAS to generate TFM conforming 4D trajectories
  - Use route evaluation tools to alert controllers to upcoming spacing problems
  - Uplink trajectories via CPDLC to equipped aircraft, if available
  - Delegate spacing task to ASAS equipped aircraft
- Air-Side
  - Utilize Flight Management System to follow generated trajectories
  - Use CPDLC for receiving and loading of more complex trajectories
  - Use ASAS equipment for speed-centric spacing operations

Mid-Term Implementation

Incremental Integration of new CNS and DSTs and controlled paradigm shit

- Incremental integration of new Technologies:
  - CNS e.g. ADS-B, TIS-B, CPDLC
  - ground-side automation e.g. EDA
  - flight deck automation e.g. CDTI

  as their underlying algorithms mature and human-automation-integration issues are thoroughly researched and addressed.
- Control paradigm shifts can occur slowly and be controlled by operational procedures rather than dictated by new automation
- The initial very limited delegation of tasks will give flight crews and controllers initial experience with new execution/monitoring roles
- The delegation of more degrees of freedom provides controller and flight crew feedback and operational performance data in a safe environment at different levels of automation integration and separation authority
- Trajectory planning can migrate to a distributed process of air and ground operations
- Enabling of advanced operational concepts like DAG-TM CE6 “trajectory negotiation” and CE 5 “free maneuvering”

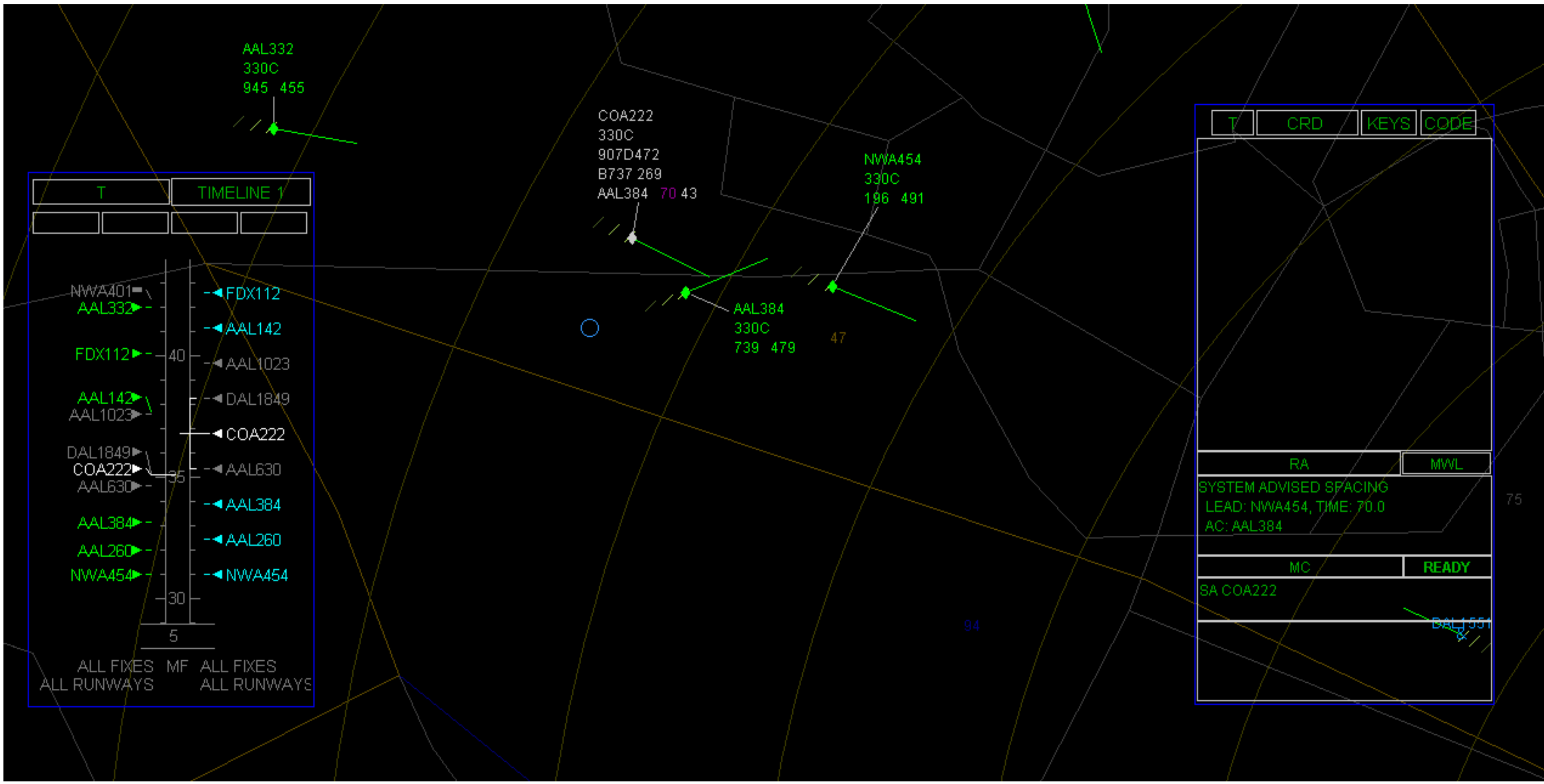
Far-Term Implementation

Autonomous trajectory planning and spacing of free maneuvering aircraft

- Appropriately equipped aircraft can plan trajectories and execute the flight autonomously as long as the trajectories
  - don’t create immediate conflicts
  - comply with TFM constraints and
  - are communicated to other participants.
- Flight deck and ground-side trajectories only need to be de-conflicted with minimal separation buffers, because the ASAS layer is still intact to support relative spacing operations.
- Flight Crews could detect the need for resolving a local spacing problem autonomously and switch to the ASAS mode while the problem exists.
- Controllers support lesser equipped aircraft with trajectory planning tasks and delegate limited spacing tasks or issue radar vectors

Concept Implementation: Ground side example

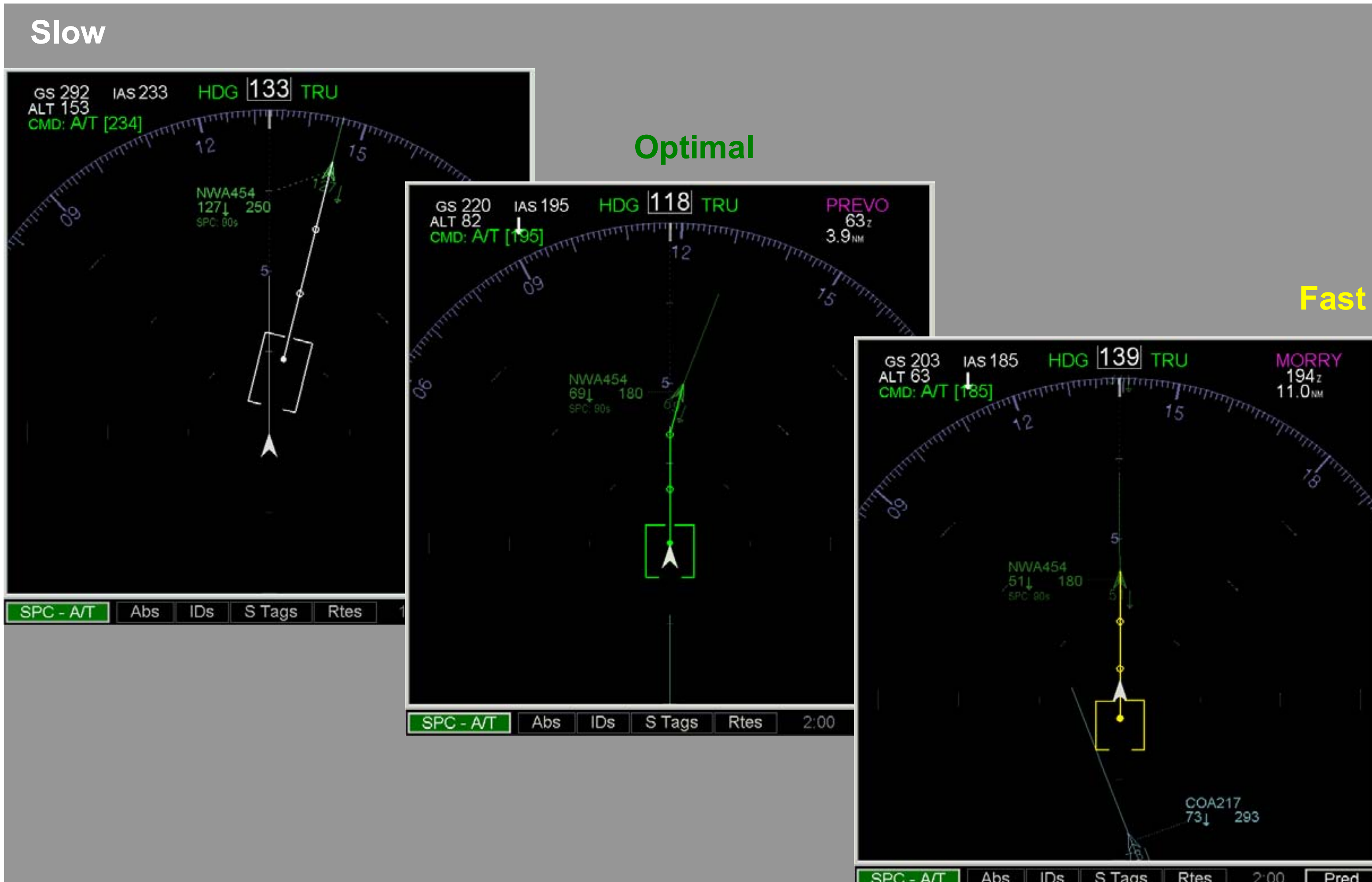
Mock-up of a display system replacement (DSR) center controller display with trajectory information on timeline and spacing information in data tag and aircraft history circle



Concept Implementation: Air side example

Flight deck display prototype indicating the ownship position relative to the desired spacing position (historical position of the lead aircraft 90 seconds ago)

The advised speed command is displayed in the upper left corner



Human Factors/ATM Research Labs at NASA Ames

Concluding Remarks

The concept:

Use trajectory-based operations to create efficient, nominally conflict-free trajectories that conform to traffic management constraints and,
maintain local spacing between aircraft with airborne separation assistance.

- Integrates two promising approaches
- Shows a potential for maintaining high safety *and* improving efficiency over today's system
- Can be implemented evolutionarily, and an immediate paradigm shift by air traffic controllers and pilots is not required
- Can build on existing tools and strategies, can provide immediate and emergent benefits, and is compatible with advanced DAG-TM concepts
- The benefits of trajectory-based operations can be realized *without* having to generate completely de-conflicted routes with 'buffers' for prediction uncertainty
- Flight crews monitoring 'local' situations in *addition* to ground controllers, is a further level of operational safety – a second set of eyes

- Research is required and planned to further develop and evaluate this concept