CENTER FOR ADVANCED AVIATION SYSTEM DEVELOPMENT (CAASD)

Trajectory-Based Operations (TBO) Conference
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The Role of the Trajectory In Decision Support

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CAASD

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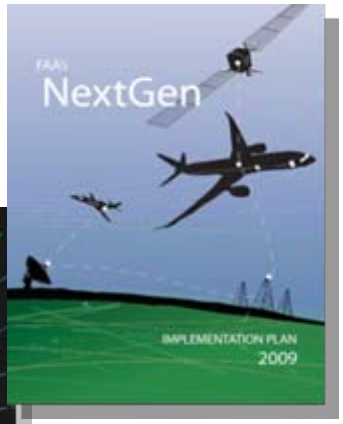
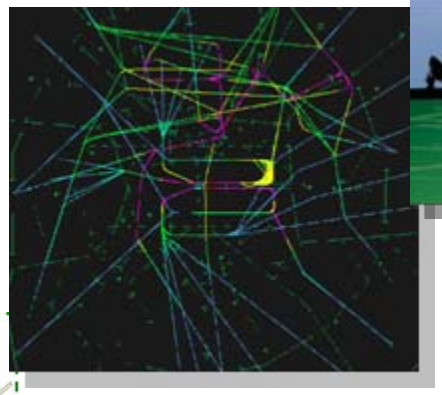
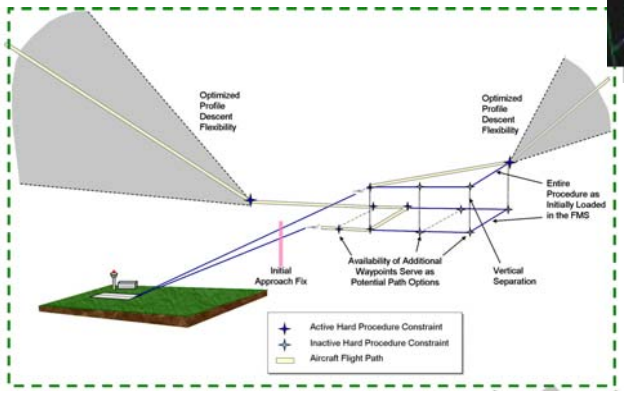
The Role of the Trajectory in Decision Support: Outline

- **Trajectory management in yesterday's and today's NAS**
- **Mid-Term decision support and trajectory management**
  - **NextGen principles relevant to trajectory management**
  - **Key mid-term needs**
- **Trajectory management challenges and key issues**







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Trajectory Management is Evolving to Increasing Precision and Levels of Automation

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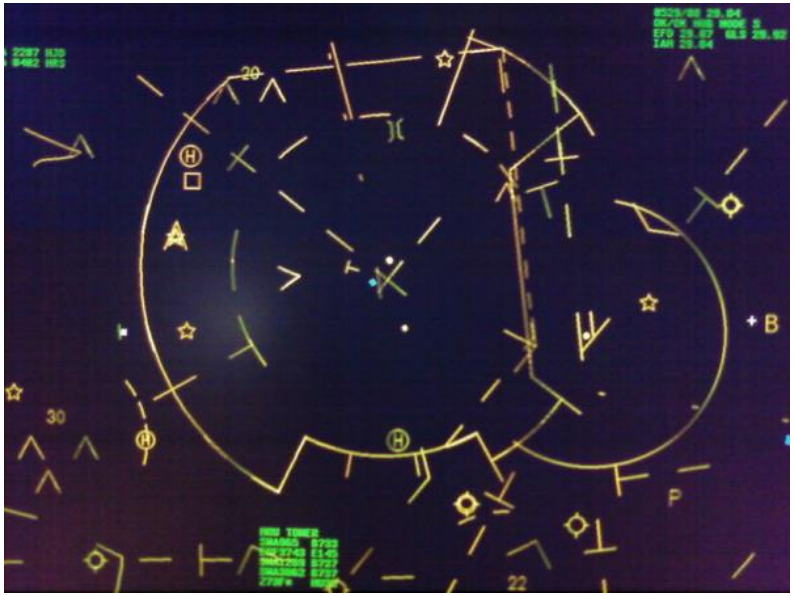
Trajectory Prediction in Today's Decision Support Systems: FAA Terminal Automation



- **Terminal Automation (such as STARS) currently uses display as aid for human trajectory prediction**
  - **Provides real-time surveillance information**
  - **Flight plan data associated with IFR targets is available**
  - **Ability to display standard instrument departures (SIDs) and standard arrival routes (STARs)**
- **No automated strategic trajectory prediction algorithms**
  - **Terminal controllers use surveillance data and traffic patterns to mentally project an aircraft's future position**

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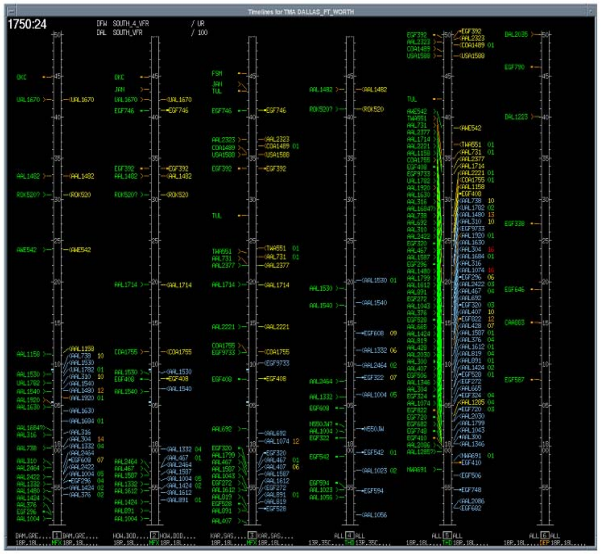
Trajectory Prediction in Today's Decision Support Systems: FAA EnRoute Automation

- **Trajectory Modeling currently used in enroute decision support systems for prediction of potential separation loss (URET) and for traffic synchronization to a metering fix (TMA)**
- **Both functions need accurate trajectory predictions to provide reliable decision support to controllers**
- **Factors affecting the quality of trajectory prediction include:**
  - **Automation internal models of aircraft characteristics and wind data**
  - **Update of automation to reflect clearances affecting the flight profile**
  - **Conformance monitoring to alert controllers if the surveilled aircraft path is not consistent with the maintained flight profile**



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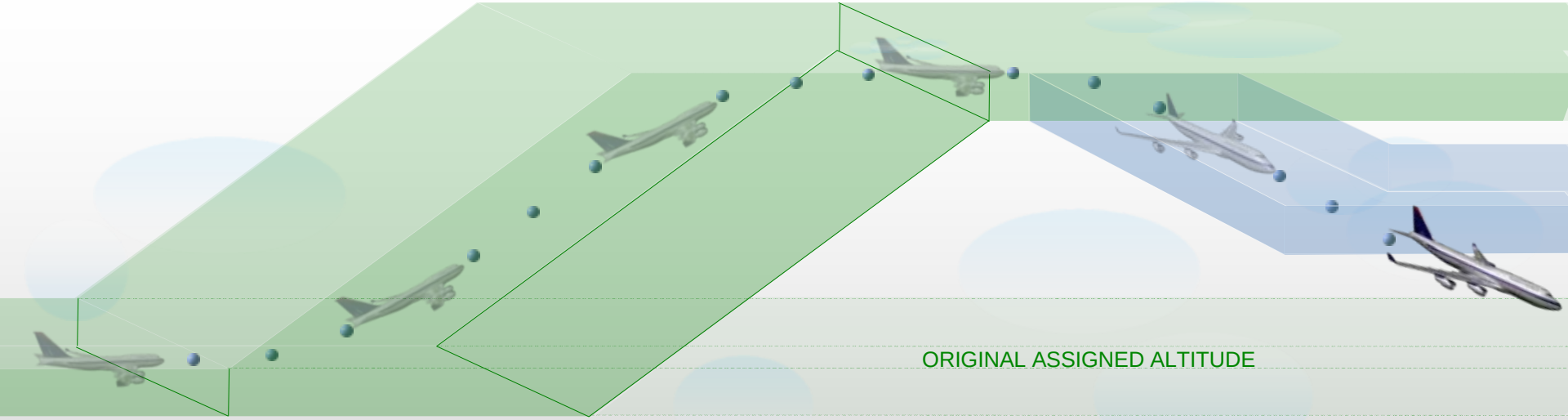
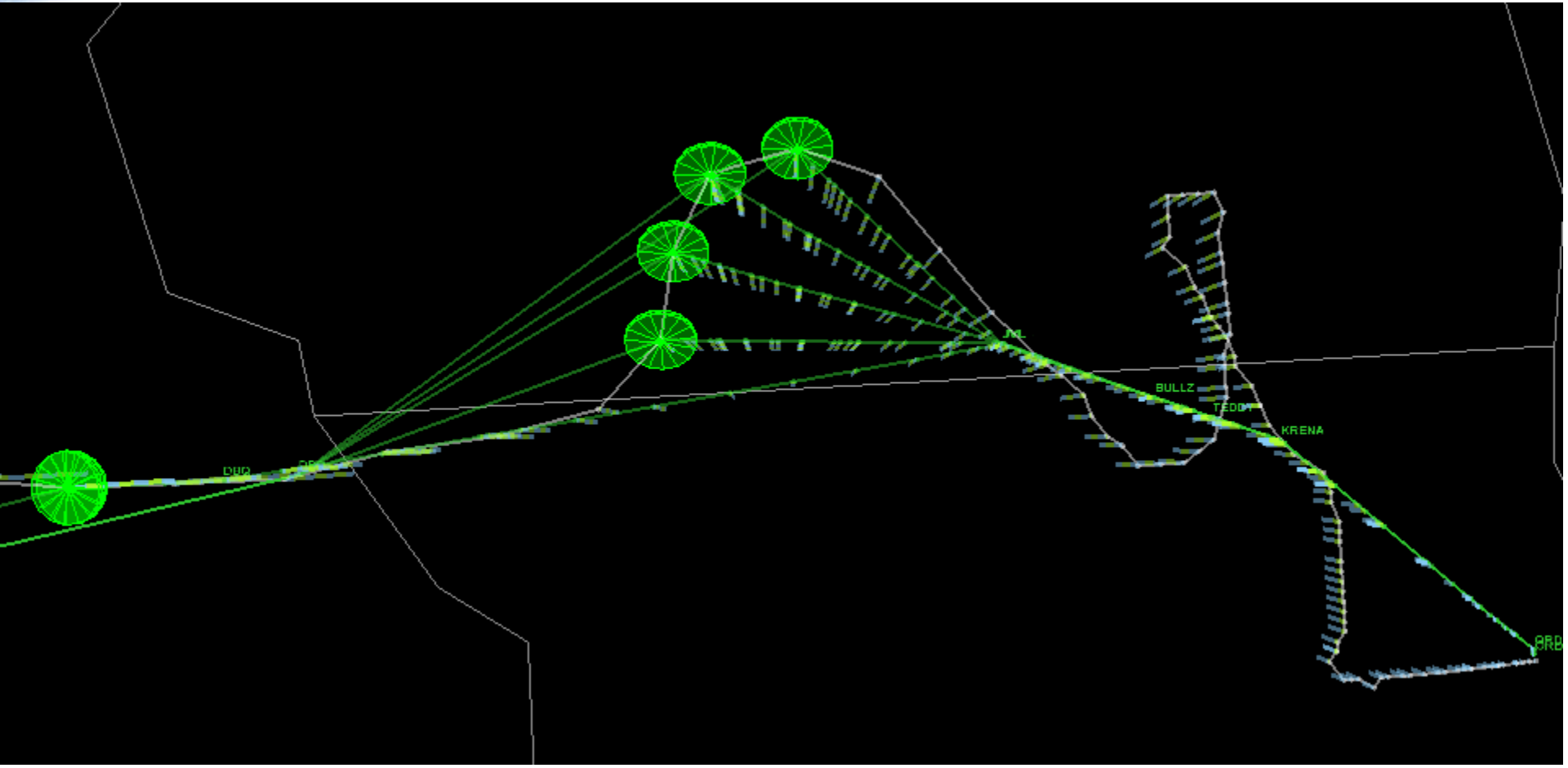
Today's Trajectory Management

Example: Conformance Boundaries for Conflict Management



Today's Trajectory Management:

Aircraft not on "known" trajectories add system uncertainties



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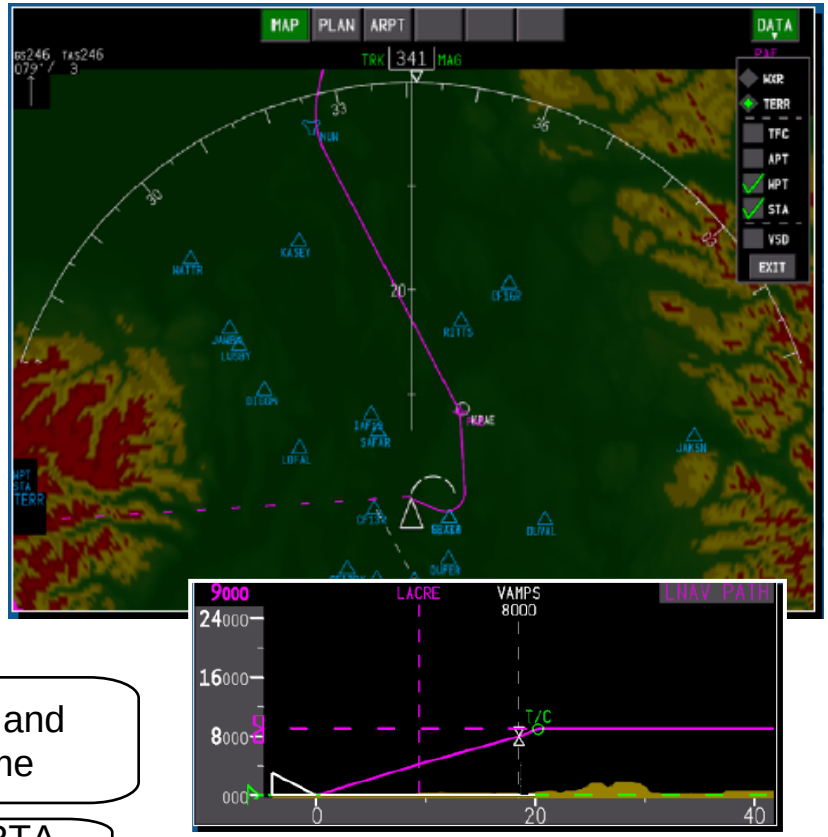
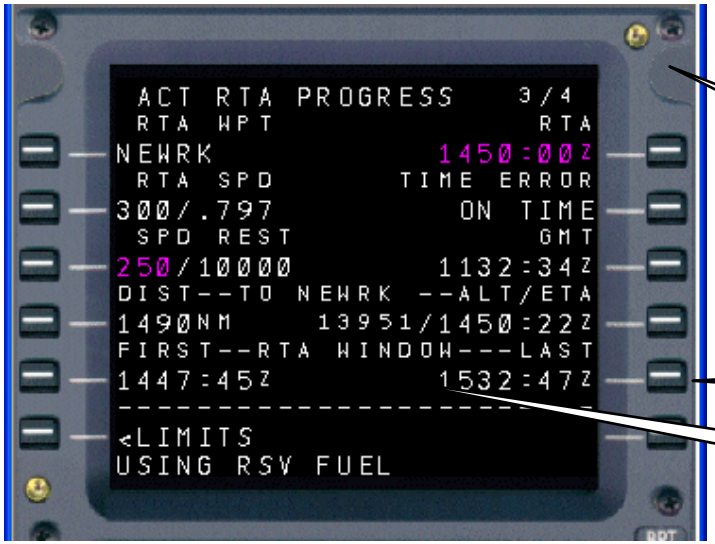
Trajectory Prediction in Today's Decision Support Systems: Aircraft Flight Management Systems

- **FMS provides pilots with:**
  - **Workload reduction through management of aircraft controls**
  - **Improved situational awareness**
  - **Ability to assess the flight impact of alternative flight profiles**



FMS plan view and vertical display capabilities of the Boeing 787, from briefing by Mike Carriker, 2006



RTA fix and req'd time

Latest RTA possible

Earliest RTA possible

Example of what if analysis: In flight, entry of an RTA causes FMS to display earliest / latest times that could be achieved at the RTA fix.

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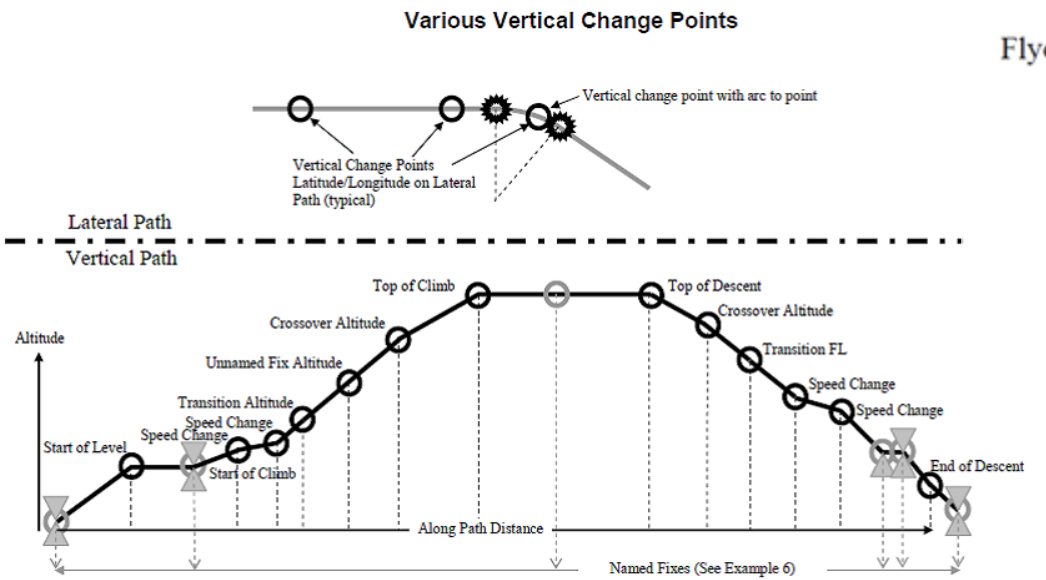
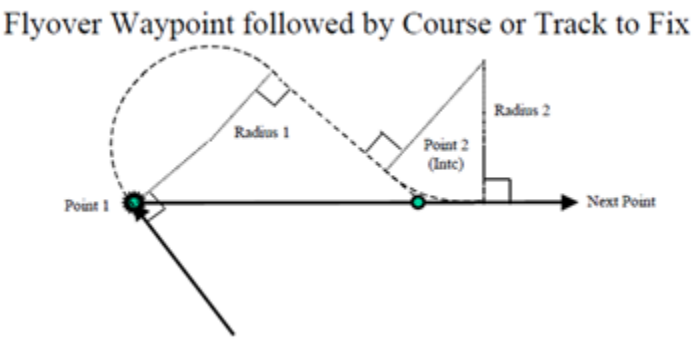
FMS Trajectory Modeling

- **FMS internal trajectory prediction function**
  - **Input for trajectory profile built from discrete points and segments entered by flight crew (or autoload function)**
  - **Computes a continuous profile (lateral and vertical)**
  - **Compares current position with calculated trajectory profile to drive aircraft controls (flight surfaces, thrust, etc)**





Illustrations from ARINC Characteristic 702A, Advanced Flight Management Computer System, 2005

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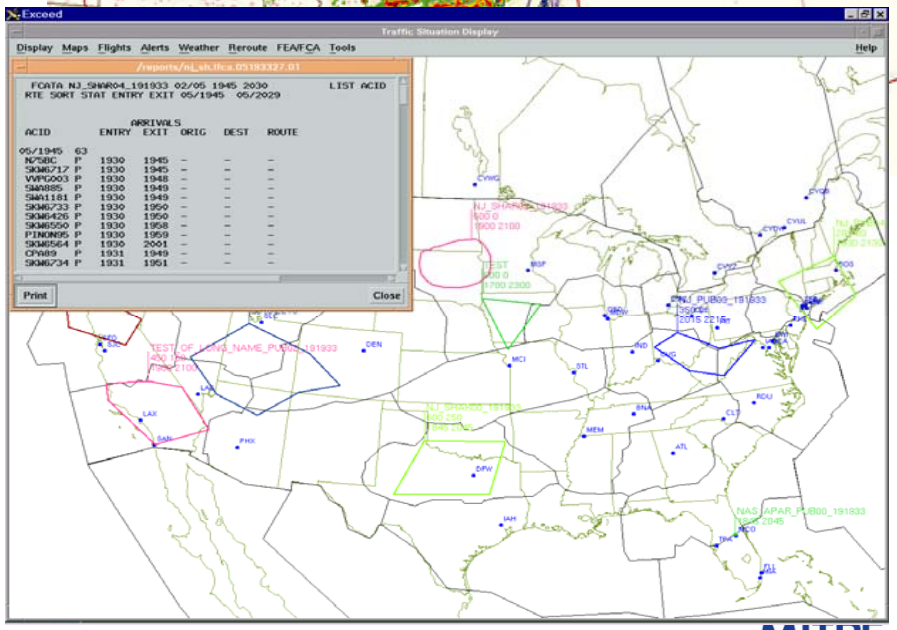
Trajectory Prediction in Today's Decision Support Systems: Traffic Flow Management (TFM)

- **TFM analysis tools use trajectory prediction models to identify when intervention is likely to be needed to maintain safe levels of traffic for airspace and airports. Eg:**
  - **Flow Evaluation Area / Flow Constrained Area, Flight Schedule Monitor, Airspace Flow Program**
- **Factors affecting predictability of demand include knowledge of aircraft departure times, uncertainties in weather forecasting, and future real-time decisions across multiple decision-makers**
- **"What if" analysis still draws significantly on operational judgment and experience**



TSD screen shot, illustrating FCAs and Flight lists, from CDM training material (S2K+3) http://cdm.fly.faa.gov/Training/S2k%2B3.html

Airspace Flow Program screen shot, from Volpe's website (www.volpe.dot.gov)

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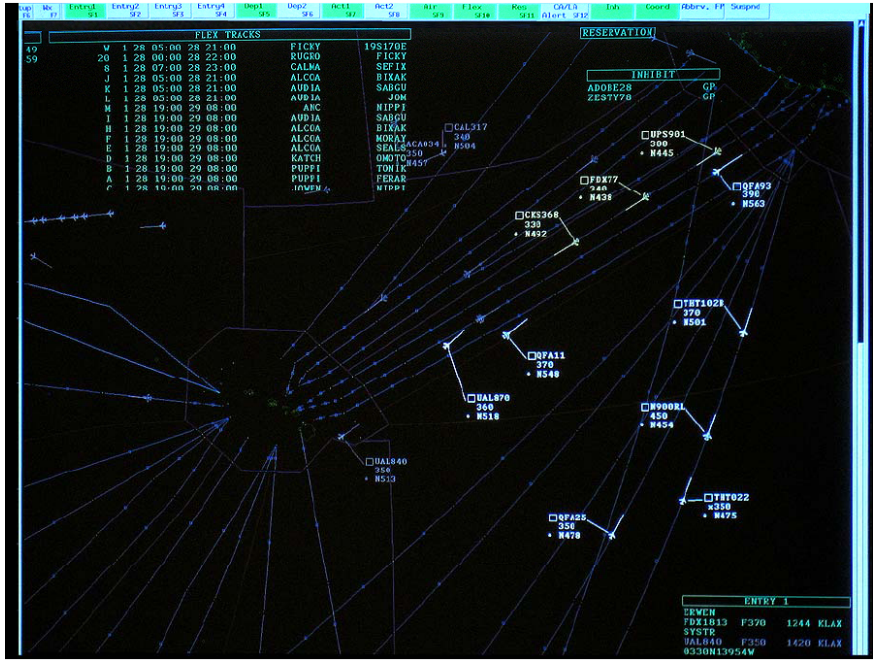
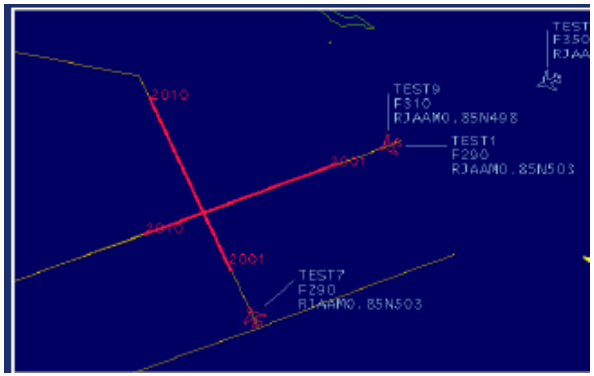
Trajectory Prediction in Today's Decision Support Systems: FAA Oceanic Automation

- **Oceanic operations today are primarily based on strategic trajectory management**
  - **Conflict probe evaluates trajectory changes and proposed trajectory changes for aircraft-aircraft and aircraft-airspace contention**
  - **Alerts controllers when there are significant changes to ETAs**
  - **Applies separation criteria based on individual aircraft CNS capability**
  - **Trajectory prediction built from aircraft-provided trajectory updates (via ADS-C)**





Screen shots from the FAA's Ocean21 system

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Mid-Term Needs for Decision Support Capabilities and Trajectory Management

- NextGen traffic will continue to grow in volume and complexity
- Continued emphasis for all stakeholders to increase efficiency and reduce per-unit costs
- Continue trends of increasing levels of automation and refining human roles to be actively engaged at strategic level
  - MITRE human in the loop (HITL) experiments show significant productivity, capacity, and flight efficiency gains are possible with improved decision support capabilities

Predictable flight paths are a fundamental underlying assumption for effective decision support evolution

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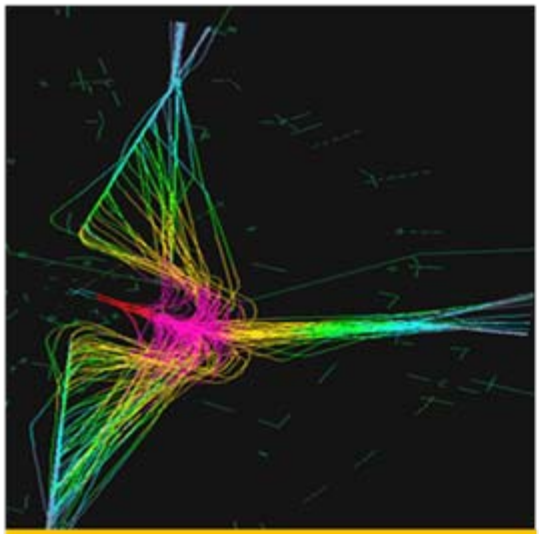
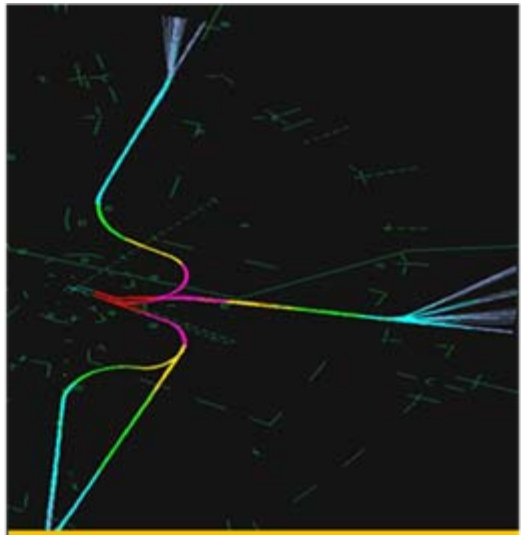
NextGen Mid-Term Principles Related to Trajectory Management (1)

- **The Trajectory represents an accurate and stable description of the expected path of a flight in all 4 dimensions**
- **Predicted trajectories will have differing levels of precision**
  - **We can't achieve capacity or efficiency benefits if we build only to the lowest common denominator**



Before RNP approaches at Portland, OR



After RNP Approach Implementation

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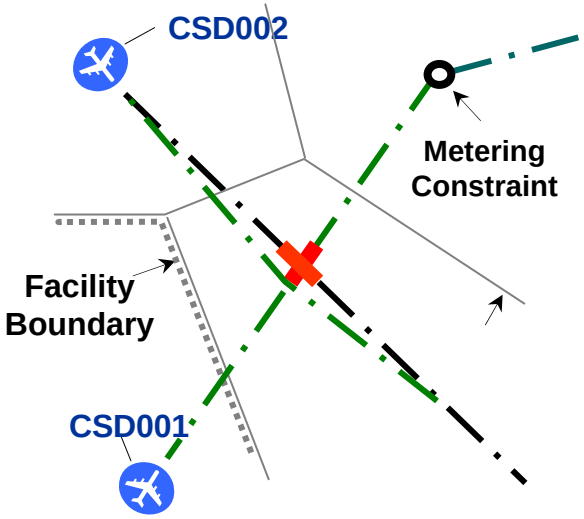
NextGen Mid-Term Principles Related to Trajectory Management (2)

- **The human has ready access to the Trajectory, is fully in the loop on all changes, and has a responsibility to keep the system up-to-date**
  - **Automation designed to facilitate entry of updated information**
  - **"Closed loop" trajectories become the norm, but the system still needs to handle cases where an aircraft's future trajectory is indeterminate**
- **Separation management becomes more strategic based on predictable trajectories**
  - **Conflict management capabilities incorporate user preferences and aircraft capabilities in generating resolutions**



Predictable trajectories enables enhanced decision support capabilities, such as strategic conflict management

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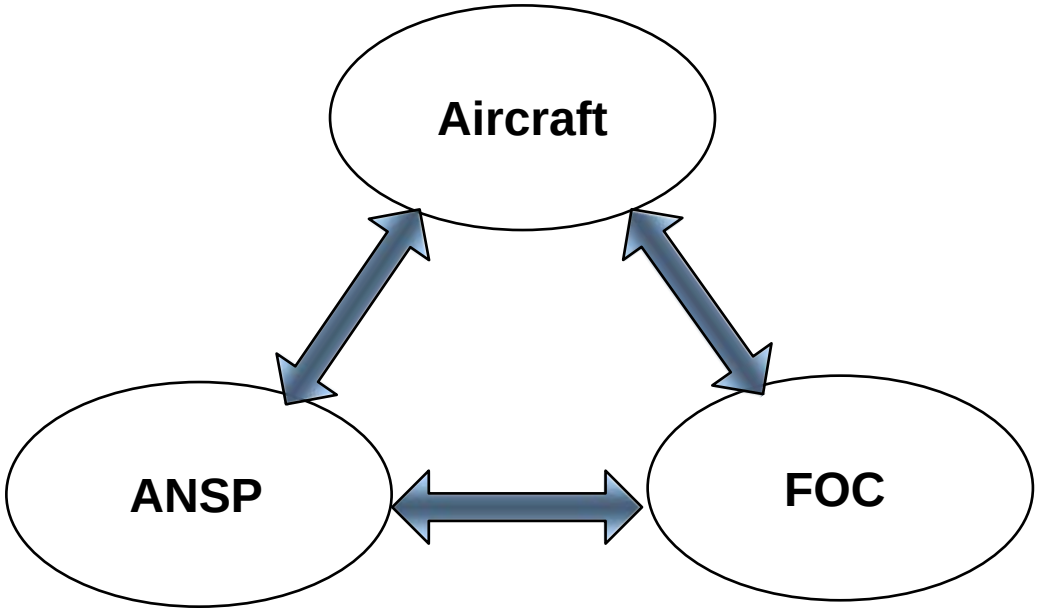
NextGen Mid-Term Principles Related to Trajectory Management (3)

- **The complete trajectory is known to the ground systems and aircraft flight management systems in ATM and is <u>consistent</u> across all systems – Flight Operations Center, ANSP, & Aircraft**



ATC Data communications, FMS autoload, FMS downlink of the reference trajectory, and enhanced AOC-ANSP data exchange foster increased consistency across systems

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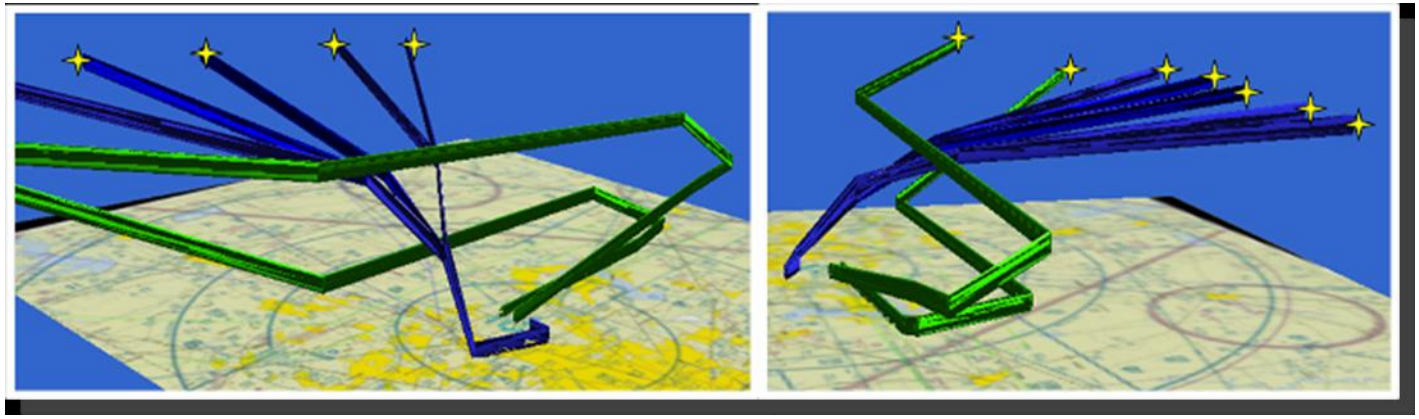
NextGen Mid-Term Principles Related to Trajectory Management (4)

- **In areas of high density, a network of predefined precise routes is used to minimize interactions among aircraft trajectories. In other areas more trajectory definition flexibility is available.**
- **Vertical path definition becomes more specific; move away from using airspace to separate vertical transitions**



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NextGen Mid-Term Principles Related to Trajectory Management (5)

- **Where operationally advantageous, tasks associated with spacing and merging with respect to another aircraft or to a meter fix time can be delegated to the flight crew**
  - **RTAs may be used when the ability to specify the time of arrival over a waypoint is important**
  - **Relative spacing, or interval spacing, is used when the primary concern is ensuring well-behaved flows**
- **Controller remains responsible for separation management**

Example cockpit display for interval spacing

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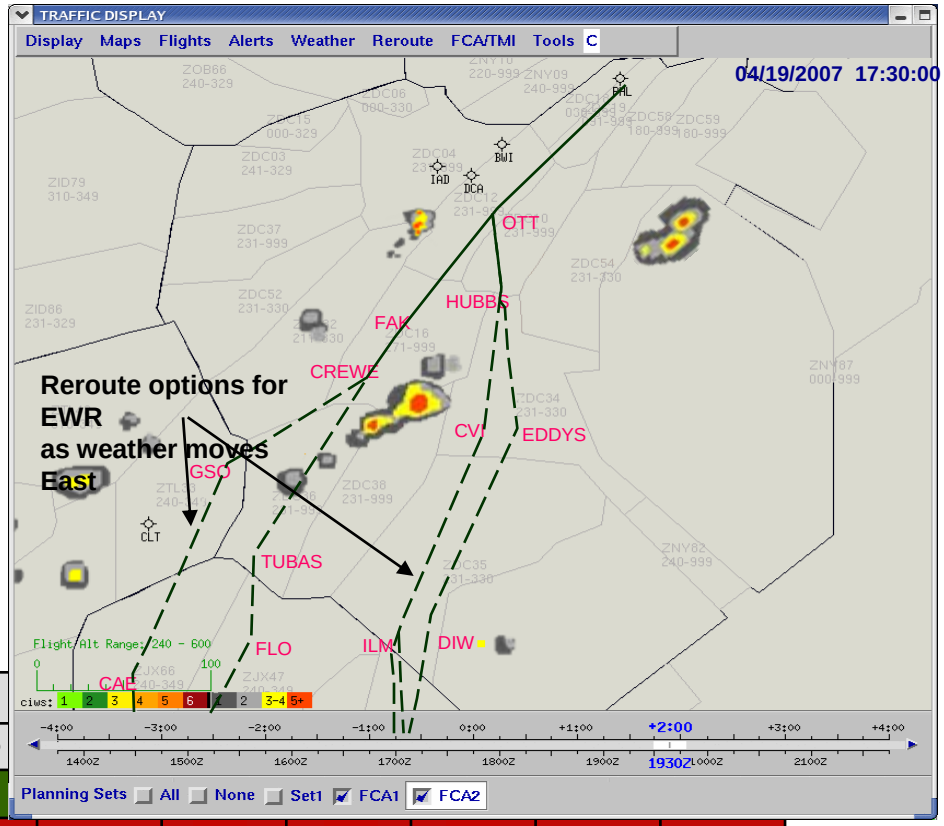
NextGen Mid-Term Principles Related to Trajectory Management (6)

- **Information on weather and other factors affecting capacity is integrated into decision-support tools to predict impacts on individual flights based on their 4D trajectories, and generate flight-specific trajectory Traffic Management Initiatives (TMIs)**



Flow/Resource Problem	Alt (Tops)	# Flts	1730	1745						
TIY. .HPW (LGA)	430	3								
TILTZ.J109.FAK (EWR)	450	6				2	1	1	1	1
RDU.J52.RIC (LGA)	450	3				1		1	1	
RDU.J207.FAK (EWR)	430	4		3				1		
RDU.HPW (LGA)	430	1				1				
SAMMB.J208.HPW (LGA)	390	2				1	1			

Show Flight List | Share Grid | Show Solutions

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Mid-Term Trajectory Management: Major Building Blocks

- Procedure changes and suitable human automation interfaces to ensure consistency in the management and analysis of trajectory agreements
  - Ability to represent 4D trajectories, including planned altitude transitions (both ANSP and FOC)
  - ANSP: capabilities to ensure consistency of trajectories across automation system
  - Ground conformance monitoring expanded to terminal operations
  - Conflict resolution guidance to controllers
  - Strategic "what-if" planning to assess congestion management strategies
  - Integration of weather with decision support tools to assess impacts on capacity and individual trajectories
- Exchange of trajectory information among decision support systems
  - Data Comm segment 1
  - FMS interface to ATC Data Comm to downlink aircraft trajectory information via (ATC Data Comm Segment 2)
  - Autoload of trajectory clearances
- ADS-B/CDTI for delegated interval spacing and merging operations

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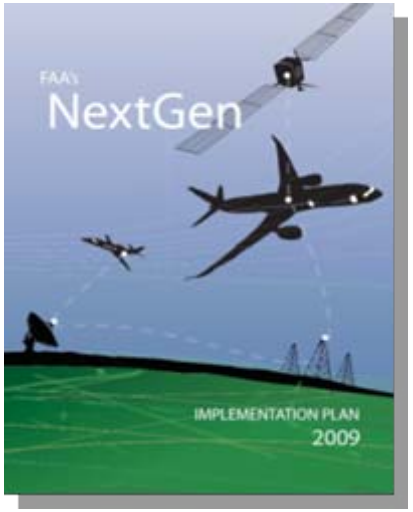
Trajectory Management Challenges and Issues

- **Mixed capability operations: To what extent can ANSP personnel manage operations and differentiated services when aircraft have different trajectory management capabilities?**
- **How are equipage objectives achieved when benefits depend on a significant percentage of aircraft equipage?**
- **What are the ground system requirements for internally representing trajectories?**
- **How do human roles evolve as decision support systems evolve to manage increased density and complexity?**
- **What are the tradeoffs among costs, benefits, and risks for different levels of capability for both aircraft and ground systems?**



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