



Visualizing
the Future
of Civil Aviation



ACES

Airspace Concept Evaluation System



ACES Development Team

- ✈ NASA Ames Research Center
- ✈ Raytheon, Network Centric Systems
- ✈ Intelligent Automation, Inc.
- ✈ Science Applications International Corporation
- ✈ Sensis, Seagull Technology

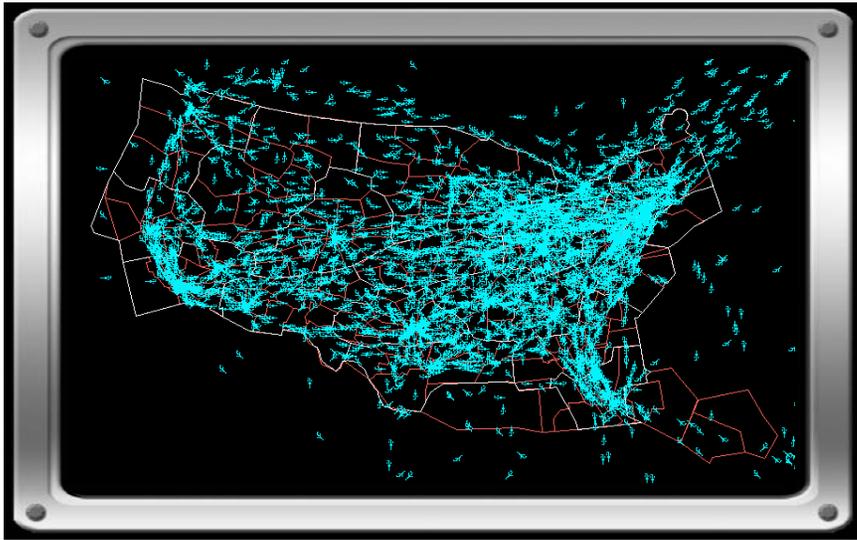


Agenda

- ✈ Motivation
- ✈ Description of ACES
- ✈ Airspace Concepts Modeled with ACES
 - ◆ Traffic flow management algorithm
 - ◆ Automated conflict resolution algorithm
- ✈ Comparison Study
- ✈ Summary

Motivation

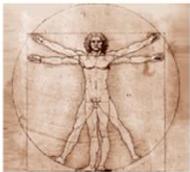
- ✈ Assess system-wide impacts of airspace technologies and operation concepts
- ✈ Predict system delays vs. different capacity and demand scenarios
- ✈ Investigate specific operational scenarios that might occur in the NAS



Study the Different Dimensions of the NAS

Major Air Transportation System Performance Dimensions

A. Pax/Cargo Demand



- Current
- Terminal Area Forecast (TAF) 2014 and 2025
- 2X TAF based constrained growth
- 3X TAF

B. Fleet Mix/Aircraft Types



- Current Sealed
- Regional Jets
- New Vehicles
 - ◆ Micro Jets
 - ◆ TiltRotors
 - ◆ UAV
 - ◆ SST
 - ◆ E-STOL

C. Business Model/Schedule



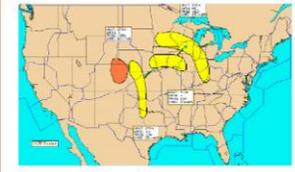
- Current (mostly Hub&Spoke)
- More Point To Point + regional airports
- Massive smaller airport utilization

D. NAS Capability



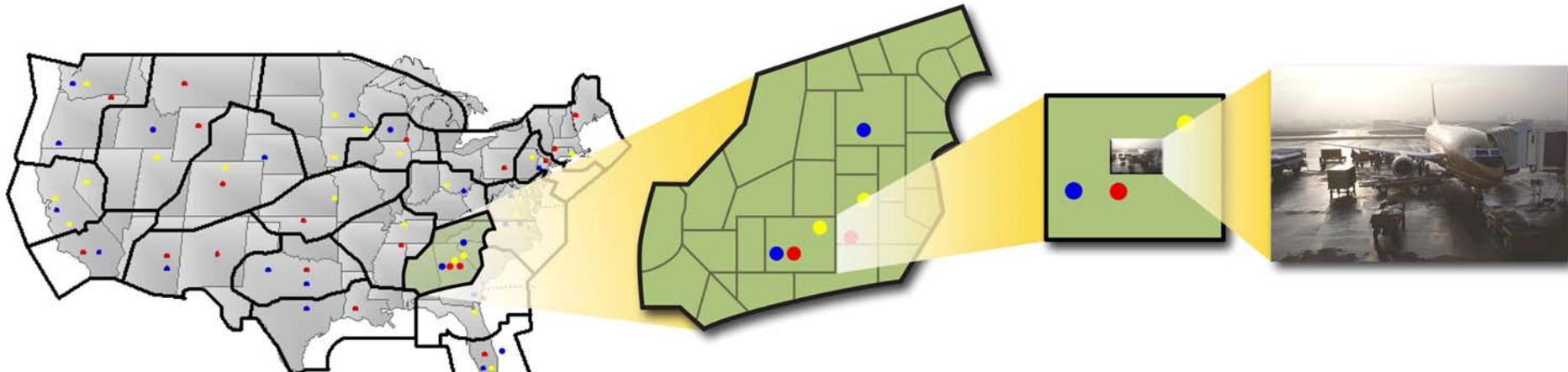
- Current
- 2010 OEP
- Increased Capacity of:
 - ◆ Surface
 - ◆ Runways
 - ◆ Terminal
 - ◆ En route
- Systemic
 - ◆ CNS
 - ◆ SWIM
 - ◆ Weather Prediction
 - ◆ Other

E. Disruptions/Weather



- Good Weather (Wx)
- Bad Wx
 - ◆ Airport IFR
 - ◆ En route
 - ◆ 7 Wx days
- Disruption
 - ◆ Sudden shutdown of an airport or region

ACES Models All Domains of the NAS



National Traffic Management

Fast-time, nationwide gate-to-gate simulation of ATM-FD-AOC operations

- Full flight schedule with flight plans, 4-D gridded winds, gate-to-gate operations

Regional Traffic Management

Thousands of participating agents:

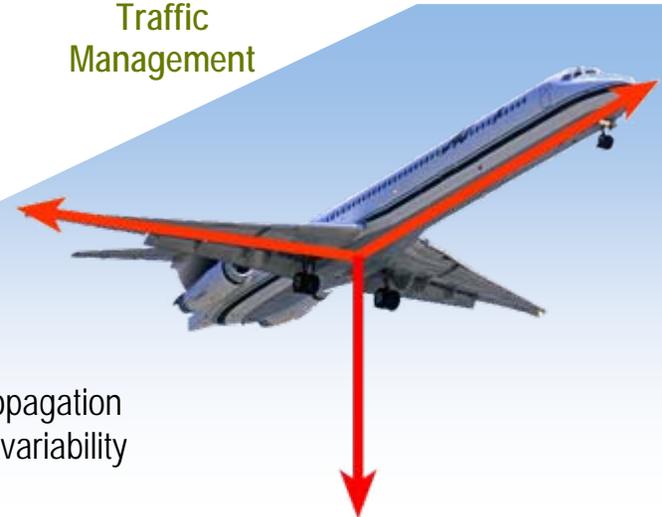
- National 1
- Regional 20
- Local 100s
- Airports 100s
- Aircraft 10,000s
- Airlines 10s

Local Approach and Departure Traffic Management

Airport and Surface Traffic Management

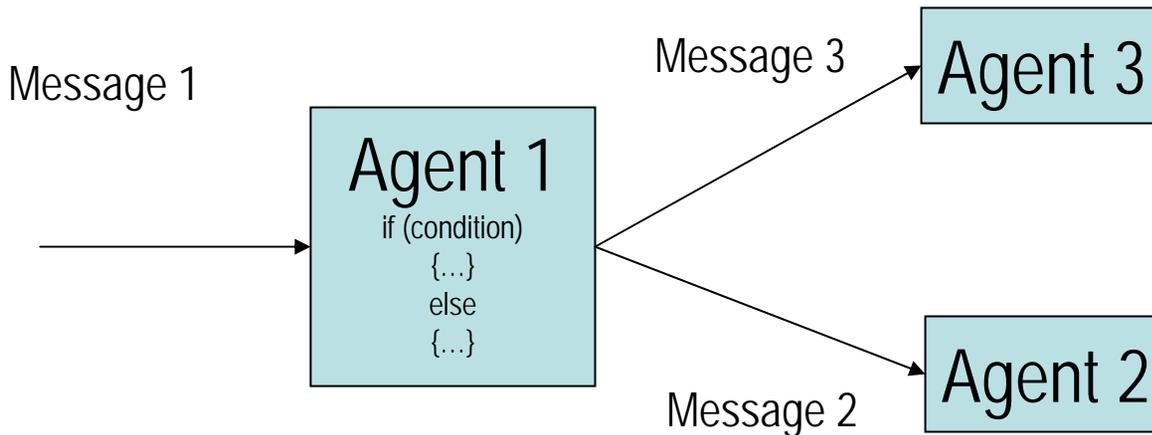
High Fidelity 4-DOF Trajectory Model

- Based on laws of physics
- Realistic pilot-based control laws
- Includes elliptic-Earth trajectory propagation
- Contains modeling for aircraft/pilot variability



Agents

- ✈ Autonomous piece of software
- ✈ Communicate with other agents via messages
- ✈ Make decisions based on events that occur within the system
- ✈ Messages are captured and stored for output



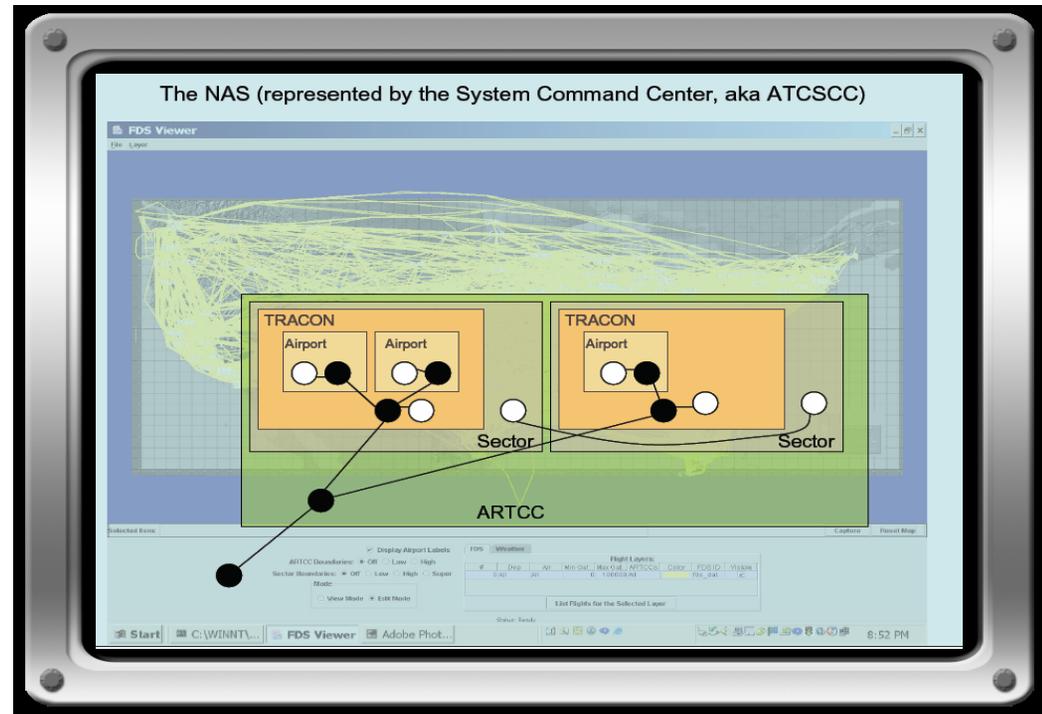
ACES Capabilities Facilitated by Agents

- ✈ Simulation of hundreds of thousands of flights
- ✈ Plug and play of new agents that model new aspects of the NAS
- ✈ Modification of scheduling and control algorithms
- ✈ Multi-fidelity modeling of different NAS domains
- ✈ Event-driven evolution of simulation time

Agent Models in ACES

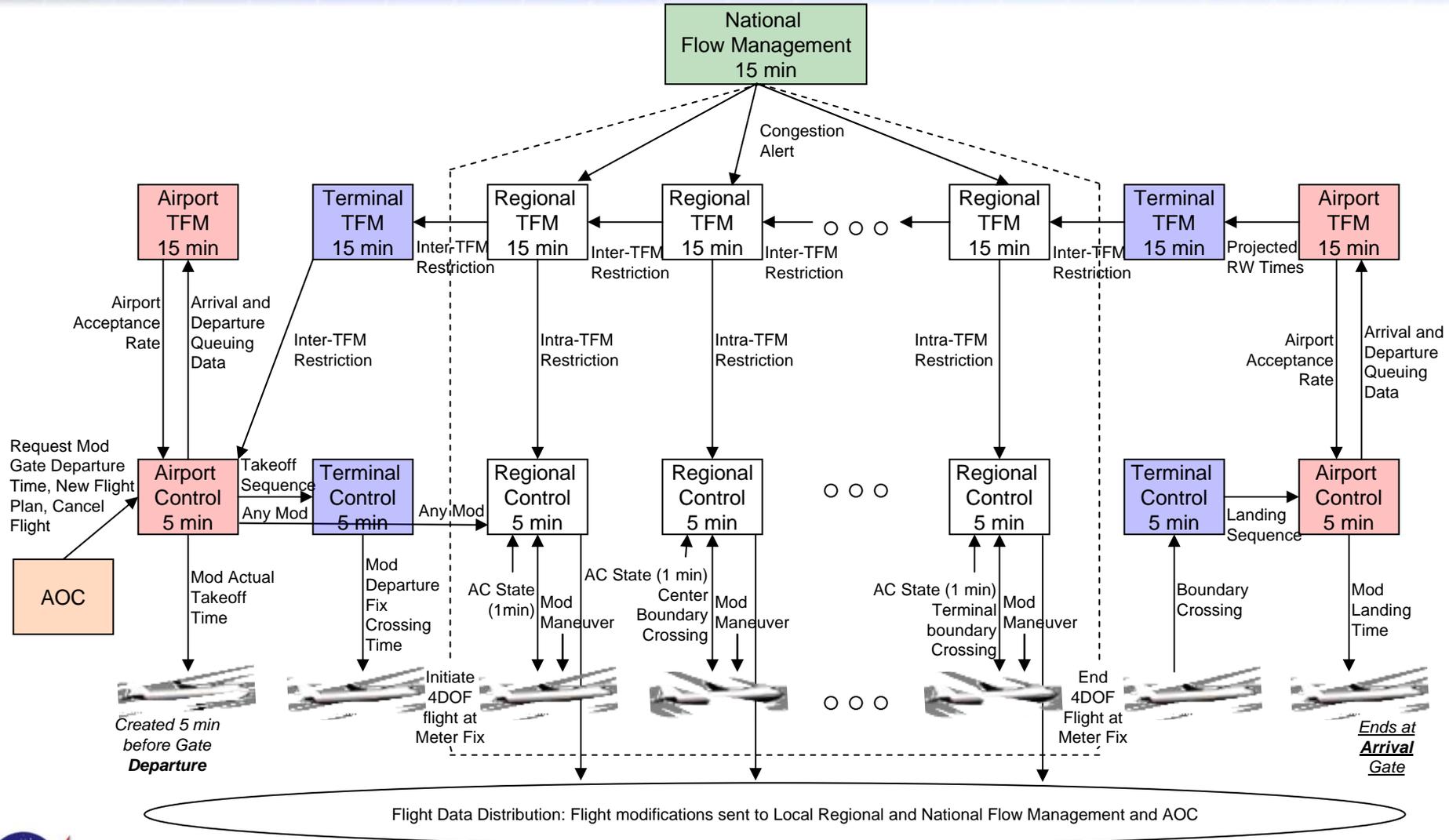
✈ Each entity in the National Airspace System (NAS) is modeled by an agent

- ◆ Flights
- ◆ AOCs
- ◆ Airport ATC & TFM
- ◆ TRACON ATC & TFM
- ◆ En-route ATC & TFM
- ◆ Command Center



✈ Agents model the physical and organizational layout of the airspace

ACES Agent Interactions

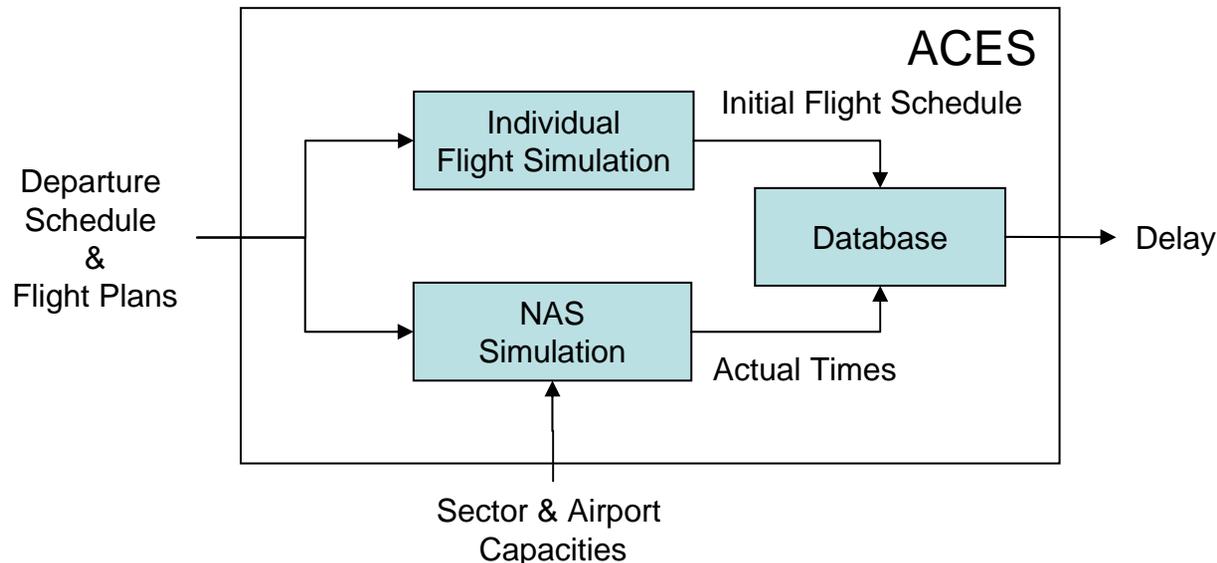


Flight Data Distribution: Flight modifications sent to Local Regional and National Flow Management and AOC



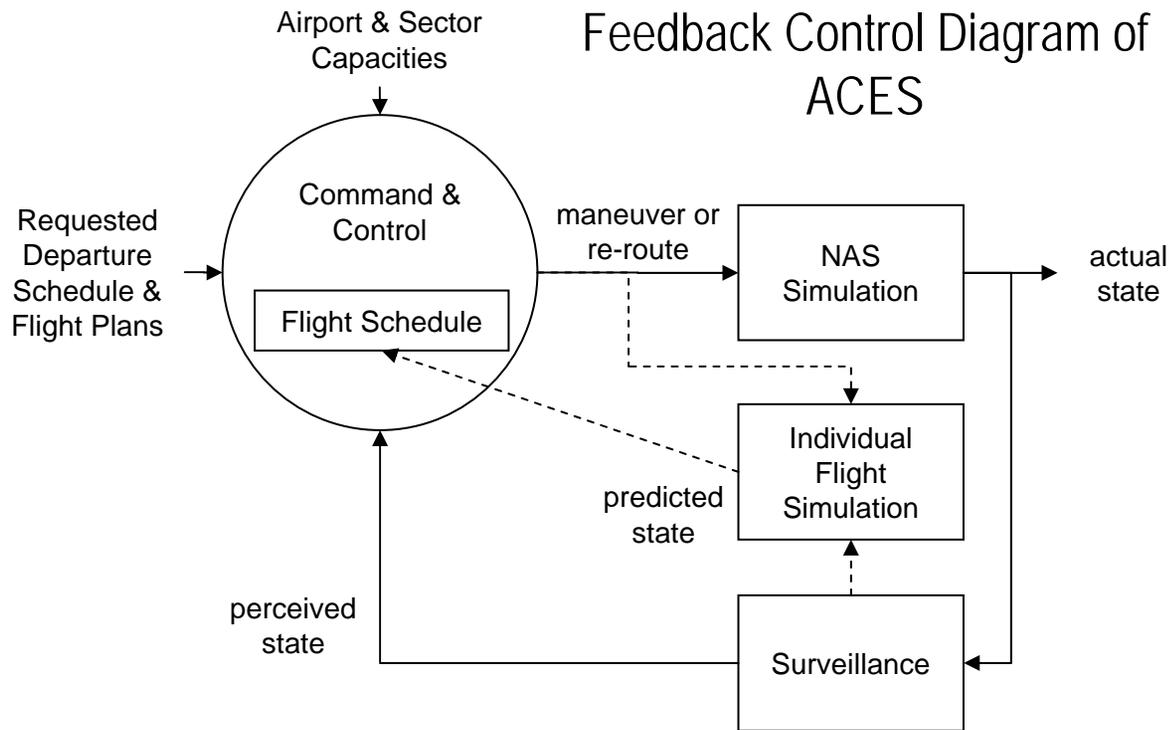
ACES Flight Schedule

- ✈ Contains sector crossing and arrival times for all flights in the simulation
- ✈ Initialized at the beginning of every ACES Simulation
 - ◆ Created by integrating each flight track individually
 - ◆ Initial schedule stored for calculating delay



Maintaining the Flight Schedule

- ✈ Updated every time a maneuver or re-route command is sent to a flight by command and control



ACES Modeling Capabilities

- ✈ Multi-fidelity modeling of the system
 - ◆ En-route – 4DOF trajectory modeling in 3D airspace
 - ◆ Airport/TRACON – node/link model
 - ◆ Detailed or aggregate runway models at airports
- ✈ Traffic flow management
- ✈ Automated conflict detection and resolution
- ✈ AOC
 - ◆ Cancellations
 - ◆ Tail tracking
- ✈ Winds

ACES Outputs

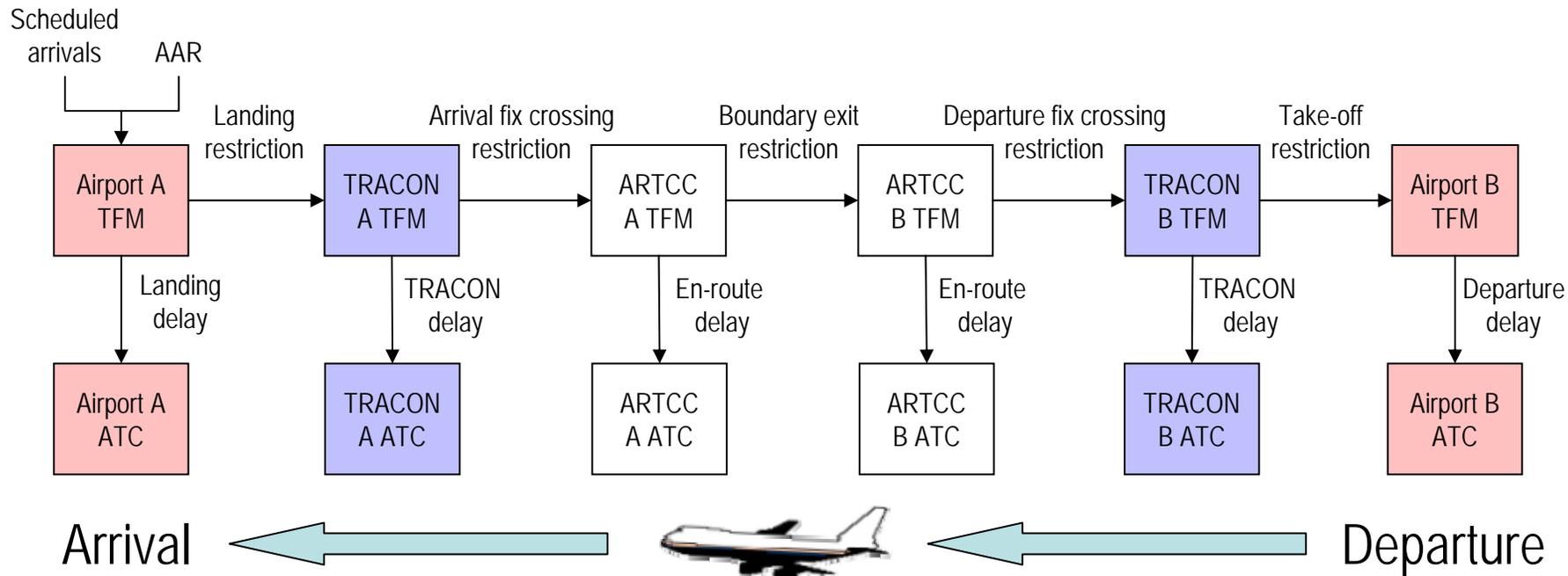
- ✈ Arrival & departure rates at specified points in the airspace or in an airport
- ✈ Sector and center flight counts
- ✈ Number, duration, and locations of delays
- ✈ Number, type, and location of flight deviations and conflicts
- ✈ Number of hand-offs, cancellations, and monitor alerts
- ✈ Models that ACES links with (open loop)
 - ◆ Noise Impact Routing System (NIRS) - population impacted by a given noise level in dB dnl
 - ◆ Emissions & Dispersion Modeling System (EDMS) - amount of CO, NOX, HC, and SOX per year
 - ◆ Communication, Navigation, and Surveillance model
 - Number of voice messages sent and lost and duration and delay of message
 - Surveillance position errors and navigation heading errors
 - ◆ Air MITAS – controller workload parameters

Traffic Flow Management Algorithm

- ✈ Airport constraints
 - ◆ Airport arrival rate (AAR)
 - ◆ Airport departure rate (ADR)
- ✈ Sector constraint
 - ◆ Monitor Alert Parameter (MAP)

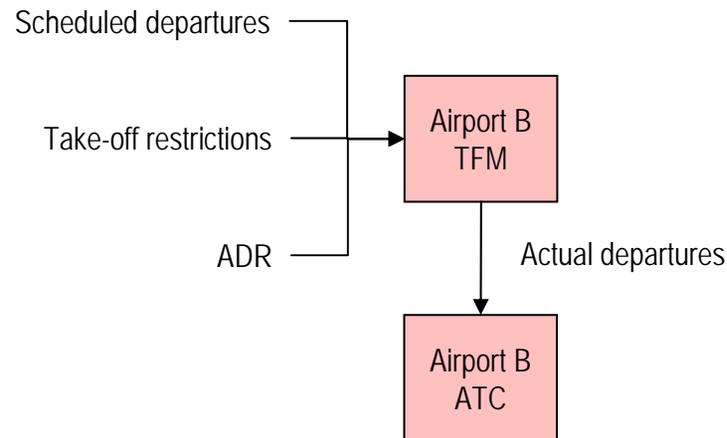
AAR Assessment

- ✈ Performed every 15 minutes over a 6 hour time horizon at every airport in the system
- ✈ Reschedules arrivals to maintain rates under AAR
- ✈ New arrival times are achieved by delaying flight upstream



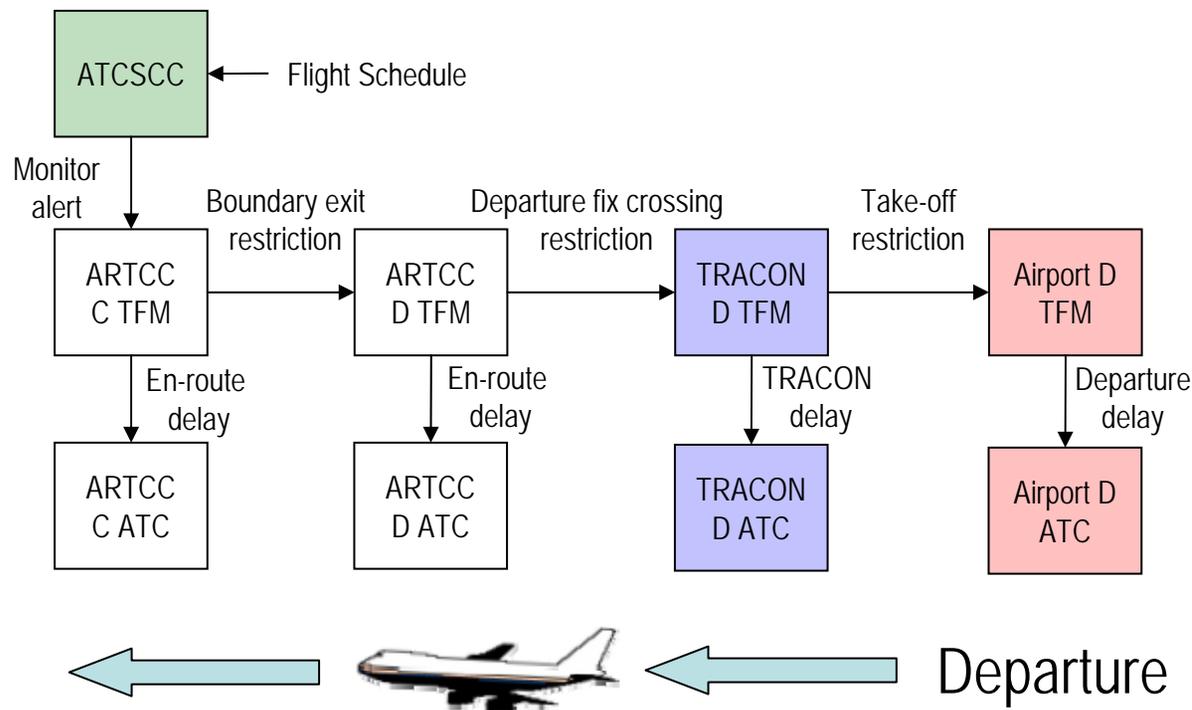
ADR Assessment

- ✈ Performed every 15 minutes over a 6 hour time horizon at every airport in the system
- ✈ Reschedules departures to maintain rates under ADR



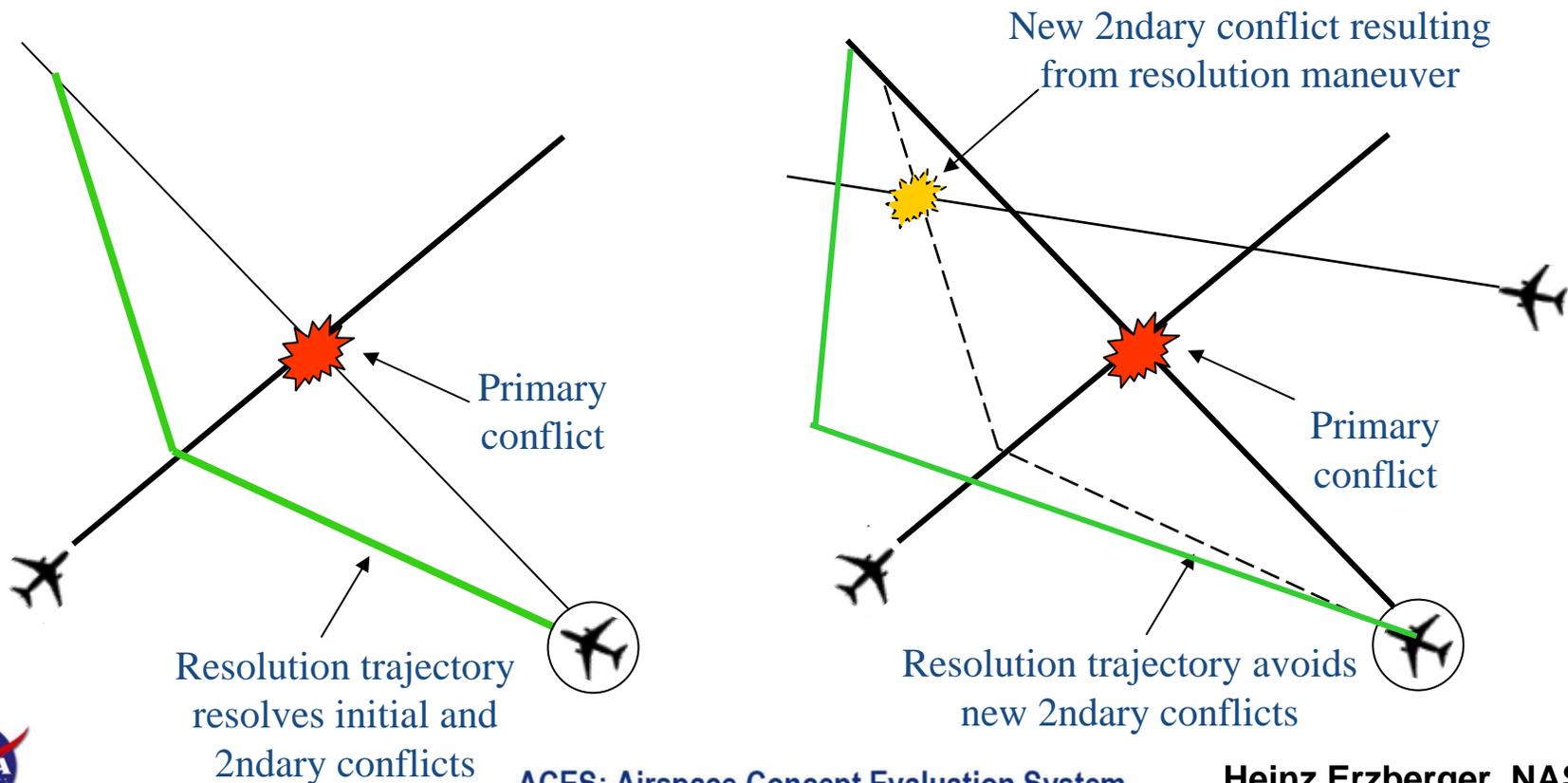
Monitor Alert Assessment

- ✈ Performed every 15 minutes over a 6 hour time horizon at ATCSCC
- ✈ Passes monitor alerts to center TFM
- ✈ Center TFM delays last flight that enters over-loaded sector to maintain sector counts under their MAP value



Automatic Conflict Detection & Resolution Algorithm

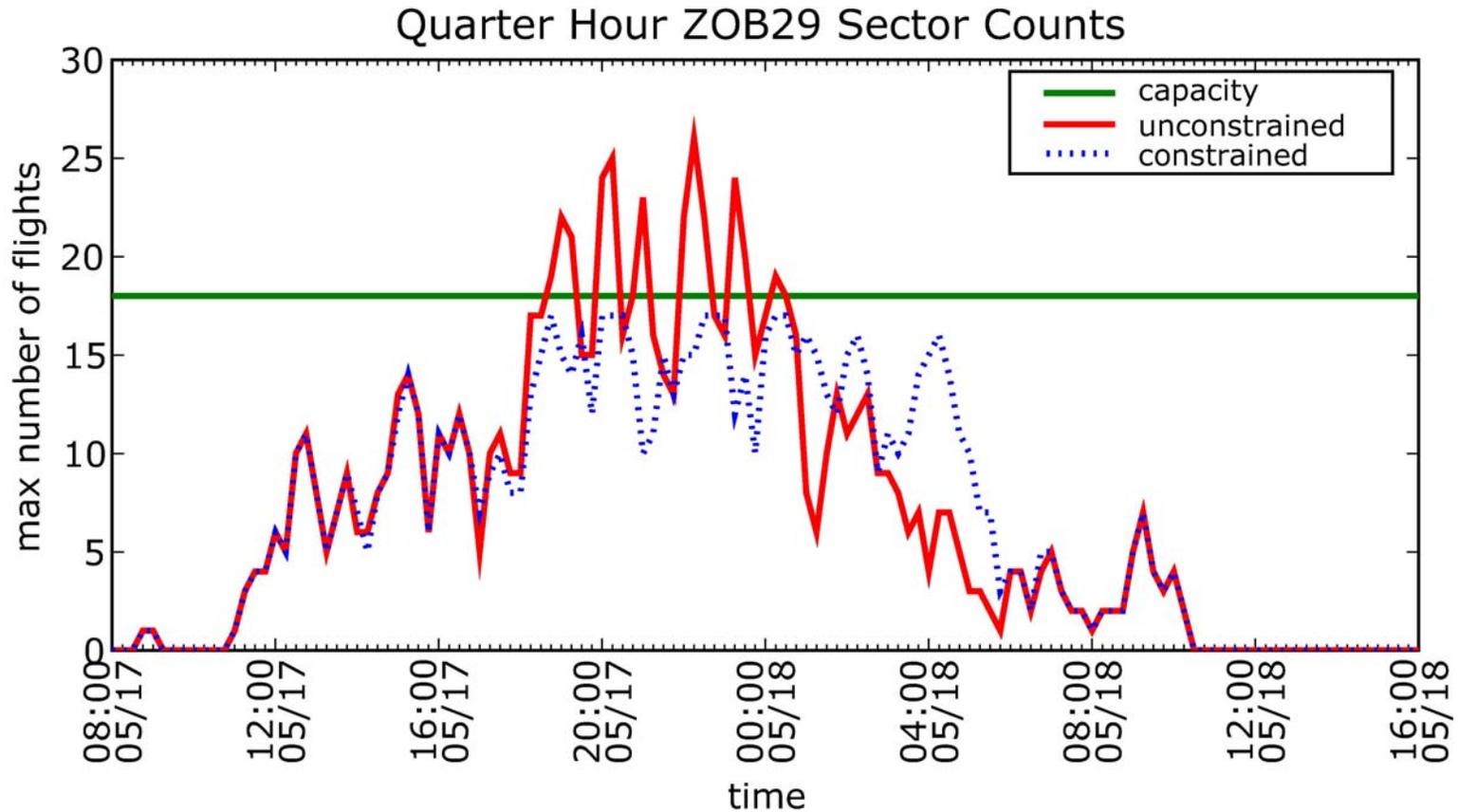
- ✈️ Algorithm automatically detects conflicts and resolves them
- ✈️ Resolves "primary" and "secondary" conflicts



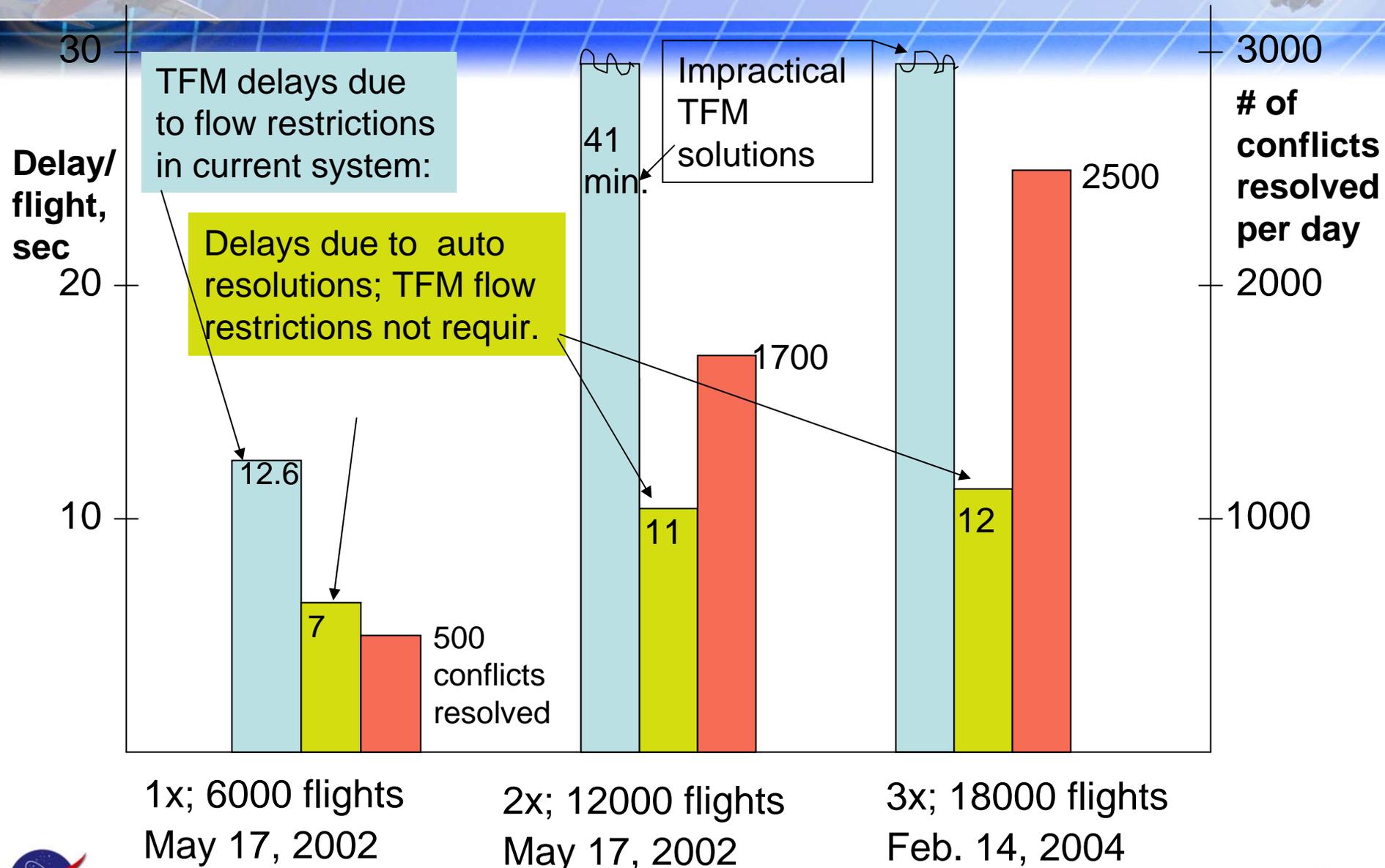
ZOB Sector Capacity Study

- ✈ Compare two airspace management strategies
 - ◆ Constraining sector counts using traffic flow management algorithm and using current flight separation procedures
 - ◆ Using automatic conflict detection and resolution algorithm
- ✈ Restricted study to flights crossing, arriving, or departing Cleveland Center
- ✈ Allowed airports to arrive and depart flights unconstrained
- ✈ Performed study for 1x, 2x, and 3x demand levels

Constraining Sector Counts Using ACES Traffic Flow Management algorithm



Performance Comparison of Constraining Sector Counts using TFM vs. Automatic Conflict Resolution



Summary

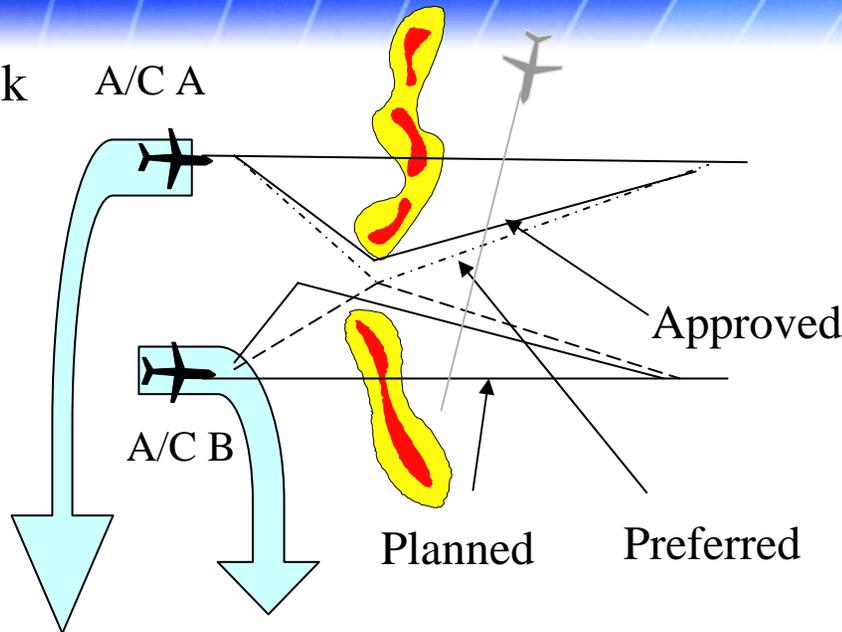
- ✈️ ACES simulates all of the domains of the National Airspace System
- ✈️ ACES can be used to perform assessments of airspace technologies and operational concepts
- ✈️ ACES can be used to predict delay vs. capacity and demand
- ✈️ Traffic flow management and automatic conflict detection and resolution algorithms were modeled in ACES
- ✈️ In a study of Cleveland center the automated conflict detection and resolution algorithm caused less delay per flight in 2x and 3x times demand cases

Performance Characteristics of Automated Resolution

- ➔ Minimum time to first loss point for initiating resolution: 1 min.
- ➔ Maximum time to first loss point for initiating resolution: User selectable (may range from 5 to 20 minutes)
- ➔ Resolution trajectory conflict free time range: User selectable (may range from 5 to 30 minutes)
- ➔ Resolution trajectory: 4D, adapted to aircraft type, FMS compatible;
 - ◆ Reducible to 3D flight paths (for non 4D FMS equipped A/C)
 - ◆ Decomposable to a sequence of standard controller clearances
- ➔ Resolution procedure types used for generating trajectories:
 - ◆ One aux. waypoint for horizontal resolution
 - ◆ One temporary altitude level for vertical resolution
 - ◆ One temporary speed change for speed profile resolution
 - ◆ All resolution types are eligible for a particular conflict
- ➔ Types of conflicts resolved: All combinations of climb, cruise, descent, including arrival vs. arrival converging at an arrival fix with altitude crossing restrictions.

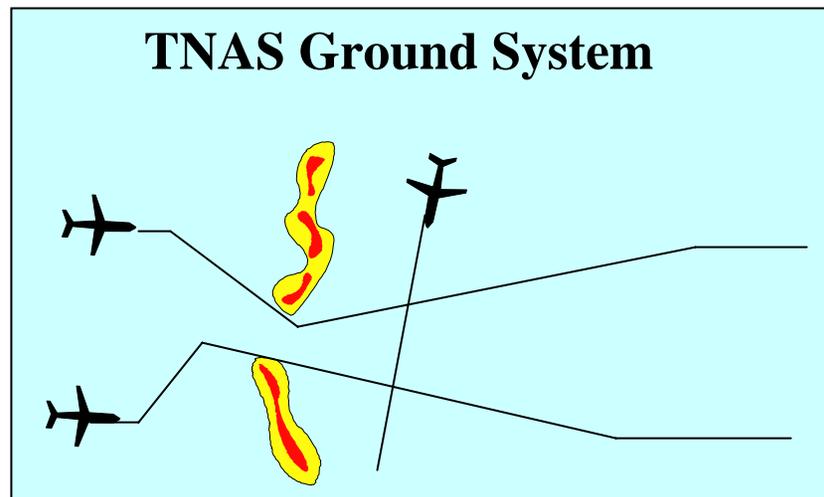
Automated Conflict Resolution

1. Pilots down link preferred trajectories



3. Pilots execute approved trajectories

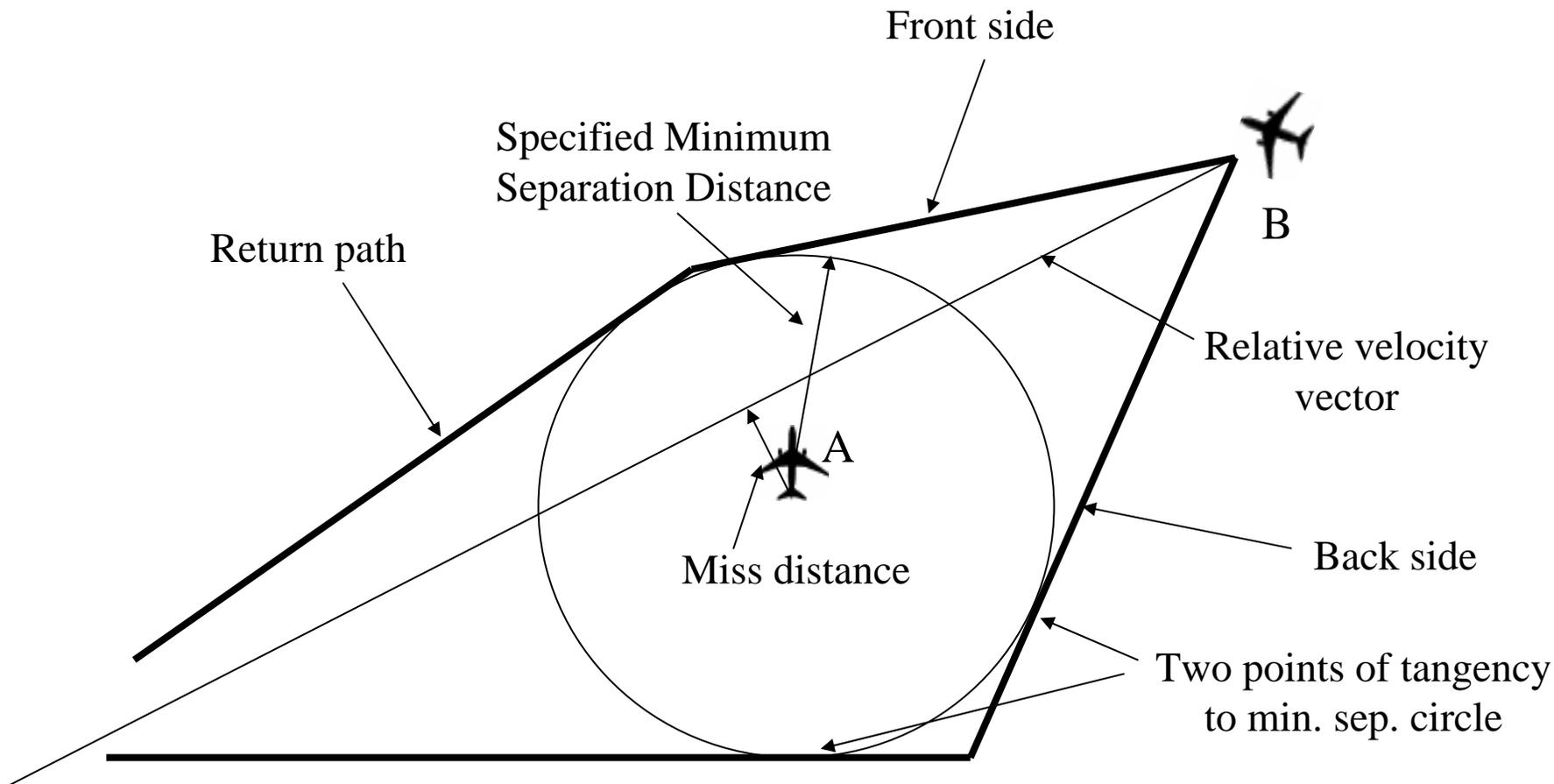
2. Ground system eliminates conflicts and TFM violations, then uplinks approved trajectories



4. Ground system monitors tracking performance and uplinks resolution advisories if necessary

Minimum Delay Resolutions for Specified Separation

(in A/C A relative coordinates)



Up to four usable resolutions are computed:
Priority given to solution requiring least time to a
return waypoint

ZOB Sector Capacity Study

Delay due to constraining sector loads using TFM
(summed for all flights and reported in minutes)

	Departure Gate	EnRoute	Total
1x	1,109	145	1,254
2x	489,867	6,619	496,084

- ✈ 1x Case contained just over 6,000 flights
- ✈ 2x Case contained just over 12,000 flights