Abstract

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NASA Ames Research Center
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Air Traffic Management Research at NASA Ames Research Center

Since the late 1980's, NASA Ames researchers have been investigating ways to improve the air transportation system through the development of decision support automation. These software advances, such as the Center-TRACON Automation System (CTAS) have been developed with teams of engineers, software developers, human factors experts, and air traffic controllers; some NASA Ames decision support tools are currently operational in Federal Aviation Administration (FAA) facilities and some are in use by the airlines. These tools have provided air traffic controllers and traffic managers the capabilities to help reduce overall delays and holding, and provide significant cost savings to the airlines as well as more manageable workload levels for air traffic service providers. NASA is continuing to collaborate with the FAA, as well as other government agencies, to plan and develop the next generation of decision support tools that will support anticipated changes in the air transportation system, including a projected increase to three times today's air traffic levels by 2025. The presentation will review some of NASA Ames' recent achievements in air traffic management research, and discuss future tool developments and concepts currently under consideration.

Air Traffic Management Research at NASA Ames Research Center

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U.C. Berkeley Chi Epsilon General Meeting
April 7, 2005

Ames Research Center

Outline

- NASA's Missions and Aeronautics Research
- Today's Air Traffic Control System
- Development of Decision-Support Tools
- The Center-TRACON Automation System (CTAS)
- The Traffic Management Advisor (TMA)
- The Multi-Center Traffic Management Advisor (McTMA)
- The Surface Management System (SMS)
- Future Directions: The Joint Planning and Development Office

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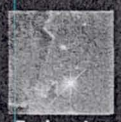
4 Mission Directorates


Exploration Systems


Science


Space Flight


Aeronautics Research

NASA's Mission: **To understand and protect our home planet**
To explore the universe and search for life,
To inspire the next generation of explorers
...as only NASA can.

Aeronautics Research Mission Directorate Objective:

Increase Mobility: "Enable more people and goods to travel faster and farther, with fewer delays."

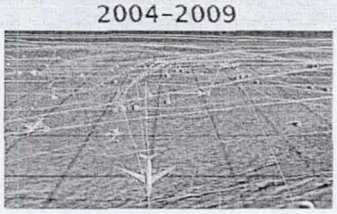
Airspace Systems Program Goal:

Enable major increases in the capacity and mobility of the air transportation system through development of revolutionary concepts for operations and vehicle systems

Current Airspace Systems Projects

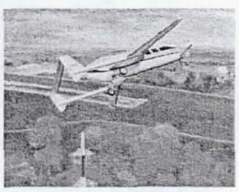
AERONAUTICS research mission directorate

NExTNAS Elements
2004-2009



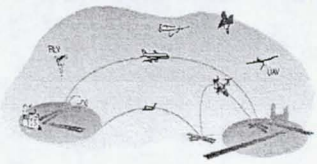
EFPM, SAU, HMP, EAS
Technologies to enable future operational concepts for a more flexible & efficient NAS

SATS
2001-2005



Improve public mobility & community access with small aircraft/airports

VAMS
2002-2006



Explore advanced concepts & model/simulate the NAS

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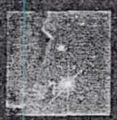
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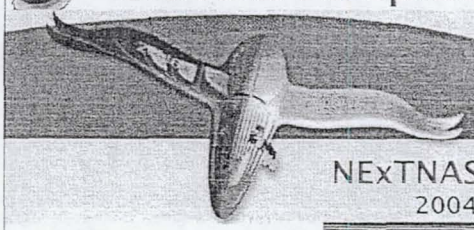

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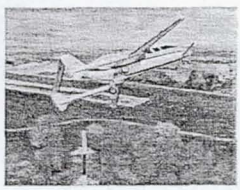

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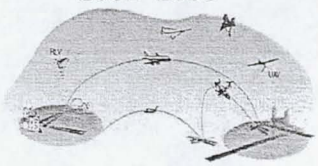

Explore advanced concepts & model/simulate the NAS

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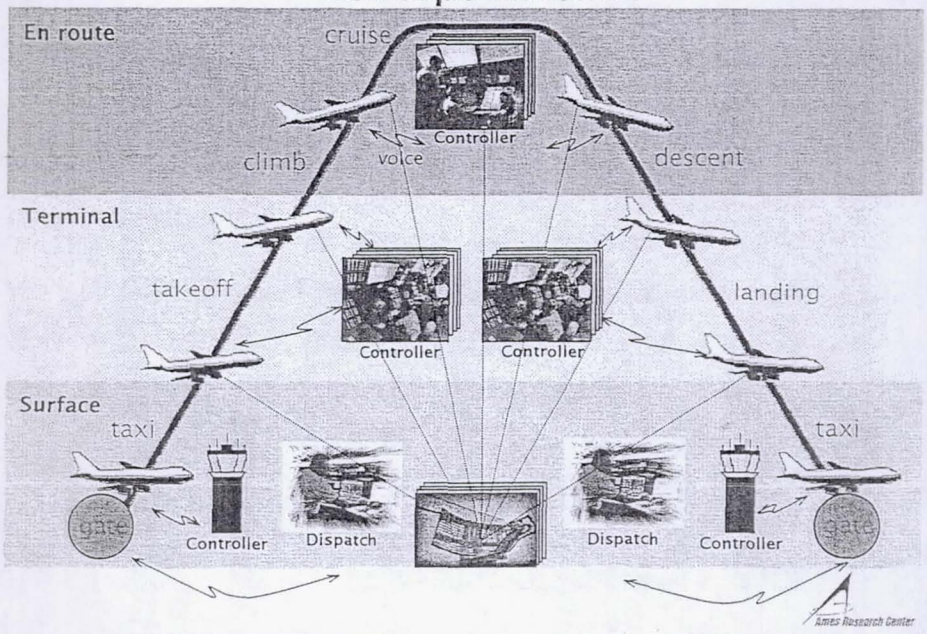
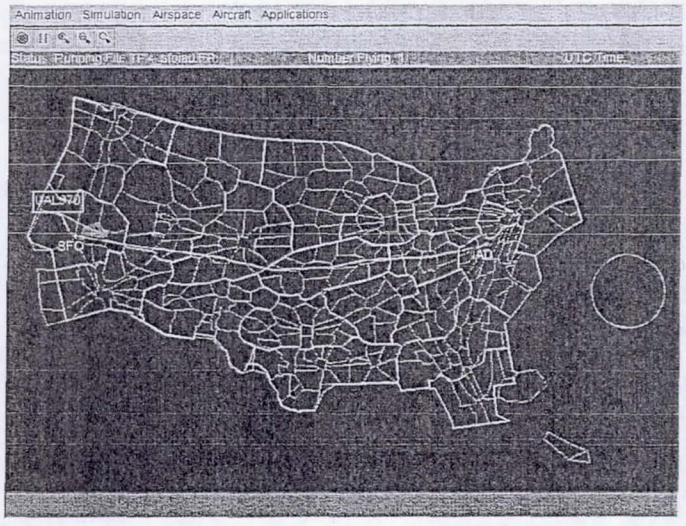
Today's Air Traffic Operational Concept Baseline



Flight from SFO to IAD



Route of flight includes transition through 35 sectors:
- 6 surface/terminal area sectors (departure)
- 23 en route area sectors
- 6 terminal/surface area sectors (arrival)

Current Daily En-Route Operations

A DAY IN THE LIFE OF
AIR TRAFFIC OVER
THE CONTINENTAL U. S.

ANIMATION CREATED USING

FUTURE ATM CONCEPTS
EVALUATION TOOL
(FACET)

FOR
AVIATION SYSTEMS DIVISION
(AF)
NASA AMES RESEARCH CENTER

UTC =
PT + 8 hrs

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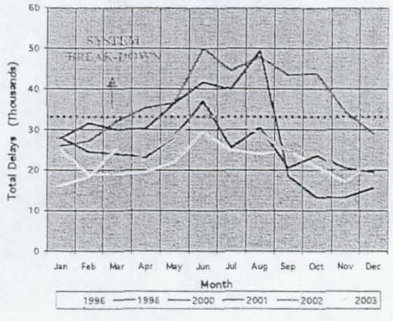
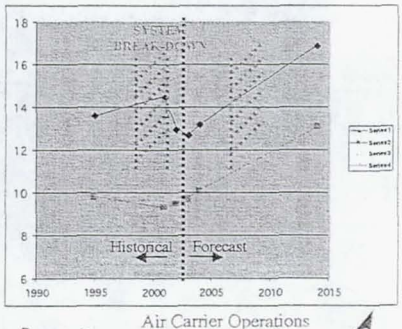
Current Air Transportation System Status

- Data indicates that the system breaks down with air carrier operations greater than 14 million per year
  - Major carriers will continue to use high density airports (cost/convenience)
  - Emerging carriers will support high density point-to-point routes (increased use of air taxis and smaller airports)

TOTAL U.S. ATC SYSTEM DELAY
(Thousands of Flights with Delay>15 min.)



Operations (Millions)



Reference: FAA Aerospace Forecasts
March 2003

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Current Air Transportation System Status (2)

- **Demand:**
  - In 2004, 17 of the nation's 35 busiest airports exceeded their pre-Sept. 11 levels
  - By the end of 2005, it is expected that flight operations at 23 of the nation's 35 busiest airports will exceed their pre-Sept. 11 levels
- **Runway Capacity:**
  - It takes approximately 10 years to build new runways
  - Approximately half of the nation's 25 busiest airports cannot add runway capacity (due to geography)

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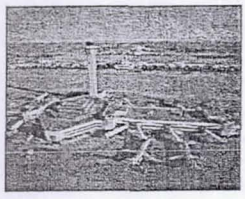
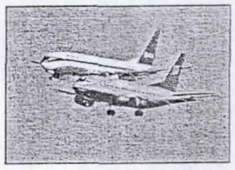
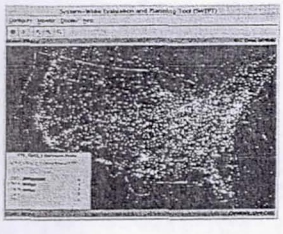
Capacity Solution Space



- Increased utilization of airports
  - Improve flow in and around airports
  - Increase use of under-utilized airports
  - Build new airports

- Increase utilization of airspace
  - Density
  - Availability
  - Structure





- Improve coordination and optimization

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Center-TRACON Automation System (CTAS)

- Developed from algorithms for flight management systems (FMS)
- Set of computer tools which assist in the efficient planning and control of air traffic
- Utilizes:
  - Expert rules
  - Highly-accurate, 4-D trajectory prediction
- Adaptable to user preferences/ constraints
- Network of workstations interfaced with current FAA Air Traffic systems (HOST and ARTS)

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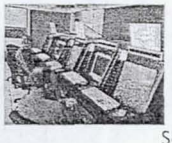
CTAS Tool Development: Technical Approach



Concept Definition

Initial Software

On-site Controllers

Airlines

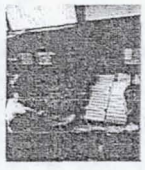
Preparation for Operational Test

Assessment Team/Cadre

Adaptation for Target Site

System Development Team

Operational Test



Controller and Pilot Involvement

Human Factors

Analysis

Shadowing

Real-time Simulation

Fast-time Simulation

Engineers, Computer Scientists, Human Factors Experts, Controllers, Pilots, Airline Dispatchers

Development Progress

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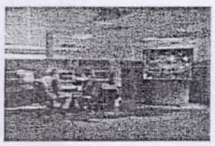
Facility Interoperability: Aviation Systems Division

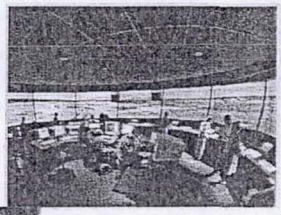
CTAS Laboratories

ATC Pseudo Aircraft



Future Flight Central

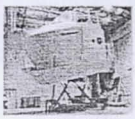
Pseudo Aircraft AOC Stations Surface Tools



CVSRF

ACFS

ATC



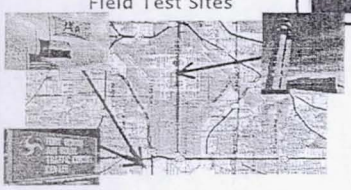
747-400

Vertical Motion Simulator

ICAB

(Fixed Base) Laboratories

Field Test Sites



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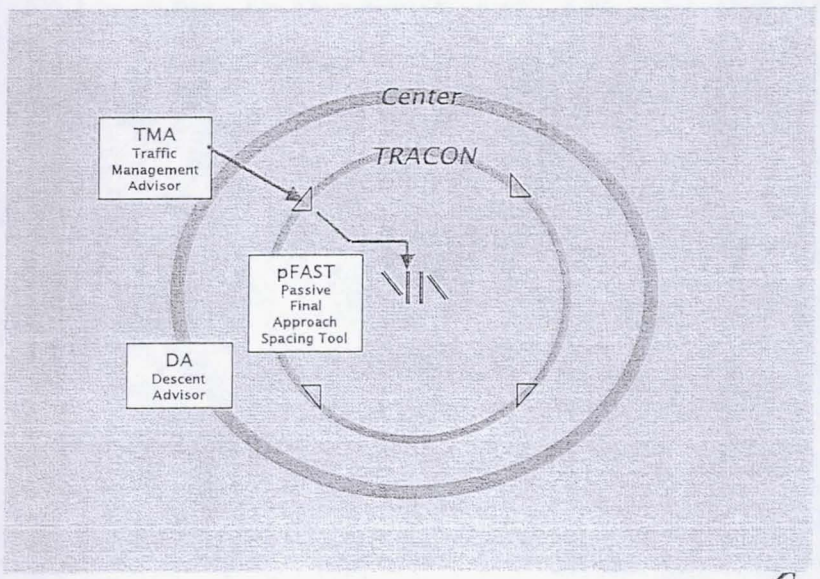
CTAS Concept (1)



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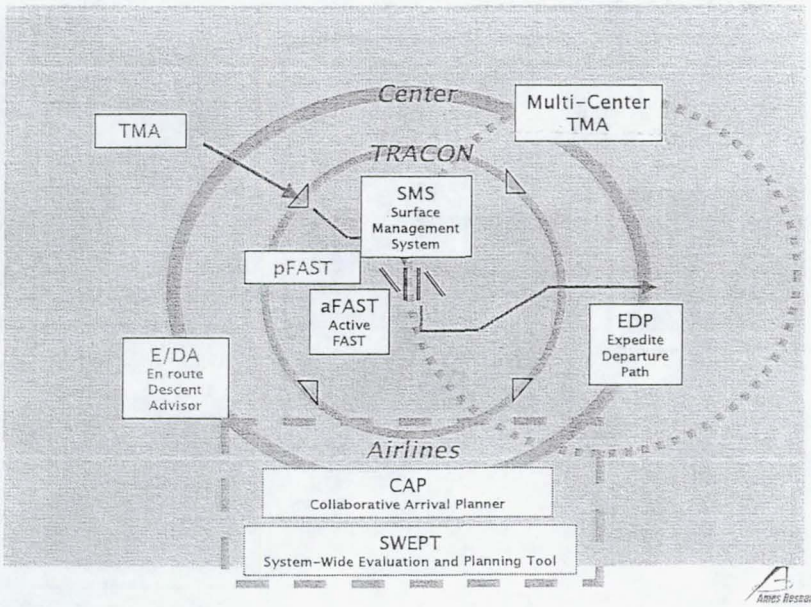
CTAS Concept (2)



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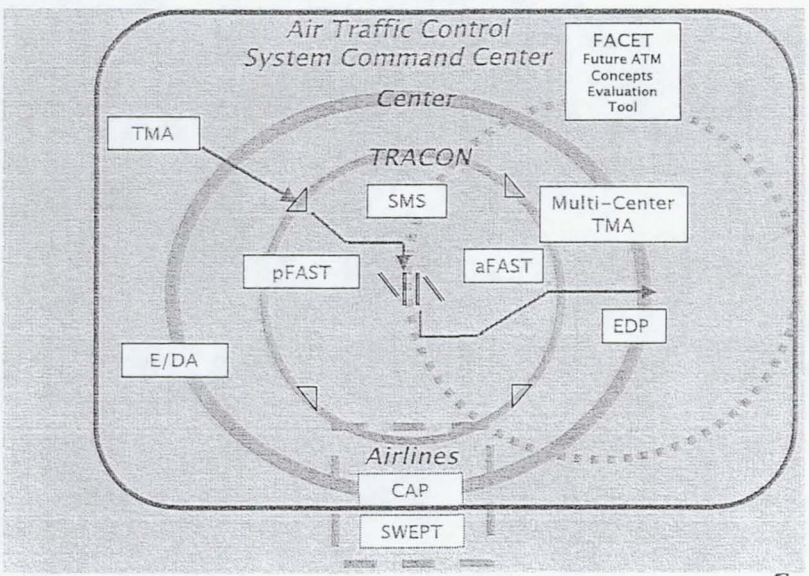
CTAS Concept (3)



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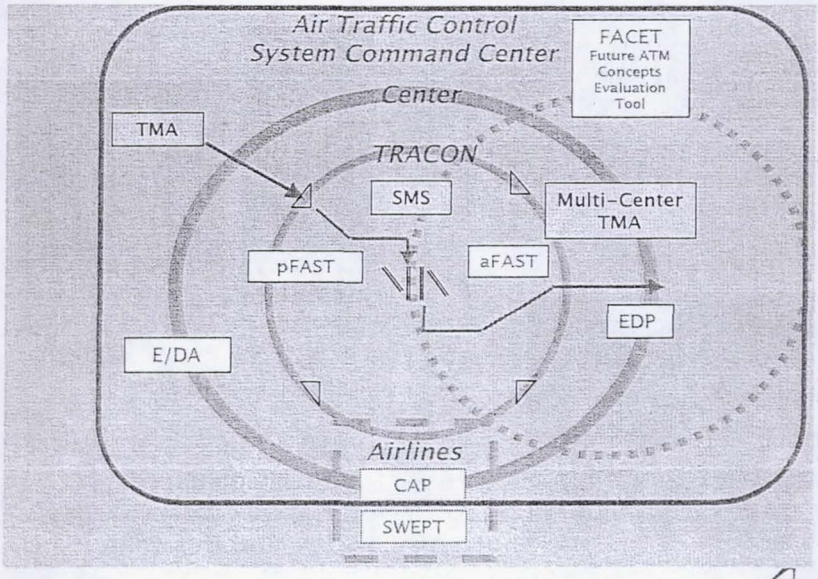

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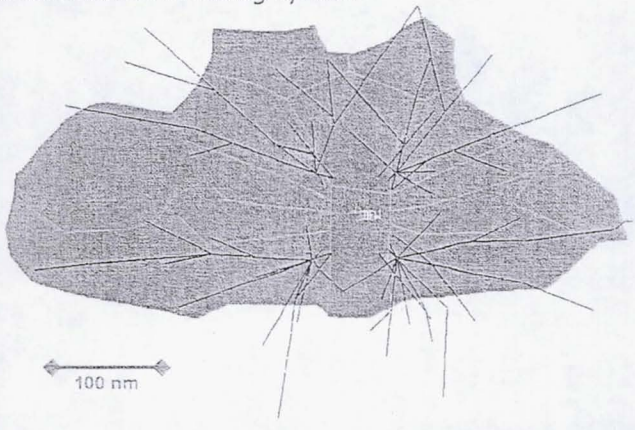
repeat?
slightly different - TMA, SMS, MCTMA are highlighted in yellow to indicate the focus of the rest of the talk

Traffic Management Advisor (TMA)

The Problem:

- Heavy traffic flows to a single major terminal area/airport leading to delays
- Inefficient miles-in-trail spacing methods
- Inefficient time-based metering system



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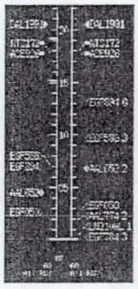
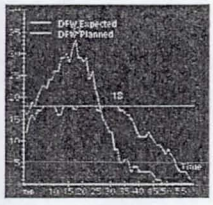
The TMA Solution

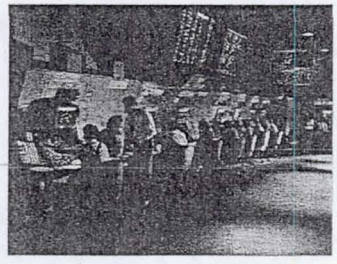
- Decision-support tool used by traffic management coordinators and enroute air traffic controllers.
- Develops a safe and efficient arrival schedule that meets, but does not exceed, the specified capacity of the airport, and minimizes delays.



TMA timeline



TMA traffic load graph



TMA in use at Denver TRACON

- Provides traffic flow visualization capability for traffic flow management.
- Advises enroute sector controllers of the optimized schedule.
- Increases airport capacity, reduces arrival delays, and reduces controller workload.

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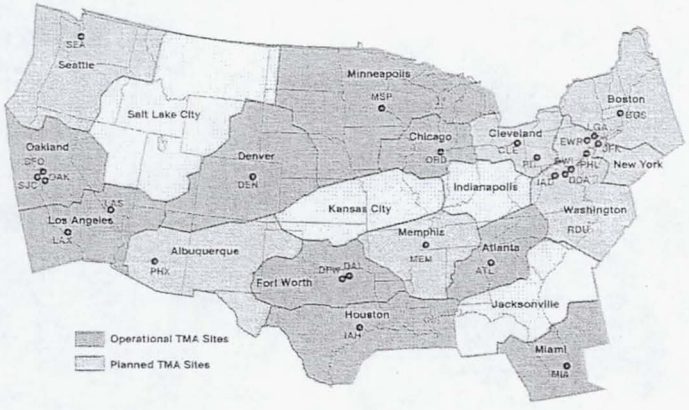
Current TMA Operational Deployment



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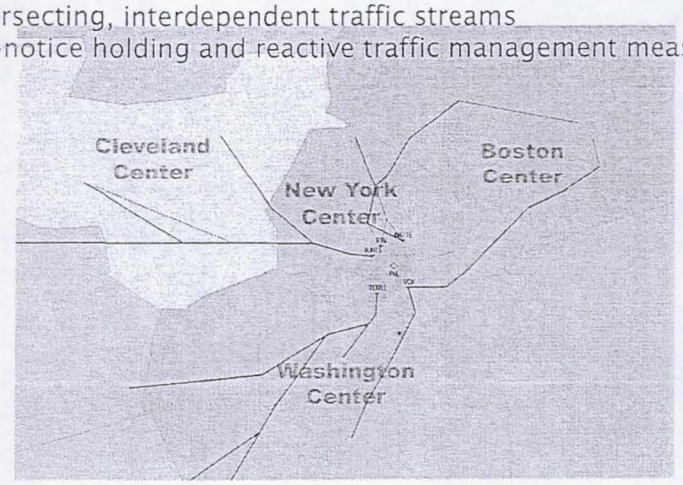
Multi-Center TMA (McTMA)

The Problem:

- Multiple facilities involved in traffic management
- Intersecting, interdependent traffic streams
- No-notice holding and reactive traffic management measures



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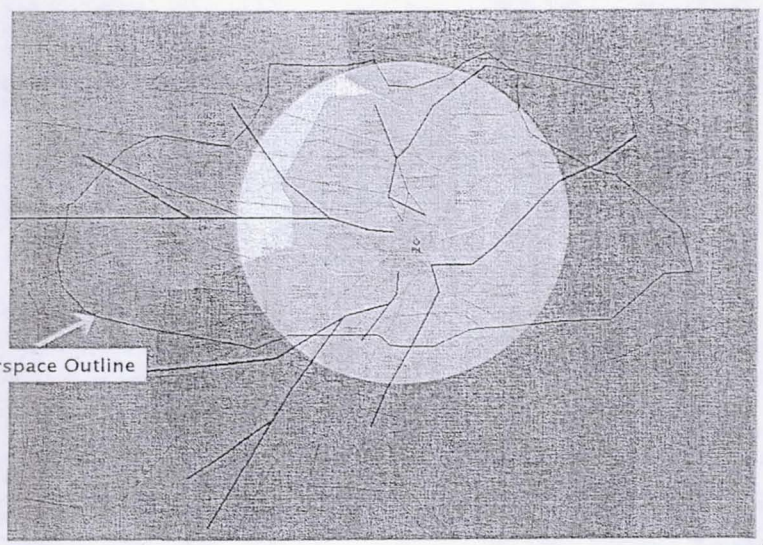
Conventional Metering Horizon



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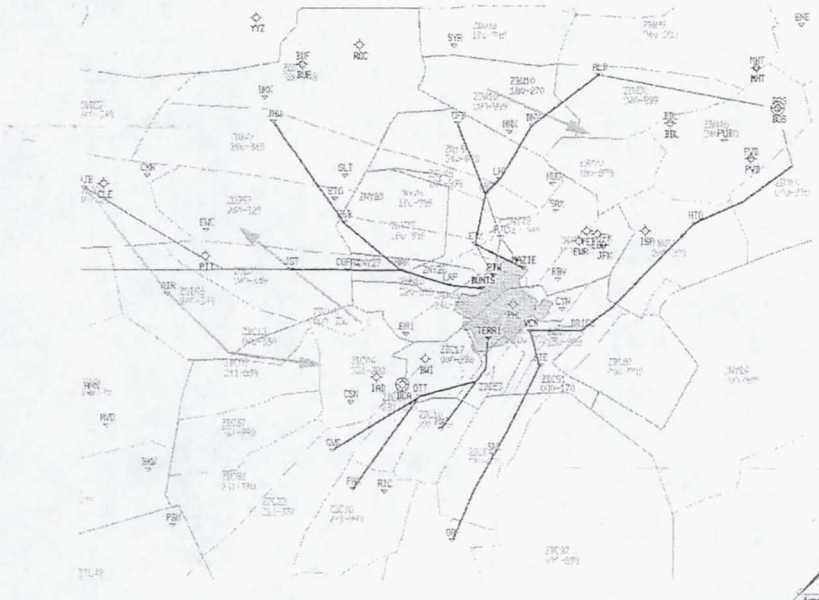
Philadelphia Arrival Flows



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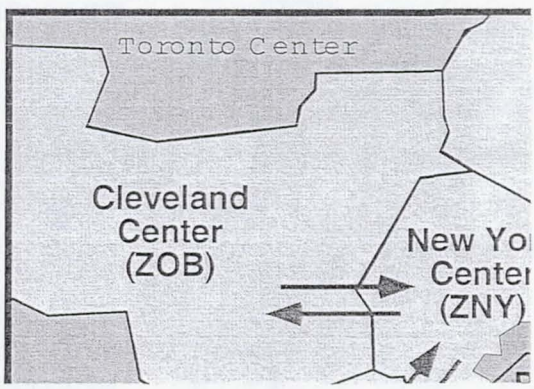
McTMA Solutions

- Extendable, flexible system architecture to link traffic predictions and schedules between facilities
- Distributed scheduler to provide robust scheduling for the entire system while preserving facility independence to address local traffic problems
- Enables inter-facility collaboration to manage arrival traffic
- Provides a generic scheduling solution for the NAS



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McTMA Accomplishments

- Developed new capabilities tested both in simulation and in the field
- Field evaluation at four ARTCCs, Philadelphia TRACON, and the Air Traffic Control System Command Center (November 2004)
- Demonstrated favorable performance of the new algorithms
- Working with the FAA to merge McTMA functionality into its existing operational baseline
- Anticipated rollout of new McTMA system to key test-sites in 2006
- Eventual deployment of "new" TMA (with McTMA functionality) to all current Single-Center TMA sites
- Estimated benefits: $70M savings for PHL, New York and Washington, DC airports (Potential of $200M/year in 2010, and $370M/year on 2015)

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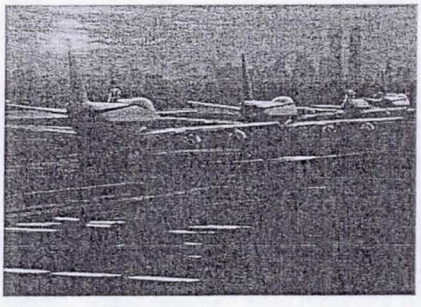
Surface Management System (SMS)

The Problem:

- Ground operations bottleneck
- Different user groups impact the surface operation
- Departure planning on the surface is reactive and very manual
- Runway capacity is a limitation for many airports



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SMS Solution

SMS is a decision aid to Tower controllers and airline surface operators to effectively manage ground congestion at ramps, taxiways and runways.

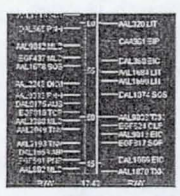
ETMS

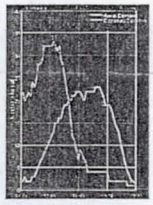
Pushback Times, Flight Plans, EDCTs, Airborne Surveillance, Parking Gates

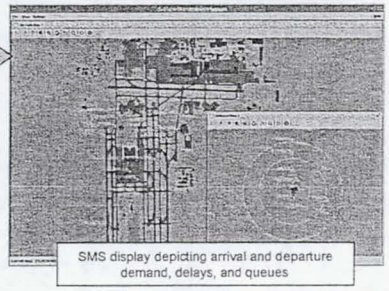
SMS

Surface Surveillance

Displays for Traffic Managers and Airline Ramp Coordinators







SMS display depicting arrival and departure demand, delays, and queues

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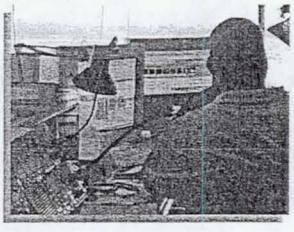
SMS Accomplishments

- The SMS project has worked closely with Fed Ex and Northwest Airlines at Memphis Airport to develop and test concepts and functionality.
- Operational demonstrations at Memphis Tower, TRACON, and Center and integration of SMS with the FAA's SafeFlight 21 Program and UPS operations at Louisville Airport were completed.
- Information provided enables Tower and Airline operators to reduce taxi delays, reduce fuel costs, and improve predictability of take-off times
- **Estimated annual benefits to the airlines of $315M/year NAS-wide**



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Future Directions

- NASA, together with the FAA, is leading the Joint Planning and Development Office (JPDO) to define the next generation of the Air Transportation System
- Other agencies/departments involved: DHS, DOC, DOT, DOD, OSTP
- As part of the output of the JPDO National Plan, NASA will be working to address much of the ATM research work needed to achieve the goals in the National Plan
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  - Expand Capacity
  - Ensure Safety
  - Protect the Environment
  - Ensure Our National Defense
  - Secure the Nation
- The plan addresses not only air traffic management, but airport infrastructure, security, aircraft equipage, environmental impact, weather, and international operations

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Future Directions (2)

- Virtual Airspace Modeling and Simulation Project
  - To define and assess future concepts for airspace operations
  - Goal to provide a revolutionary improvement in system capacity, while maintaining affordability and safety
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  - Addresses bottleneck created by human controller workload (limitations in sector size reductions)
  - Separation assurance no longer the responsibility of the air traffic controller for equipped aircraft
  - Utilizes Controller/Computer-Pilot Datalink
  - Requires an automated separation monitoring and conflict avoidance system

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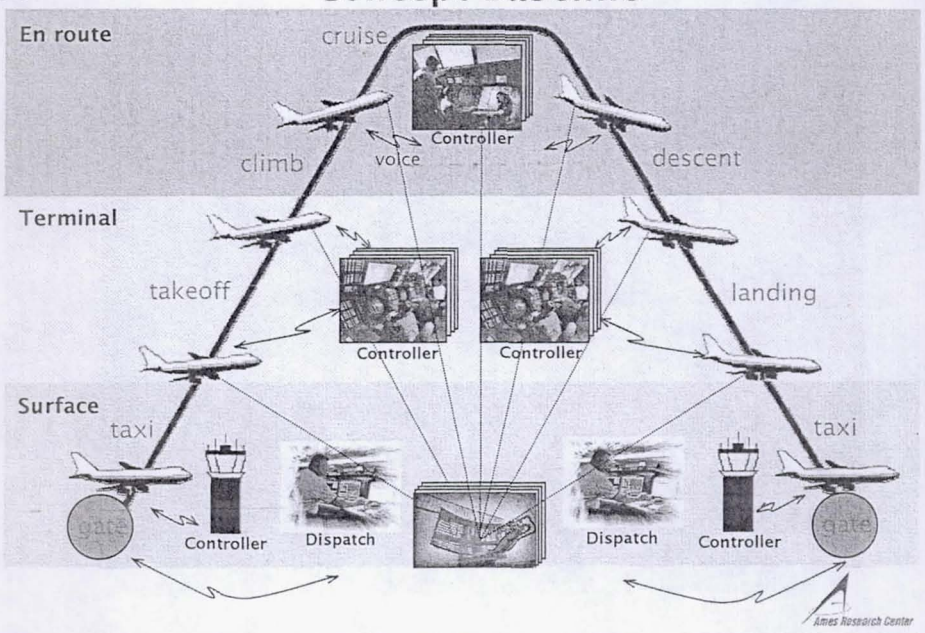
Today's Air Traffic Operational Concept Baseline



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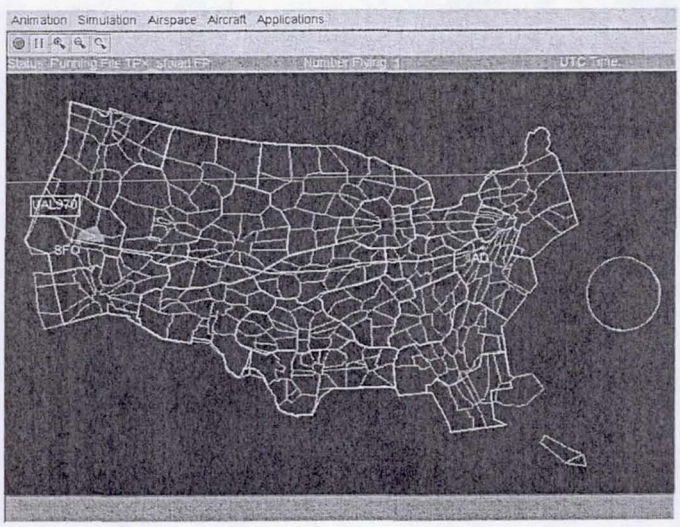
Flight from SFO to IAD



Route of flight includes transition through 35 sectors:
- 6 surface/terminal area sectors (departure)
- 23 en route area sectors
- 6 terminal/surface area sectors (arrival)

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Current Daily En-Route Operations

A DAY IN THE LIFE OF
AIR TRAFFIC OVER
THE CONTINENTAL U. S.

ANIMATION CREATED USING

FUTURE ATM CONCEPTS
EVALUATION TOOL
(FACET)

FOR
AVIATION SYSTEMS DIVISION
(AF)
NASA AMES RESEARCH CENTER

UTC =
PT + 8 hrs

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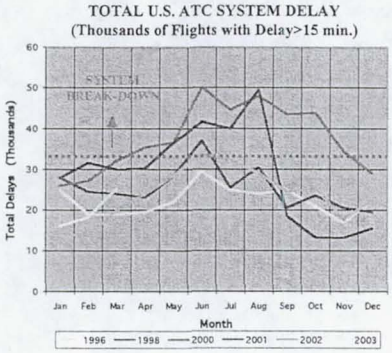
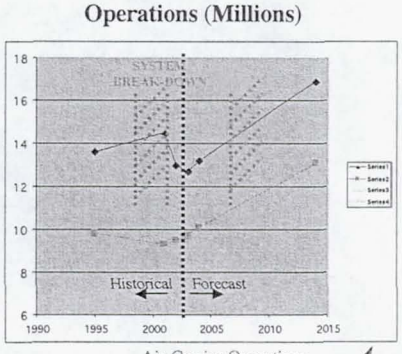
Current Air Transportation System Status

- Data indicates that the system breaks down with air carrier operations greater than 14 million per year
  - Major carriers will continue to use high density airports (cost/convenience)
  - Emerging carriers will support high density point-to-point routes (increased use of air taxis and smaller airports)





Reference: FAA Aerospace Forecasts
March 2003

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Current Air Transportation System Status (2)

- **Demand:**
  - In 2004, 17 of the nation's 35 busiest airports exceeded their pre-Sept. 11 levels
  - By the end of 2005, it is expected that flight operations at 23 of the nation's 35 busiest airports will exceed their pre-Sept. 11 levels
- **Runway Capacity:**
  - It takes approximately 10 years to build new runways
  - Approximately half of the nation's 25 busiest airports cannot add runway capacity (due to geography)

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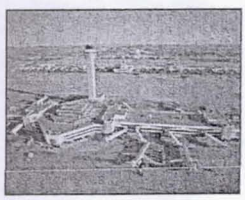
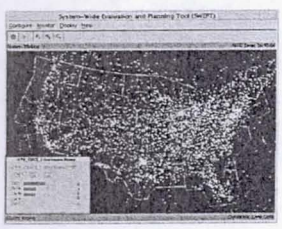
Capacity Solution Space



- Increased utilization of airports
  - Improve flow in and around airports
  - Increase use of under-utilized airports
  - Build new airports

- Increase utilization of airspace
  - Density
  - Availability
  - Structure



- Improve coordination and optimization

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Center-TRACON Automation System (CTAS)

- Developed from algorithms for flight management systems (FMS)
- Set of computer tools which assist in the efficient planning and control of air traffic
- Utilizes:
  - Expert rules
  - Highly-accurate, 4-D trajectory prediction
- Adaptable to user preferences/ constraints
- Network of workstations interfaced with current FAA Air Traffic systems (HOST and ARTS)

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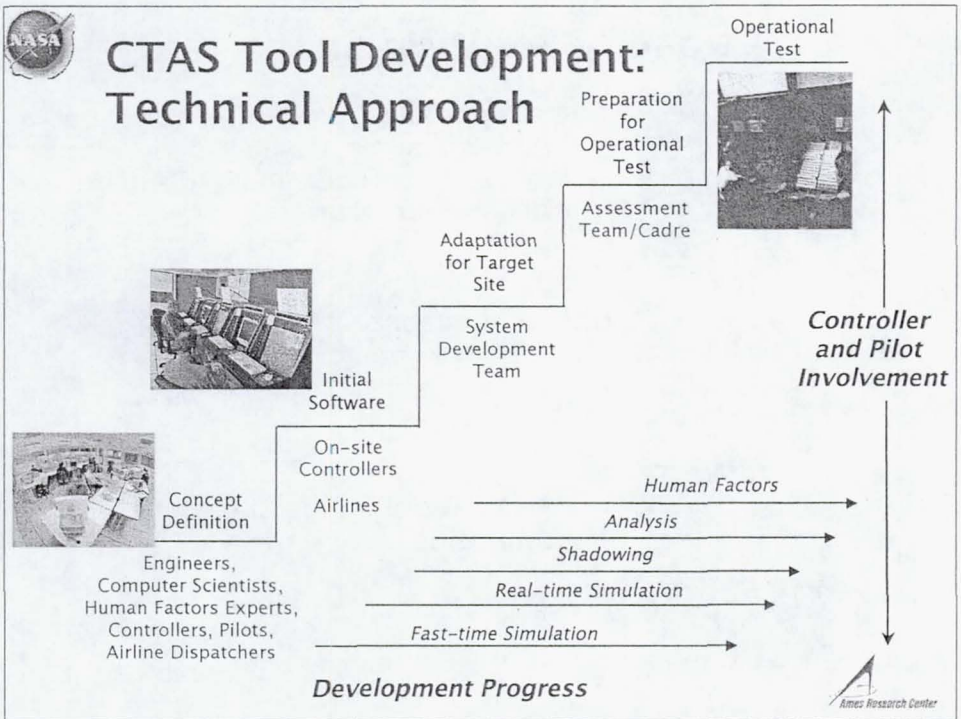
CTAS Tool Development: Technical Approach



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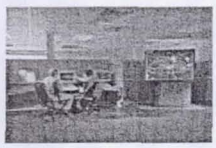
Facility Interoperability: Aviation Systems Division

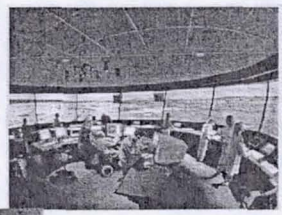
CTAS Laboratories

ATC Pseudo Aircraft



Future Flight Central

Pseudo Aircraft | AOC Stations | Surface Tools



CVSRF

ACFS

ATC

747-400

Vertical Motion Simulator

ICAB

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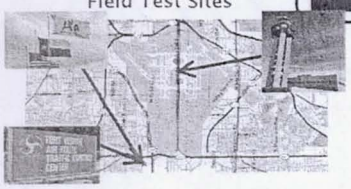
Laboratories

Field Test Sites



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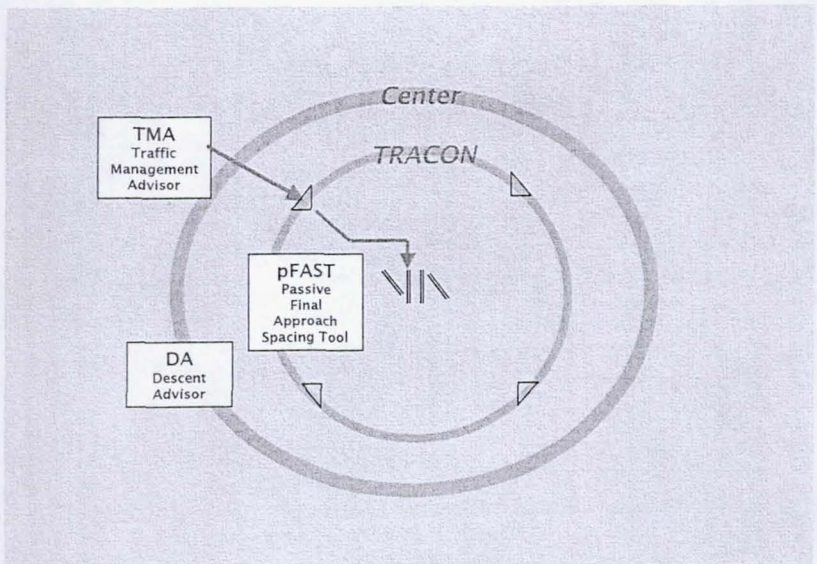
CTAS Concept (1)



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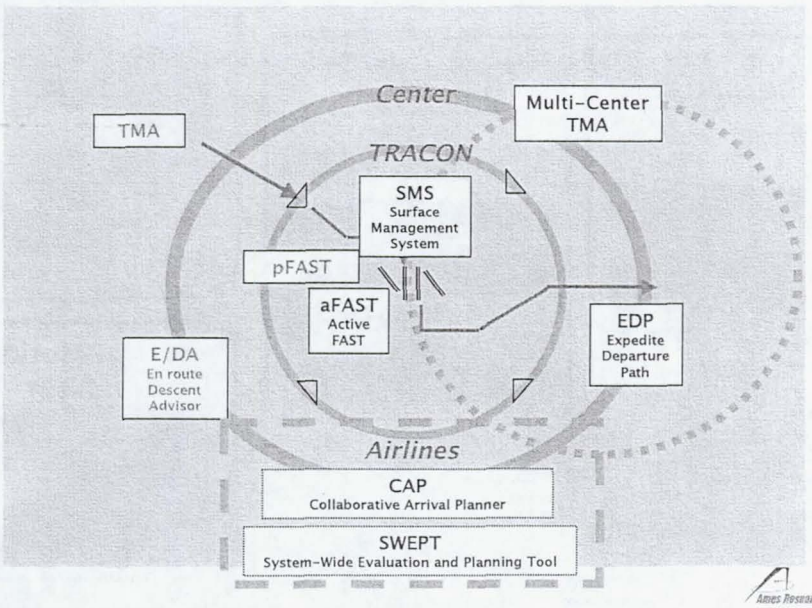
CTAS Concept (2)



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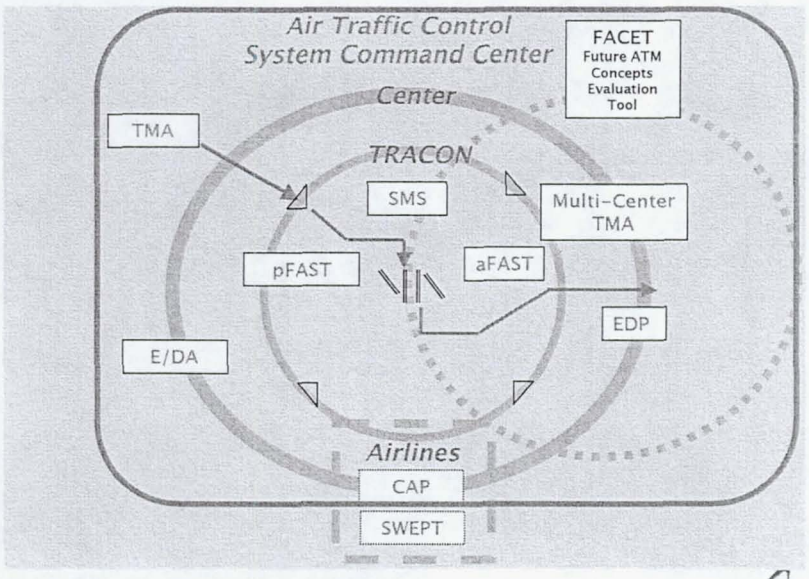
CTAS Concept (3)



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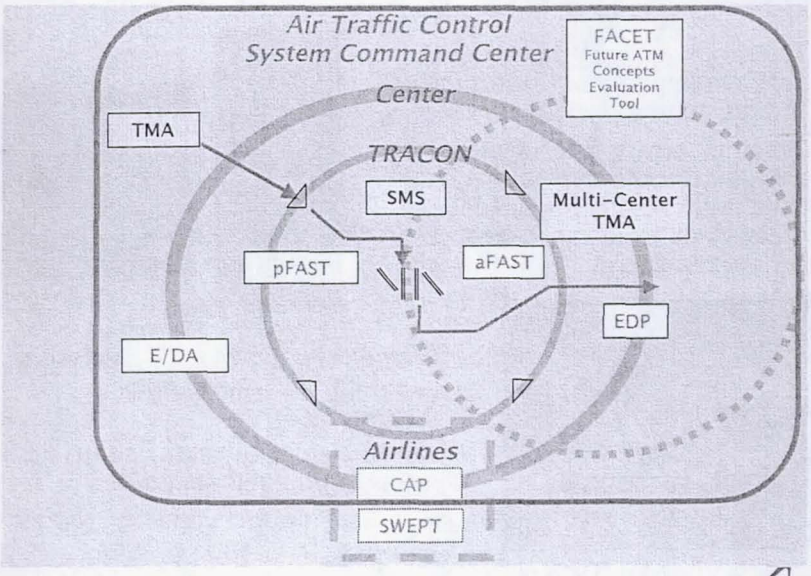
CTAS Concept (3)



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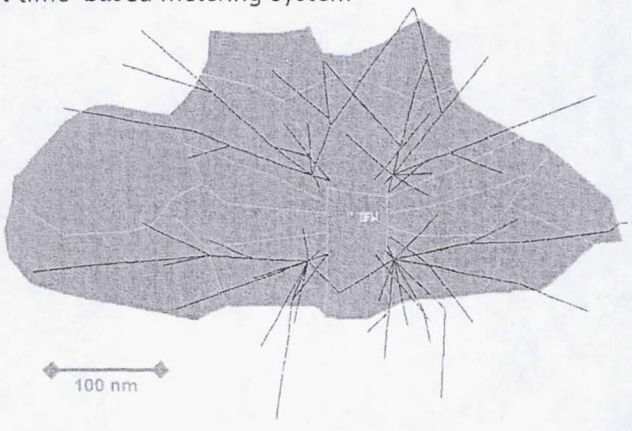
repeat?
slightly different - TMA, SMS, MCTMA are highlighted in yellow to indicate the focus of the rest of the talk

Traffic Management Advisor (TMA)

The Problem:

- Heavy traffic flows to a single major terminal area/airport leading to delays
- Inefficient miles-in-trail spacing methods
- Inefficient time-based metering system



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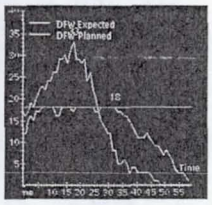
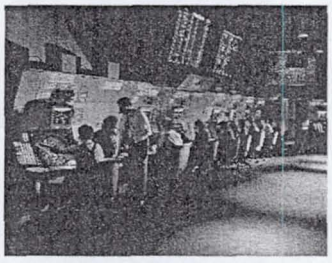
The TMA Solution

- Decision-support tool used by traffic management coordinators and enroute air traffic controllers.
- Develops a safe and efficient arrival schedule that meets, but does not exceed, the specified capacity of the airport, and minimizes delays.

TMA timeline



TMA traffic load graph



TMA in use at Denver TRACON

- Provides traffic flow visualization capability for traffic flow management.
- Advises enroute sector controllers of the optimized schedule.
- Increases airport capacity, reduces arrival delays, and reduces controller workload.

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Current TMA Operational Deployment

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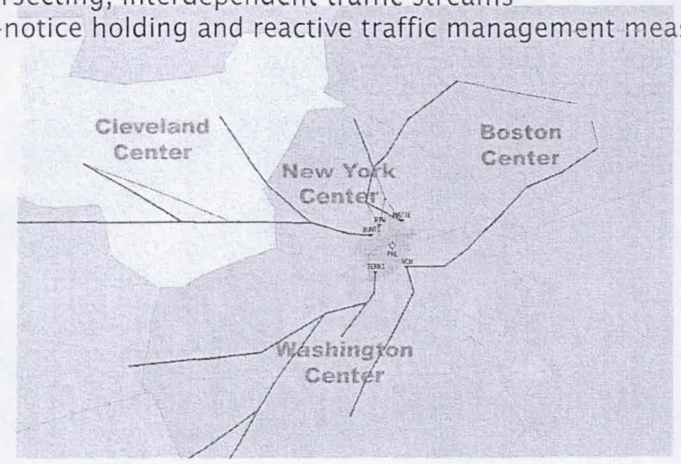
Multi-Center TMA (McTMA)

The Problem:

- Multiple facilities involved in traffic management
- Intersecting, interdependent traffic streams
- No-notice holding and reactive traffic management measures



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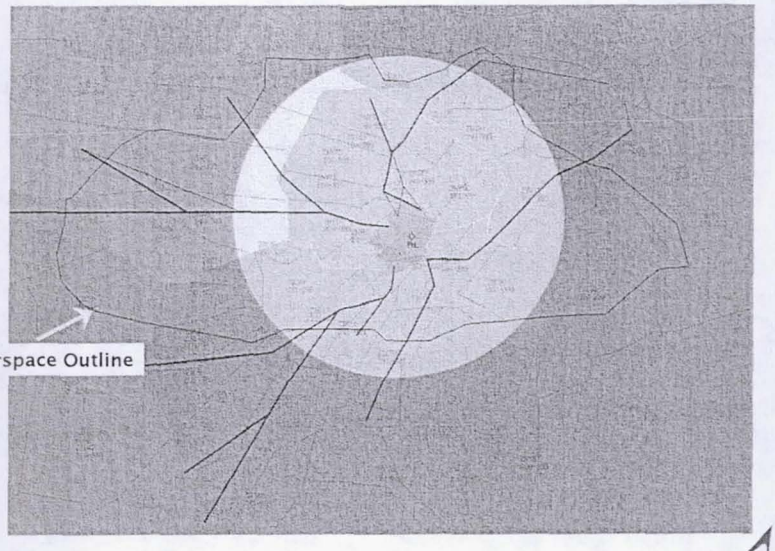
Conventional Metering Horizon



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Philadelphia Arrival Flows

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McTMA Solutions

- Extendable, flexible system architecture to link traffic predictions and schedules between facilities
- Distributed scheduler to provide robust scheduling for the entire system while preserving facility independence to address local traffic problems
- Enables inter-facility collaboration to manage arrival traffic
- Provides a generic scheduling solution for the NAS

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McTMA Accomplishments

- Developed new capabilities tested both in simulation and in the field
- Field evaluation at four ARTCCs, Philadelphia TRACON, and the Air Traffic Control System Command Center (November 2004)
- Demonstrated favorable performance of the new algorithms
- Working with the FAA to merge McTMA functionality into its existing operational baseline
- Anticipated rollout of new McTMA system to key test-sites in 2006
- Eventual deployment of "new" TMA (with McTMA functionality) to all current Single-Center TMA sites
- Estimated benefits: $70M savings for PHL, New York and Washington, DC airports (Potential of $200M/year in 2010, and $370M/year on 2015)

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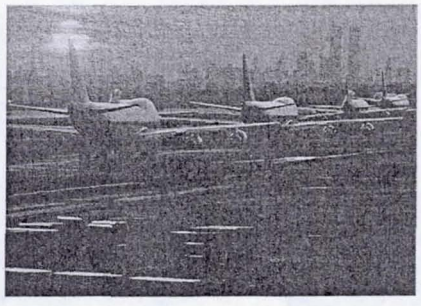
Surface Management System (SMS)

The Problem:

- Ground operations bottleneck
- Different user groups impact the surface operation
- Departure planning on the surface is reactive and very manual
- Runway capacity is a limitation for many airports



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SMS Solution

SMS is a decision aid to Tower controllers and airline surface operators to effectively manage ground congestion at ramps, taxiways and runways.

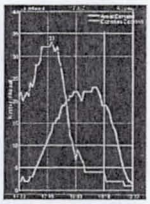
ETMS

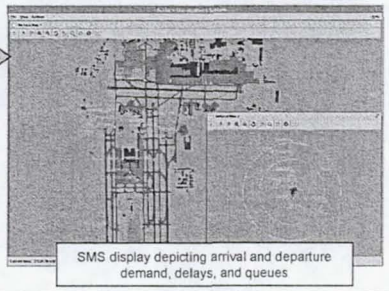
Pushback Times,
Flight Plans,
EDCTs,
Airborne Surveillance,
Parking Gates

SMS

Surface Surveillance

Displays for Traffic Managers and Airline Ramp Coordinators





SMS display depicting arrival and departure demand, delays, and queues

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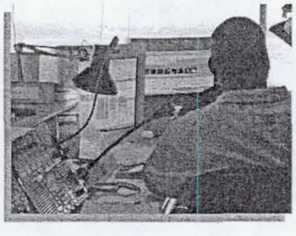
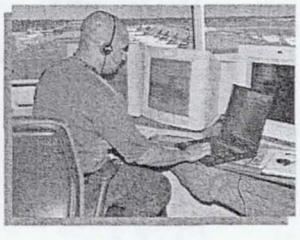
SMS Accomplishments

- The SMS project has worked closely with Fed Ex and Northwest Airlines at Memphis Airport to develop and test concepts and functionality.
- Operational demonstrations at Memphis Tower, TRACON, and Center and integration of SMS with the FAA's SafeFlight 21 Program and UPS operations at Louisville Airport were completed.
- Information provided enables Tower and Airline operators to reduce taxi delays, reduce fuel costs, and improve predictability of take-off times
- **Estimated annual benefits to the airlines of $315M/year NAS-wide**





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