Air Traffic Management Research and Development Overview: The US Perspective

Presentation to the First USA / Europe ATM R&D Seminar
17 June 1997

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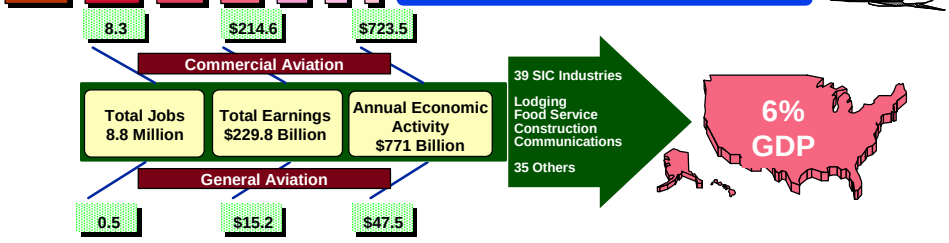
Outline of Presentation

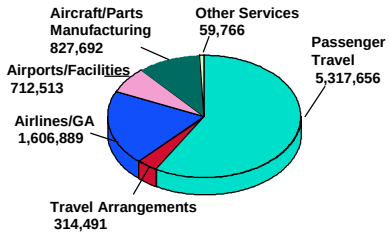
- **Context and Drivers for ATM Research and Development**
  - **Operational**
  - **Systems and Technology**
- **Emerging and Evolving Solutions**
  - **Operational Concept for 2005**
  - **National Airspace System Architecture**
- **US ATM Research and Development**
  - **Approach**
  - **Research Thrusts**
  - **Processes**
- **Key Research Areas**
- **Conclusions**

Aviation: A Critical Element of US Economy



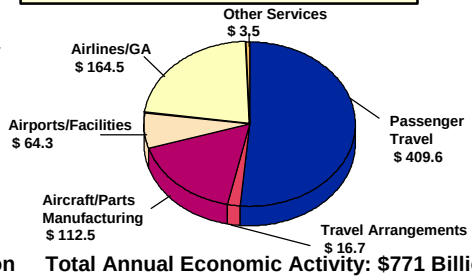
*Includes "Multiplier Effects" based on the U.S. Department of Commerce Input/Output Model

... Creates Jobs



Total Aviation Related Jobs: 8.8 Million

... Generates Economic Activity



Total Annual Economic Activity: $771 Billion

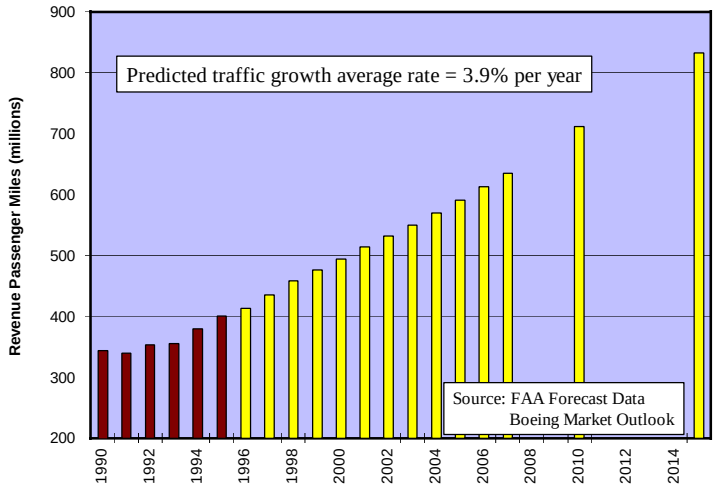
1. Source: "The Economic Impact of Civil Aviation on the U.S. Economy, Update 1993," Wilbur Smith Associates, April 1996. Constant Dollar values escalated from 1993 to 1996 using OMB specified inflation factor of 1.085

Why is Change Needed?

- In early 1990's airlines recorded record losses
- The Air Transport Association estimated cost of delays at magnitude of $3.5B per year - some unavoidable and some avoidable
- National Committee to Ensure a Strong Competitive Airline Industry (August 1993 report)
  - "...In the history of American business, there has never been a major commercial industry whose minute-by-minute operating efficiency was capped by the daily operating efficiency of the federal government - except for the airlines."
  - "...the outmoded air traffic control system is costing airlines and consumers billions of dollars each year in delays, and it badly needs to be modernized."
- Growing recognition that the Air Traffic Management system was not making significant progress toward taking advantage of advances in communications, navigation, surveillance and computing technology

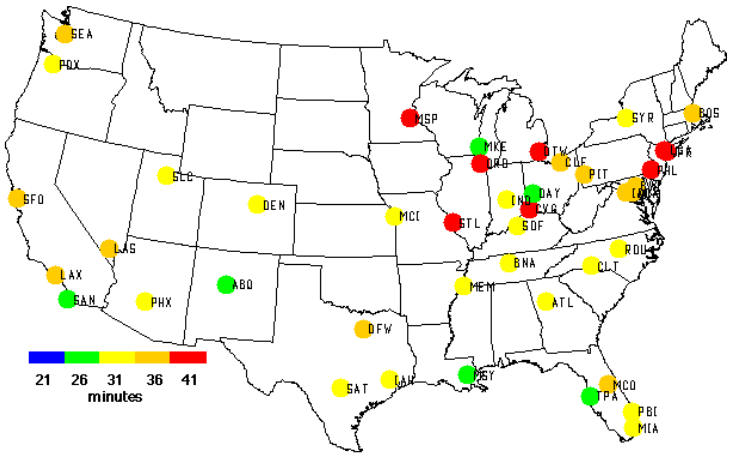
Why is Change Needed?

Projected Traffic Growth (1996-2015)
Domestic U.S. Carriers Only



Why is Change needed?

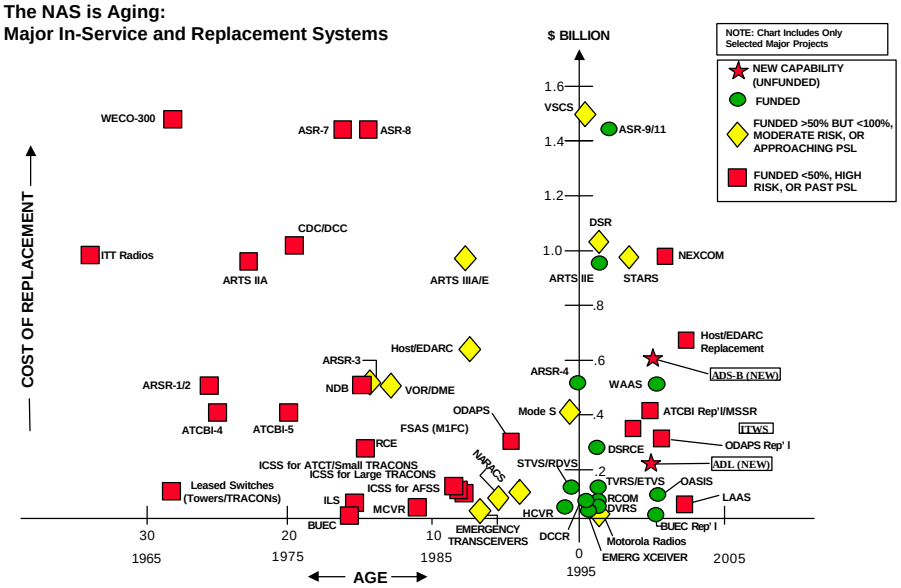
Mean Descent Times from FL290 - FL410
Nov 20, 1996 ETMS data



Why is Change Needed?

(1)

The NAS is Aging:
Major In-Service and Replacement Systems

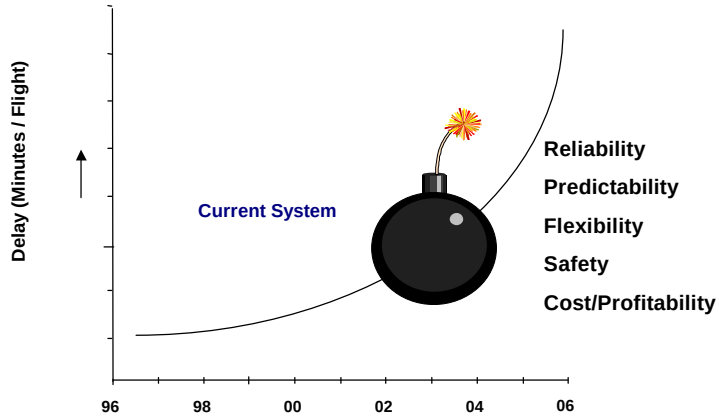


Why Change is Needed?

- **The NAS is large and complex**
  - **5400 public-use airports (18,000 total)**
  - **470 Airport Traffic Control Towers**
  - **177 Terminal Radar Approach Control facilities**
  - **21 Air Route Traffic Control Centers**
  - **Serving international air transport, general aviation (175,000), Military (15,000) aircraft**
- **Over 34,000 items of maintainable equipment in the NAS**
  - **Radars, communications, nav-aids, computers, radios...**
- **Average age of major equipment is 20+ years**
- **Average age of major facilities is ~30 years**
- **The NAS has experienced instances of system outages due to equipment failures, with projected increases in occurrence, and expenditure of scarce funds in stopgap measures**
  - **Risk of absorbing resources needed for new advances in ATM just to maintain current capabilities with "new" equipment**

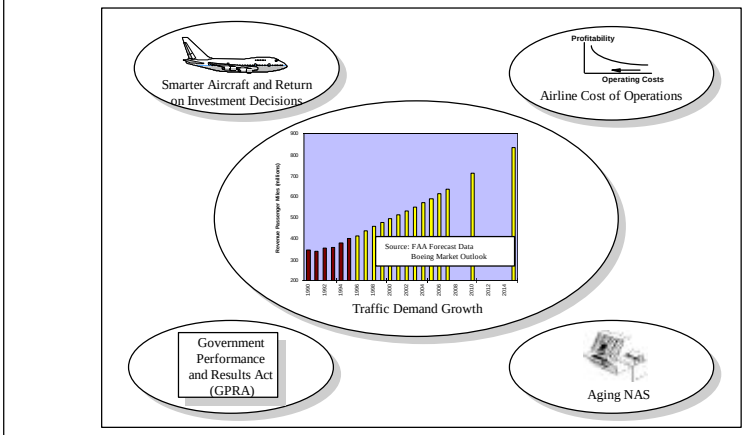
Why is Change Needed?

Traffic growth with constrained capacity will increase delays and reduce predictability --- endangering scheduled operations



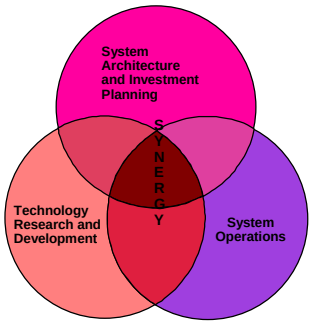
ATM Research Must be Responsive to the Problems of Today ... and Tomorrow

Key Drivers for ATM Solutions

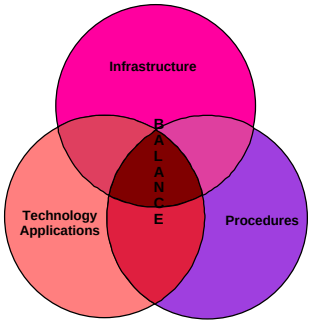


Enhancing Air Traffic Management

Interrelated Needs



Solution Set



Key Characteristics of the CONOPS/NAS Architecture

- **Implement Free Flight objectives**
- **Safety remains #1 priority**
  - **Increase capacity, optimize efficiency, improve productivity**
- **Separation assurance remains responsibility of service provider**
  - **Increased occasions in all phases of flight for transfer of separation assurance to flight deck**
- **Increased collaboration amongst users and service providers for planning and strategic problem resolution**
  - **Distributive decision-making; service provider/flight operations/cockpit**
- **Decision support tools, including expert systems, increase efficiency and ability to give users flexibility**
- **Separation standards reduced to take advantage of new technologies and aircraft characteristics**
  - **May vary based on factors such as aircraft type or traffic situation**

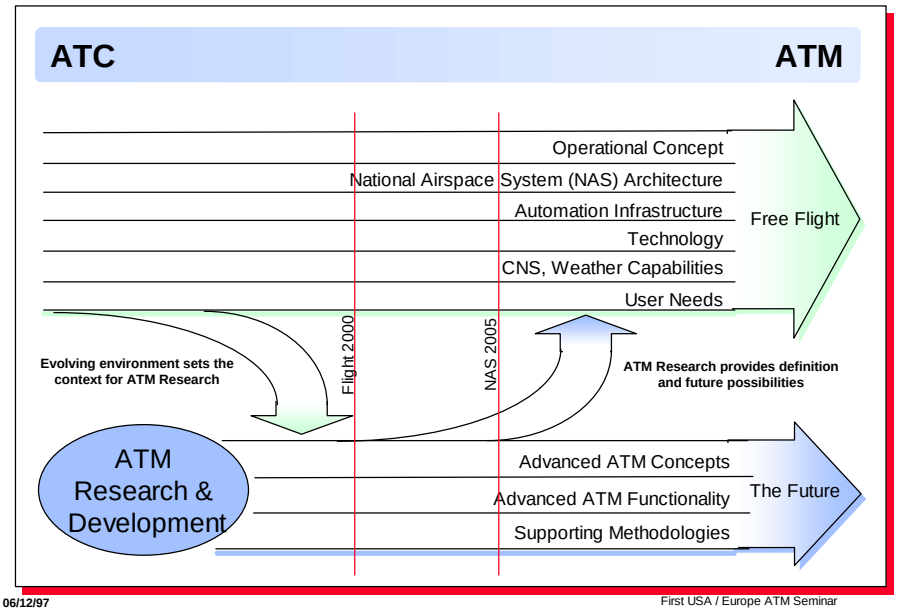
Key Characteristics of the CONOPS/NAS Architecture

- All NAS users have continuous, real-time access to information
  - NAS-wide information system and electronic data exchange
  - NAS status, SUA, weather,...
  - Cockpit and ground
- Dynamic air traffic control sector boundaries
- Paperless flight information displays
- Expansion of flight plan into *flight object*
- Common automation infrastructure and applications for tower, terminal, en route and oceanic operations

Key Characteristics of the CONOPS/NAS Architecture

- Communications incorporates digital technology for voice and Data Link
  - All-digital communications interfaces and backbone circuitry
  - Transition closely linked to air carriers and communications providers
- Navigation employs augmented Global Positioning System (GPS) as NAS-wide sole means navigation/landing system for increased accuracy and economies
  - Portions of ground-based navigation infrastructure maintained beyond 2005, but no later than 2010
- Surveillance becomes satellite-based using GPS and cooperative dependent techniques for greater accuracy and economies for both airborne and ground needs
  - Distributed, multi-sensor processing surveillance architecture
  - ADS-B replaces secondary radar, primary radar serves as a backup
  - Air-air separation, collision avoidance, situational awareness
- New or modified avionics required to support the NAS Architecture and new operational concepts

ATM R & D Environment



The ATM Research Program in the US

Responsive

Changing Paradigm

Air Traffic Management

ATM
(Air Traffic Management)
- ensure safe, efficient movement of air traffic

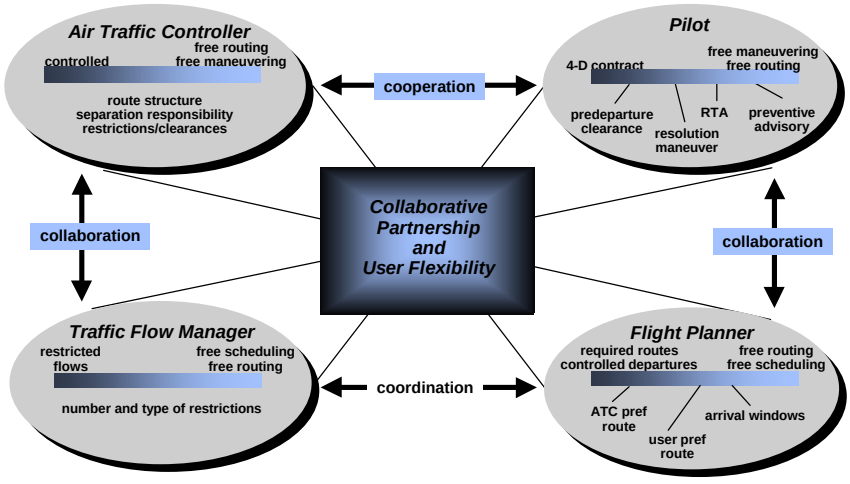
ATC
(Air Traffic Control)
- assure aircraft separation
- enhance safety

TFM
(Traffic Flow Management)
- ensure efficient, equitable, effective air traffic flows
- enhance system effectiveness

Users
Planning and Dispatch
- manage airline operations
- schedule flights

Airborne

Perspectives on Principles



ATM R & D - Mission and Outcomes

Mission: Provide automated air traffic management (ATM) tools and procedures that support user and service provider needs to improve system capacity, safety and performance, reduce delays, and maximize the flexibility and efficiency of gate-to-gate operations throughout the National Airspace System.

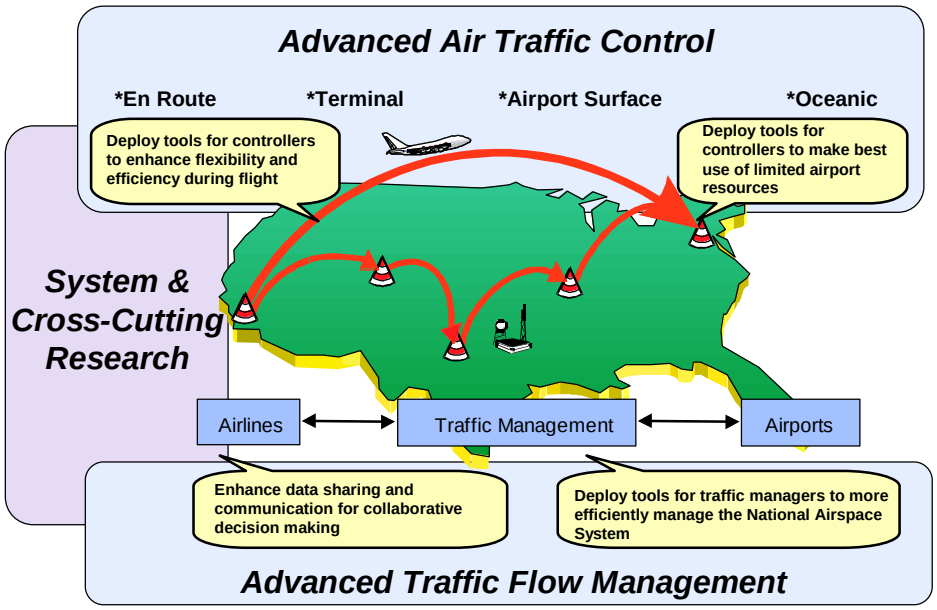
R & D Program Outputs:

- Advanced ATM Concepts
- Advanced ATM Functions
  - Air Traffic Control
  - Traffic Flow Management
- Prototype Systems
- System Assessments
  - Support technology & investment decisions
- Technology Transfer Packages

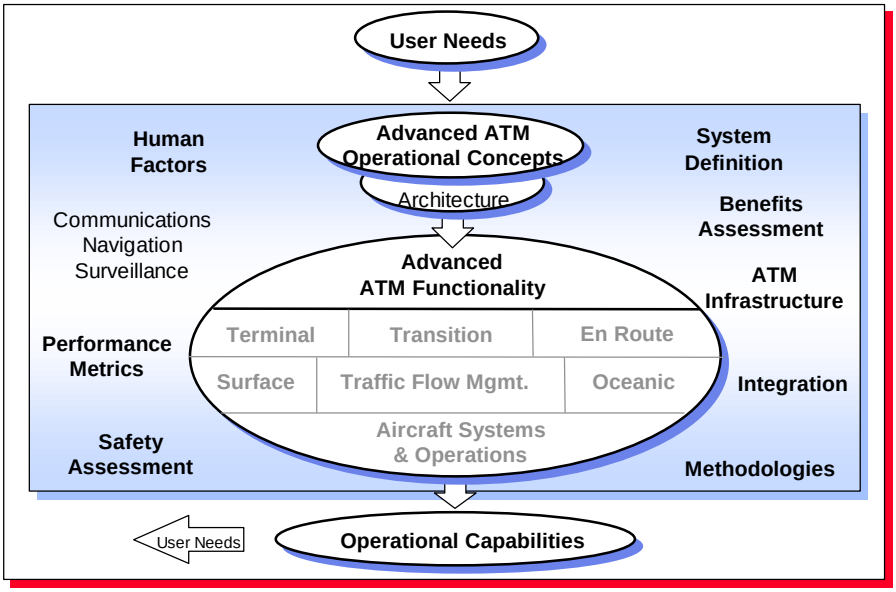
Outcomes:

- Improved Safety
- Improved Flexibility
- Improved Capacity Mgt
- Reduced Costs
- Reduced Delays
- Improved Access
- Predictability
- Evolutionary Improvement in Services

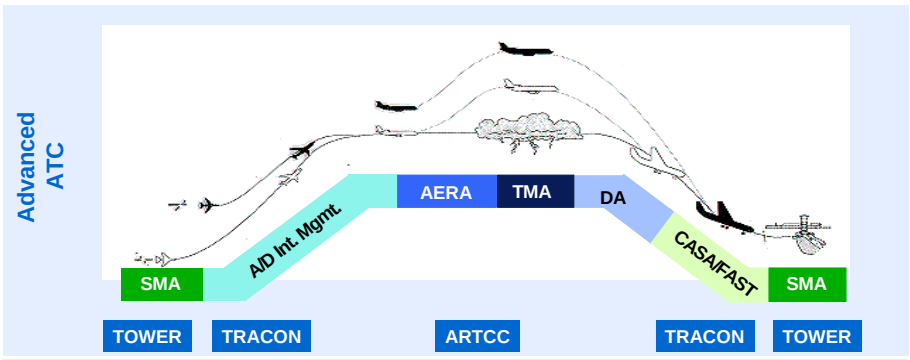
ATM R&D Program Areas



ATM Research Elements



ATM Research Focus: Integrated ATM Capabilities



Advanced TFM

ATCSCC

FAA/Industry Data Exchange (ASD, GDP…)	Decision-Support Tools for NAS Analysis	Collaborative Decision Making	CDM-Ground Delay Program (FSM, Ration-by-Schedule, Schedule Compression...)

TRACON: Terminal Radar Approach Control
ARTCC: Air Route Traffic Control Center
ATCSCC: ATC System Command Center
ASD: Aircraft Situation Display
NAS: National Airspace System
FAST: Final Approach Spacing Tool
FSM: Flight Schedule Monitor

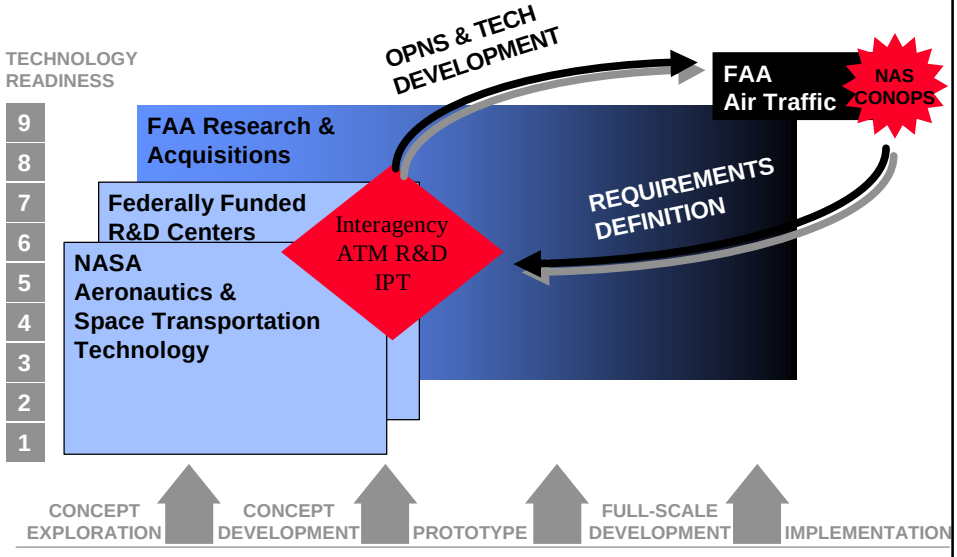
SMA: Surface Movement Advisor
A/D: Arrival/Departure
AERA: Automated En Route ATC
TMA: Traffic Management Advisor
DA: Descent Advisor
CASA: Controller Automated Spacing Aid
CDM: Collaborative Decision Making

ATM R&D Approach

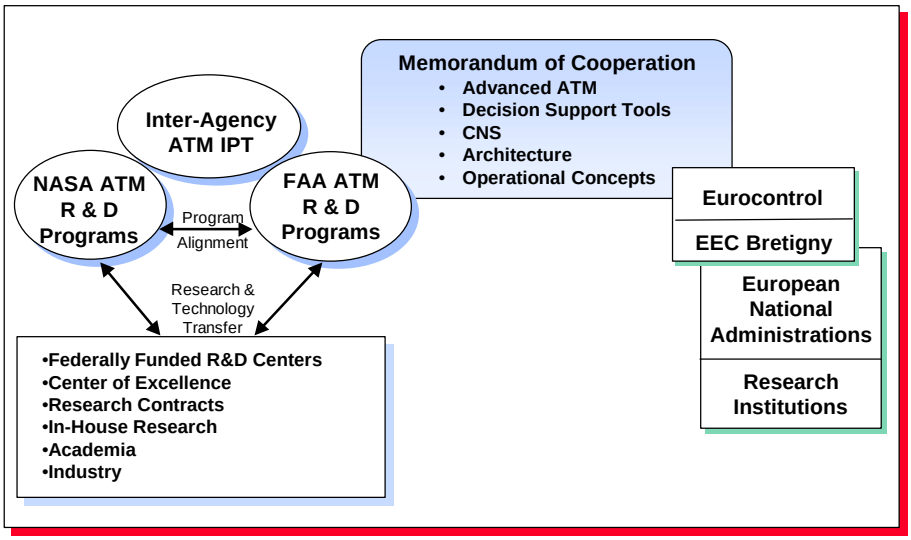
- Address opportunities for "low hanging fruit"
  - Procedures
  - Additional capabilities with minor infrastructure changes
- Implement mature capabilities already in the pipeline to achieve benefits
- Identify greatest opportunities for other improvements and focus future research there
- Determine sensitivity and applicability of solutions to different airspace, procedures, operations, traffic mix, aircraft equipage, time frames, etc. in <u>early</u> stages of research
  - May mean different solutions for different areas or time frames
- Recognize that the best "technical" solution may not be best "operational" solution for service providers or users
- Plan, develop, and implement in incremental steps to adapt to changing operational environment and technology advances

ATM R&D: The Interagency ATM IPT

INTEGRATED NATIONAL PROGRAM– *NOT JUST COORDINATED*– CONCEPT EXPLORATION THROUGH IMPLEMENTATION



ATM R&D Linkages



The ATM Research Program in the US

Key Areas of Research

Key ATM R&D Drivers and Goals

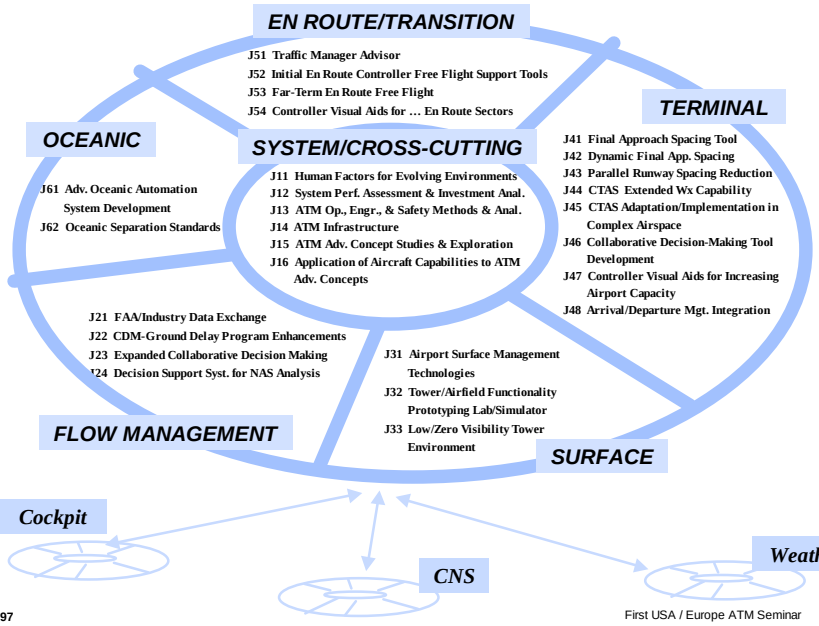
- FAA - Industry Free Flight Implementation Planning
- FAA NAS Modernization by 2005
  - Operational Concept
  - NAS Architecture
  - Flight 2000 Beta Site Evaluation
  - Political Backing (Gore and Minetta Commissions)
- User Requirements
  - Flexibility, Efficiency, Access, Safety
- FAA ATS Requirements
  - Productivity, Efficiency, Predictability
- Opportunities for System Improvements
  - Bottoms Up

Summary of ATM Research for Near Term Issues

- Information Exchange
- Collaboration for Decisions
- Accommodation of user preferences at all altitudes and all airspace regions
- Efficient merging of traffic into terminal areas
- Safe and efficient management of airport resources
- Demand/capacity prediction and “what if” modeling
- Air/Ground allocation of roles and responsibilities
- Analysis of system dynamics
- Transition / Evolution

Portfolio that addresses all areas to some extent, builds on past research, and emphasizes near-term payoffs

Integrated Research Areas & Research Projects



System / Cross - Cutting Key Research Areas

• **Advanced ATM Concept Studies and Exploration** – **Evaluate feasibility and benefits of concept elements: Free Scheduling, Free Routing, Free Maneuvering, and other RTCA recommendations.** – **Specific system/cross-cutting research supporting RTCA Task Force 3 recommendations**	Exploration of operational and technical issues for use of FMS capabilities for approaches Terminal airspace arrival/departure management leading to definition of next steps and/or development of procedures e.g.: Can capabilities currently under development be integrated to accomplish evolution? What is the operational concept for use of legacy systems? Assess feasibility of decreasing the 200 nmi radius restriction for NRP filing Develop operational concept and methodology/tools for "dynamic density" Assess the feasibility of transfer of separation responsibility to the aircraft Assess the further expansion of the NRP below FL290 Determine requirements for reduced en route horizontal separation standards
• **Human Factors Research** – **Flight Deck, ATC, Flight Deck / ATC integration**	Cockpit System Design, procedures, and training Guidelines to reduce system-induced human operational errors Impact of integrated air ground systems on flight crew and controller performance and situational awareness
• **System Performance Assessment and Investment Analysis**	Development of quantitative NAS performance measurement capability
• **ATM Operations and Engineering Methods/Analysis**	Development of tools to evaluate NAS system level performance
• **ATM Infrastructure**	Performance, portability, and inter-operability of COTS, and NDI components Data Architecture

Traffic Flow Management - Key Research Areas

• **Enhanced FAA/Industry Data Exchange**	Airport Configuration Information, NAS Status Information, and Dynamic SUA Information
• **Ground Delay Program Enhancements**	Flight Schedule Monitor Ration by Schedule Flight Substitution Simplification Schedule Compression Delay Management DSS Enhancements Control by Time of Arrival Probabilistic Flow Mgt. Initiatives
• **Expanded Collaborative Decision Making**	Initial Severe Weather Capability Collaborative Rerouting Interactive Flight Planning Advanced TFM concept exploration
• **Decision Support Systems for NAS Analyses**	Performance Assessment Capability Automated Problem Recognition Compliance Monitoring Capability Dynamic Density Monitor System Impact Assessment Advanced TFM Concept Exploration

Surface - Key Research Areas

• **Airport Surface Management Technologies**	Surface Movement Advisor (SMA) Builds Collaborative Departure Scheduling Gate to Gate Planning Cockpit Tower Integration Integrated arrival/departure management New Technologies Applications -- low-cost airport surface detection system and surface incursion technologies
• **Tower/Airfield Functionality Prototyping Laboratory/Simulator**	Develop a high-fidelity Surface Development and Testing Facility
• **Low/Zero Visibility Tower Environment**	Low/Obstructed Visibility Enhancement Develop a “Virtual Tower Cab”

Terminal - Key Research Areas

• **Multiple Runway Development Procedures**	Develop ATC procedures to reduce airport delays by more fully utilizing runway capacity during IMC
• **Wake Vortex Separation Standards**	Safely reduce separation standard leading to increased airport capacity
• **Aviation System Capacity Planning**	Develop an overall capacity strategy Conduct measurement and assessment of airports and technologies and development of tools
• **Controller Visual Aids for Increasing Airport Capacity**	Development of FMS/GPS operational procedures for use in terminal airspace – Can beneficial IFR triple approaches to non-parallel runways be achieved safely? – What controller automation aids are needed to support GPS/FMS routes in the terminal area where CTAS/FAST may not or not yet be available? – Can runway capacity be increased by decreasing the inter-arrival separation without resorting to a metering system?

En Route/Transition - Key Research Areas

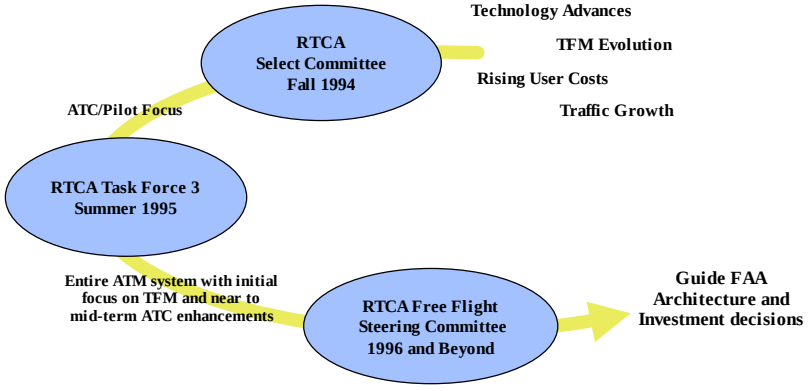
• **Initial En Route Controller Free Flight Support Tools** – **Conflict Probe on D-side**	Continued evaluations of capabilities and benefits Procedure definition Interfacility operations
– **Mid-term Conflict Probe (including automated resolution)**	What operational decisions and collaborative tasks will have to be supported by a conflict probe capability? aircraft trajectory modeling to support reliable detection of problems involving traffic, airspace, severe weather, and flow management constraints? What technical performance can be achieved with the conflict probe under field conditions expected in the ATM mid-term? Issues related to managing aircraft with different level of avionics equipage? Operational versus Mathematical Tradeoffs
• **Far Term En Route Enhancements**	Mid-term conflict probe capability affected by the mature free-flight concepts of alert and protected zones in the system of filters employed by the probe Optimization of conflict probe performance across the large number of ATM/CNS system and environmental variables How can emerging generations of FMS capabilities best support air/ground information sharing in a way that improves probe performance? How can ADS-derived position and intent information be best applied to optimize conflict probe performance? Separation assurance roles of ATM specialists and pilots in an era of reliable conflict probe operation?
• **En Route Controller Visual Aids**	Can TMCs take advantage of gaps in traffic using a simple automation aid and help in the facilitation of NRPs? Can a near-term automation tool increase the effectiveness of metering across center boundaries and merging flows during periods of peak traffic?

Oceanic - Key Research Areas

• **Advanced Oceanic System Development**	Develop a concept and necessary automation aids for conducting two-person sector operations Develop concepts/tools to enable controllers to allow reduced separation minima Assess application of new technologies (e.g., GPS/ADS-B) to enhance oceanic ATC operations Develop concept for information sharing and collaborative decisions to enhance efficiency of oceanic operations Develop oceanic Free Flight concepts/capabilities to evolve oceanic ATM to Free Flight
• **Oceanic Separation Standards**	Develop and coordinate reduced separation standards, including those necessary to enable Free Flight Perform top level hazard assessment of mid-term oceanic environment considering effects of increased automation aids Identify requirements and certification methods for further reduction of separation standards: coordinate with international community Conduct top level hazard assessments related to evolution to free flight concepts and automation tools

Free Flight: A Partnership

- **The FAA joined with aviation users in fall of 1994 to initiate development of consensus concept for "Free Flight" to be used as the Air Traffic Management concept in the U.S.**



The Path to Free Flight

Future ATM

Universal Two-way Data Link
Satellite-based Navigation and Surveillance
Automated Dependent Surveillance (ADS)
Collaborative Decision Support

Free Flight (all domains)

RVSM Domestic

Dynamic / Adaptive Sectors (Airspace)
Dynamic Use of Special Use Airspace

Separation Standards Reduction

Conflict Probe/Collaborative Resolution
Free Flight in Low Density areas

Procedures for RNAV/FMS

Collaborative Decision Making

RVSM Oceanic
FANS concept exploration

Limited En Route Free Flight
NRP Expansion and Improvement

Terrestrial-based Navigation and Surveillance
NAVAIDS
RADAR
Limited Decision Support

Current ATC

ATM: Air Traffic Management
FANS: Future Air Navigation System
NAVAIDS: Navigational Aids
NRP: National Route Program
RNAV/FMS: Area Navigation/Flight Management System
RVSM: Reduced Vertical Separation Minimum

Keys to the Free Flight Operational Concept

Removal of Restrictions

"...any removal of restrictions to flight is a move in the direction of Free Flight."

Flexibility

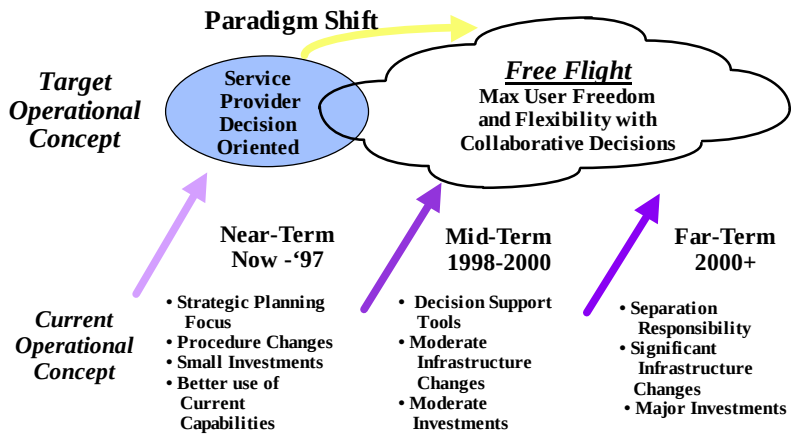
A National Airspace System that is adaptable to different equipage levels and changing user preferences

Collaboration

Involve users in making decisions that affect them to ensure their needs and desires are incorporated into the actions taken

Free Flight - Evolutionary Implementation

"Emphasis needs to be placed on what can be done *now* that will provide significant benefits at low cost and low implementation risk using proven technologies." - RTCA TF3 Final Report



Priority Capabilities for Free Flight

- **Collaborative Decision Making**
  - involves users in the decision making process to ensure their needs and desires are incorporated into the actions taken, and
  - provides capabilities for information exchange for all decision makers to have a shared view of the situation
- **Conflict Probe**
  - allows users to fly their preferred routes, by
  - providing capabilities for en route controllers to safely and efficiently accommodate traffic that is not on structured routes
- **Traffic Management Advisor**
  - allows more efficient sequencing and spacing of arrival traffic, and
  - provides more accurate prediction of arrival times
- **Passive Final Approach Spacing Tool**
  - allows more efficient spacing of arrivals on final approach to the runway, to
  - provide a greater arrival rate
- **Data Link**
  - provides communication between the ground and the air, to
  - share information, enhance situational awareness, and reduce voice congestion for improved safety and efficiency

Flight 2000

- White House/Gore Commission mandate: Accelerate modernization of the NAS and move more rapidly towards Free Flight
- Flight 2000 initiative to evaluate an initial implementation of Free Flight integrated capabilities in Alaska and Hawaii beginning in 2000, as a step towards NAS modernization
- Involves equipping significant numbers of aircraft with new avionics required to participate, and integrating new capabilities and procedures into the operational environment

Flight 2000

- Purpose
  - Demonstrate safety and efficiency benefits
  - Evaluate CNS transition issues without requirement for mandate
  - Develop procedures to produce benefits
  - Certify new avionics and improve installation
  - Reduce risks for accelerated modernization
  - Develop controller and pilot tools for transition
  - Take the step beyond near-term procedural changes to make Free Flight a reality
- Program details are emerging from intensive planning effort
  - Three Parallel Tiers
    - « Initial Services (integration and demonstration)
    - « Evaluation Services
    - « Test Bed
  - An operational concept for Flight 2000 is being coordinated

Conclusions

Recap of Key Themes

ATM R&D Must be Responsive to the Problems of Today ... and Tomorrow

Keys to Free Flight

Removal of Restrictions
"...any removal of restrictions to flight is a move in the direction of Free Flight."

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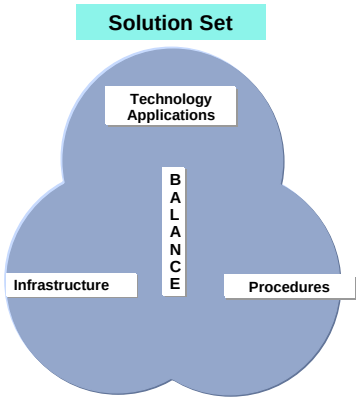

Opportunities

Common Problems?
Common Solutions?
Common Direction?

- **Identify and collaborate on areas where common solutions are critical to support international air transport operations across institutional or geo-political boundaries**
- **Identify and collaborate on areas where efforts are complimentary, research can be leveraged, and duplication of effort avoided**
- **Share information where unique problems mandate unique solutions**

Final Remarks (At Last!)

- **The ATM R&D programs of the Eurocontrol Organization, the European National Administrations, and the USA all have a lot to offer each other**
- **Cooperation and collaboration is key to building a global, harmonized ATM system**

Charge to Participants

Exchange ideas, information, and perspectives

Be open to new ideas, intellectual critique

Focus on how research can be applied in the real world

Actively participate throughout the sessions