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First Aviation System Technology Advanced Research (AvSTAR) Workshop

Ames Research Center, September 21-22, 2000

Workshop Organizer
Dr. Dallas G. Denery

Recording Secretary
Mr. Del W. Weathers

January 2001

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Preface

First Aviation Systems Technology Advanced Research (AvSTAR) Workshop

NASA Ames Research Center
September 21–22, 2000

A two-day NASA/FAA/Industry workshop was held at the NASA Ames Research Center, located at Moffett Field, Ca, on September 21-22. The purpose of the workshop was to bring together a representative cross section of leaders in air traffic management, from industry, FAA, and academia, to assist in defining the requirements for a new research effort, referred to as AvSTAR (Aviation Systems Technology Advanced Research). AvSTAR is being planned by NASA in cooperation with the FAA.

The AvSTAR Program has two distinct components: one that addresses the technology and research needed to support the requirements over the next several years, and one that addresses longer-term needs of the ATM system. The program also includes an effort to develop the modeling and simulation capability required to evaluate these concepts at the requisite level of fidelity.

The stated goals of the AvSTAR effort are:

1) Accelerate the development of selected NASA ATM technologies that have been identified by industry and FAA to improve the capacity and reliability of the current system over the next several years, and
2) Provide the foundational research and long term exploratory investigations for the air transportation system of the future.

The workshop was organized to first provide the participants with a brief summary of NASA's and FAA's initial AvSTAR planning. This was followed by two panels composed of a representative cross-section of industry leaders to obtain industry views on the primary challenges facing the nation's ATM system. The first panel addressed the requirements for "Tomorrow's ATM System" and was chaired by Mr. Raymond LaFrey of Massachusetts Institute of Technology (MIT) Lincoln Laboratory. The second panel addressed the needs of the "Future Air Transportation System" and was chaired by Professor John Hansman of MIT. The purpose of the panel presentations was to set the stage for three breakout sessions that were designed to engage industry participation in the planning process. The breakout sessions formed the heart of the workshop.

The purpose of this report is to summarize the workshop recommendations and discussion. The workshop participant list can be found in Appendix 1.

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Workshop Summary

Dallas G. Denery, National Aeronautics and Space Administration
Raymond LaFrey, Massachusetts Institute of Technology Lincoln Laboratory
John Hansman, Massachusetts Institute of Technology
Hugh McLaurin, Federal Aviation Administration

The United States air transportation system is on the verge of gridlock, with delays and cancelled flights reaching all-time highs during the past two years. As demand for air transportation continues to increase, fueled by a strong economy and e-commerce, the capacity of the air traffic control system needed to accommodate the expected growth in traffic is falling farther and farther behind. To meet these challenges, the Government, working with industry, has initiated several programs. For the near term, NASA has developed a portfolio of software tools for air traffic controllers, called the Center-TRACON Automation System (CTAS), that provides gains in capacity and efficiency. The Federal Aviation Administration is deploying CTAS tools as well as other tools at many airports and regional control centers around the country to help meet the near-term increases in capacity as part of its Free Flight Program.

While these improvements will provide relief over the next several years, they will not permit the levels of air traffic that are widely anticipated by the end of the decade. While we must continue to support these enhancements, the nation must begin laying the foundations for new technologies and procedures that will meet our air transportation needs for the future.

As a result of these concerns, NASA has begun planning a new research program called AvSTAR. AvSTAR is being designed to address the needs of the aviation component of an inter-modal transportation system. Within this context, AvSTAR will support the research and development required to:

- Develop the tools and modeling capabilities required to assess the requirements of an advanced air transportation system
- Conduct system-level assessments of new capabilities for air traffic management
- Develop the core technologies required to complete the goals of the Free Flight Program initiatives and set the foundations for the air transportation system beyond the Free Flight Program as currently defined.

A NASA workshop was recently held to initiate a national AvSTAR partnership with industry. The workshop began with an overview that included:

- A summary of the government's overall strategy for addressing the country's future requirements for air transportation, the "Air Transportation System After Next".
- An overview of NASA's and FAA's initial planning within AvSTAR that included a description of the research needed to complete the Free Flight Program, referred to as "Tomorrow's ATM System", and a description of the research to define the requirements

for the air transportation system beyond the Free Flight Program, referred to as "The Future Air Transportation System".

- Two industry panels that presented views on the primary challenges facing the nation's ATM system. The first panel addressed the requirements for "Tomorrow's ATM System". The second panel addressed the needs of the "Future Air Transportation System". A vision of the future air transportation system was also presented.
- Breakout sessions designed to engage industry participation in the planning process. The breakout sessions formed the heart of the workshop.

In summary, the workshop participants expressed great enthusiasm for AvSTAR and appreciation to NASA for involving the community in the program planning process. The participants welcomed the idea of a national partnership and expressed strong interest in having a continuing opportunity to participate in the planning process.

The seven program elements identified in the program under "Tomorrow's ATM System" were believed to encompass the needed steps to fill the gaps and augment the steps to achieve the goals of the FAA's Free Flight Program. The participants did not identify any obvious missing elements.

The participants were equally supportive of the investment in laying the foundations for the future system. They were unanimous in their view that the challenge for the future is real and that there is a need for AvSTAR to deliver now in order to meet that challenge.

There was broad consensus that the research for both "Tomorrow's ATM System" and the "Future Air Transportation System" needed to be supported, but also a strong caution that the investment in the future must be protected from encroachment due to near-term pressures. Two other major topics of discussion involved the need to increase the awareness of the problem at the national/federal level, while at the same time properly managing expectations.

Other recommendations, organized by area, follow:

Systems Engineering

There was consensus on the need to assure that new capabilities or automation tools are compatible with the evolving ATC system and fit together into an overall system architecture. A number of participants believed that NASA could increase its success in developing ATM "tools" by further improving how these tools are integrated into ongoing ATC operations without being operationally disruptive.

Information Flow Analysis

Some workshop participants felt that the ATC system should be thought of as an information exchange problem. It was suggested that NASA examine "Information Technology" processes to see what can and should be applied to the ATC problem.

Development of Models

Most workshop participants also recommended that NASA develop a simulation/modeling capability for understanding the needed improvements in ATC operations and assessing the performance of the system with the insertion of a new capability. They observed that the continued development of decision support tools, in the absence of such an understanding, is not likely to lead to a substantial improvement in airspace capacity.

Weather

The participants stressed the importance of proper use of weather information in air traffic management decision making. The current ATM tools do not take advantage of recent advances in weather forecasting skills and it is possible that they could actually lead to increased delays. Proper accounting for weather within ATM systems and in the cockpit over all time horizons must be a priority.

Dynamic Resectorization – Dynamic Flow Structure

The workshop participants agreed on the need for a tool to re-allocate airspace and approach fixes in response to operating conditions, weather, capacity, traffic flow, etc. It was generally agreed that the current "fixed" structure of the ATC flows is capacity limiting, and a tool to dynamically change that structure for en route operations should be considered. Associated with this is a consideration of noise profiles, which will likely limit the universal application of such a tool in the terminal area.

Safety of Air Traffic Management Systems

There was a strong consensus for an assessment of the safety implications associated with the introduction of new automation and/or procedures. The safety assessment should include redundancy and recovery operations.

Automation

As we move beyond the Free Flight Program, there will be a need to move to a greater level of automation. The actual form of this automation is not fully understood, but may result in a significant change in the role of the controller. This topic occupied much of the discussion within the "The Future Air Transportation System" breakout session.

A more complete list of specific recommendations can be found in section 8 of this report, "Breakout Session Summaries".

Agenda

First Aviation Systems Technology Advanced Research (AvSTAR) Workshop

Ames Research Center
Moffett Training and Conference Center
Ballroom
September 21–22, 2000

First Day

08:00 A	Introductions/Agenda	D. Denery
08:15 A	Opening Remarks	R. Rosen
08:30 A	Air Transportation System after Next	R. Pearce
09:00 A	AvSTAR	D. Denery
10:00 A	Break	

Panel Discussions

10:15 A Panel 1: Tomorrow's System

- R. LaFrey (Chair), MIT Lincoln Laboratory
- R. Morgan, FAA
- R. Wall, Federal Express
- A. Haraldsdottir, The Boeing Company
- J. Evans, MIT Lincoln Laboratory

11:30 A Lunch

12:00 P A Vision of the Future — H. Erzberger

12:30 P Panel 2: Future Air Transportation System

- J. Hansman (Chair), MIT
- R. Morgan, FAA
- R. Spitzer, The Boeing Company
- J. Jackson, Honeywell, Inc.
- R. Stone, United Air Lines
- C. Billings, Ohio State University
- R. Golaszewski, GRA
- G. Donohue, George Mason University

01:45 P Break

02:00 P	Breakout Sessions	

	Tomorrow's ATM System Breakout Session:
	Chair, R. LaFrey
	    Terminal/Surface:
	    Industry Chair, R. Wall; NASA Co-Chair, T. Davis
	
	    En-route, TFM, and ATM/TFM Weather Integration:
	    Industry Chair, R. Kelly; NASA Co-Chair, B. Sridhar	

	The Future Air Transportation Breakout Session: Industry Chair, J. Hansman; NASA Co-Chair, K. Roth	

Second Day

08:00 A	Continue Breakout Sessions	
09:00 A	Breakout Session Summaries	
	Tomorrow's ATM System	R. LaFrey
	Terminal/Surface	R. Wall
	En-route, TFM, ATM/TFM Weather	R. Kelly
	Future Air Transportation System	J. Hansman
10:00 A	Discussion	All
10:40 A	Next Steps	D. Denery
12:00 P	Adjourn	

1. Opening Remarks

Robert Rosen, Associate Director for Aerospace Programs
NASA Ames Research Center

Dr. Robert Rosen provided the welcoming on behalf of Dr. McDonald, the Director of NASA's Ames Research Center, and made a few opening remarks. First, he thanked the participants for taking the time in helping us put together a program plan that will benefit the country. He then provided a brief discussion on the background of the AvSTAR program.

Key Comments by Dr. Rosen

In the recent past the aviation community has had considerable success in getting the first generation of decision support tools into the National Airspace System, Free Flight Phase 1. This success has led to our regaining some external credibility. However, even though these tools will provide a measure of relief in reducing ATM delays from what would have occurred without them, the studies we have all seen show that we are still faced with a serious problem. The improvements we will achieve from the implementation of the FAA's Free Flight Phase 1 (FFP1) and Free Flight Phase 2 (FFP2) tools will shortly be overcome by increased demand, and delays will again be at unacceptable levels.

The situation is actually worse than it seems on the surface. Not only will delays increase, but also there is no real ongoing research that can lead to significant additional capacity in this timeframe. So the country is doing nothing to alleviate the problem. NASA funding in its base program for ATM research was rightfully moved some time ago to support the Advanced Air Transportation Technology Program (AATT) and initiation of the Aviation Safety Program. Also, while there are considerable funds in AATT, they cannot be diverted because they are fully committed. So a new program is needed which will provide the technology for this future system. This program is AvSTAR.

NASA, working internally, has put together an initial framework that will form the basis for what is reviewed in this workshop. This has been briefed to a small number of people and, based on the comments we have received, we are convinced that we are on the right track. What is now needed is the broader aviation community's input to build on the framework. That's what the workshop is all about—to engage the community in helping us make AvSTAR into as valuable a program as possible. A critical part of gaining Administration approval is establishing industry support for NASA's effort. This can only be accomplished if AvSTAR is the right program.

2. Air Transportation System after Next

Robert Pearce, Director Strategy and Analysis
Office of Aerospace Technology
NASA Headquarters

A copy of Mr. Pearce's presentation is attached as part of Appendix 3 and is available on the ASC web site.

To set the stage for how NASA views its efforts in the future ATM environment, Robert Pearce presented NASA's top-level goals. His presentation was entitled "Transportation System After Next." Mr. Pearce started by discussing the need to establish the overall mission goals and to identify what research and development (R&D) programs are needed to support the achievement of those goals. He then briefly talked about the need to define the goals and the needs of the future system.

Mr. Pearce showed some world traffic demand forecast information for railways, buses, automobiles, and aircraft across 1960, 1990, 2020 and 2050 timeframes. There was discussion citing that some major challenges for any future transportation system would be an aging population, continued population pattern shifts, and increased international trade. He discussed a white paper in preparation that will describe future transportation trends, define the problems, identify the solution space (technical/operational leverage) at a top level with some detail on barriers and issues, provide a matrix of options for consideration, and discuss major uncertainties and questions. He stated that one of the critical questions is "How does the air transportation system fit into the total picture?".

Mr. Pearce then mentioned that improving the air transportation system will continue to have national urgency—since many analyses indicate that with continued growth, delay within the system will remain a critical factor. Next the need to address complexity was discussed—the air transportation system is extremely complex and displays the behavior of a non-linear, dynamic system. He pointed out that there are a large number of stakeholders within the system and showed two quotes from the Washington Post to support his position. He discussed that dealing with an urgent and complex problem with many stakeholders will have many potential solutions, some of which are not acceptable or economically feasible.

He emphasized the need to continue evolutionary technology development and implementation in the near-term while working the fundamental research and concepts for the long-term. He also pointed out that this requires high-fidelity testing to prove out concepts and technology. He stated that any program pursued must get buy-in from key stakeholders and mentioned that for advanced ATM concepts there will be a continuing need to protect the long-term efforts from being diminished to address the shorter-term needs.

He talked about strategies for moving forward and the need to continue support of Free Flight implementation through the development of automation aids. This could be achieved by aggressively pursuing system concept studies to develop overall system architecture options that can be operated at higher capacities. There will be a need to develop a large-scale, non-linear simulation capability for the air transportation system to better perform trade-off analyses for technology and advanced concepts. Mr. Pearce concluded by stating that there is a growing recognition for the need for dramatic changes in our transportation system to meet the mobility needs of the nation. Aviation is the key for the growing demand for rapid transportation.

3. AvSTAR Overview

Dallas G. Denery
Deputy Chief, Aviation Systems Division
NASA Ames Research Center

A copy of Dr. Denery's presentation is attached as part of Appendix 3 and is available on the mentioned web site.

Dr. Denery gave an overview the AvSTAR effort. He made the point that the presentation included advocacy material as well as initial thinking on program content and that he was looking to the group to help in building as compelling a case as possible as well as improving the technical content.

Key Comments by Dr. Denery

Background [vg 2-9]

Dr. Denery began by pointing out that the program planing began in the spring of 2000 and has involved Ames, Langley and Glenn Research Centers and the FAA. He mentioned that he had reviewed the planning with a few individuals within industry but that this workshop was the first opportunity to bring industry into the planning process in a major way.

The air transportation system is on the verge of gridlock, with delays and cancelled flights this summer reaching all time highs. As demand for air transportation continues to increase, fueled by a strong economy and e-commerce, the capacity of the air traffic control system needed to accommodate growth in traffic is falling farther and farther behind. NASA, working with the Federal Aviation Administration and industry, is pursuing a major research program to develop air traffic management technologies that have the ultimate goal of doubling capacity while increasing safety and efficiency.

The current system has several constraining factors that set fundamental limitations on capacity and safety. For the near term, NASA has developed a portfolio of software tools for air traffic controllers, called the Center-TRACON Automation System (CTAS), that provides modest gains in capacity and efficiency. The Federal Aviation Administration is deploying CTAS tools as well as other tools at many airports and regional control centers around the country to help meet the near-term increases in capacity as part of the FAA's Free Flight Phase 1 program.

Numerous authorities believe this system, even with the improvements expected from Free Flight Phase 1 (FFP1) and Free Flight Phase 2 (FFP2), will not permit the growth in air traffic that is widely anticipated. A new architecture will be required. While NASA will continue to support FFP1 and FFP2 under the NASA AATT and AvSTAR programs, it is believed that we must begin laying the foundations for a revolutionary change in the way we operate the airspace system.

There is a growing consensus that the future air transportation system must provide seamless operations for all vehicle classes across all airspace for the purpose of movement of people and cargo. There is also general agreement on the immediate steps required to provide near-term relief (i.e., FFP1, FFP2 and related efforts). However, there is still considerable research and development required for completing the near-term goals and there is no research being conducted to support the longer-term requirements of the "Future Air Transportation System". Furthermore, we do not have the capability for evaluating the operational effectiveness of future concepts.

The Program [vg 10-11]

This problem provided the basis for the definition of the AvSTAR objectives.

- Complete the development of technology for tomorrow
- Provide the foundations for the future

In defining the program goals, it is recognized that AvSTAR is addressing only the aviation component of an inter-modal transportation system. The program goals/metrics are still notional and are provided as a departure point for further investigation. There are two studies underway to improve the goals shown in vg 10. These studies will also map the program content against those goals.

The program includes three elements: "Program Integration", "Tomorrow's ATM System", and the "Future Air Transportation System".

Program Integration [vg 10-11]: The "Program Integration" element is responsible for maintaining the concept of operations for both "Tomorrow's ATM System" and the "Future Air Transportation System" and for conducting system-level simulation. In the case of "Tomorrow's ATM System", the RTCA/FAA Concept of Operations is the guiding document. In the case of the "Future Air Transportation System", there will be a set of competing concepts of operations that will be defined and evaluated within the program. The "Program Integration" element will be responsible for coordinating this work with FAA and industry, defining the transition from "Tomorrow's ATM System" to the "Future Air Transportation System" and evaluating these concepts through system-level simulation.

To allow the FAA or NASA to perform evaluations of candidate future system architectures, NASA must be able to provide the ability to simulate the air traffic system components with a requisite degree of fidelity. Here the individual components of the system, such as ground operations, en route flight management, etc. would be integrated, in a modular manner, into candidate concepts of operation. Various system-wide assemblies of these components would be examined in order to develop accurate evaluations of the system attributes and deficiencies.

Past and present simulation environments at NASA include Future Flight Central, the Vertical Motion Simulator and Crew-Vehicle System Research Simulators, to name a few. NASA has extensive, and it is believed unique, experience in linking distributed simulators, computing centers and facilities into an integrated system. The Information Power Grid is an example of this capability. Numerous simulations have been performed at Ames integrating research flight simulators, air traffic control laboratories, and live air traffic information.

Tomorrow's ATM System [vg 12-21]: The goal of the "Tomorrow's ATM System" element of the program is to develop technologies to the point that the FAA can make a deployment decision. This is equivalent to a NASA Technology Readiness Level 6. It is expected that this part of the program will have a large industry involvement.

Based on RTCA recommendations and other analysis, the near-term challenges required to provide some relief include: 1) improving traffic flow management predictions and decision making, 2) removing restrictions across facility/sector boundaries, 3) reducing separation requirements in the terminal area and 4) eliminating surface congestion. These challenges are being addressed through the seven planned activities identified in vg 14 followed by more detailed discussion in vg 14-21. These activities are "Surface Congestion Alleviation", "Runway Productivity", "Arrival/Departure Decision Support Tools", "Integrated Airspace Decision Support Tools", "National Traffic Flow Management", "ATM/TFM Weather Integration", and "Runway Independent Aircraft Operations". These activities are building on work initiated in AATT and TAP Programs.

The Future Air Transportation System [vg 22-30]: The goal of the "Future Air Transportation System" element is to provide the foundations for the future air transportation system. This is equivalent to a NASA Technology Readiness Level 4. It is expected that this component of the program will include University as well as industry involvement.

Because the concept of operations for the future system is only notional, and because the capability for evaluating or assessing concepts that deviate from the current paradigm do not exist, this element of the Program must include three distinct activities: 1) System-Level Definition. 2) Methodologies and Understanding and 3) Candidate Breakthrough Concepts.

System-Level Definition: The System Level Definition must include a functional definition. architectural/infrastructure implications and interfaces with local transportation. It must also include an assessment of: 1) the system integrity, reliability and maintainability, 2) robustness to sub-system failure and 3) the transition from Tomorrow's ATM System. These capabilities and features will be evaluated through simulation at the requisite degree of fidelity.

Breakthrough Concepts: The candidate breakthrough concepts include:

- The introduction of automation for improved traffic management
- New technologies for quantum leaps in capacity/throughput at airports and in and around severe weather
- Infrastructure concepts including high bandwidth/high reliability communications

- Technologies for providing seamless operations for all vehicle classes including space operations and unmanned air vehicles.

The breakthrough concepts being considered in automation for improved traffic management (ATM Automation) and technologies for quantum leaps in capacity/throughput (Quantum Leaps in Capacity/Throughput) are expanded below.

ATM Automation: Limiting factors on capacity are the controller's ability to achieve separation requirements without an operational error, and the separation requirements themselves. To make a serious reduction in separations, it appears that we must consider ways of removing the controller from the responsibility of tactical control of traffic. The current approach to managing ever-increasing traffic density is to reduce sector size so that the number of aircraft that a sector controller team must deal with stays constant and the workload stays manageable. Unfortunately, this approach is close to its limit in high-density airspace such as the Northeast corridor. Any workload relief that may be provided by further reducing sector size is offset by increased requirements for inter-sector coordination. One approach that needs to be considered is to move away from sector-based control or to move towards "super-sectors" through ATM automation. This will require an automated conflict detection and resolution capability, thereby elevating the role of the controller to a system-level manager.

Moving away from sector-based control of traffic is a first step in achieving a real-time system-wide optimization capability. Success will require a continuous updating of decision making over all time horizons whereby weather, demand/capacity requirements, and other factors influencing traffic flow are accounted for probabilistically. The system will move away from the stratification of planning time horizons within the System Command Center, local flow-control, and sector control that characterize today's system.

The interaction between the human operator and a highly automated air transportation system is critical. The system cannot be designed under the assumption that the human will step in and revert to today's operation in the event of a failure. Nevertheless, since the human will still be responsible for system operation, the anticipated level of automation will require the development of a highly interactive computer-based monitoring and goal-setting capability that will assist the human in managing the system in responding to varying priorities and sub-system failures.

Quantum Leaps in Capacity/Throughput: The technologies shown here represent a first attempt at identifying some innovative solutions to the capacity problem. These and other concepts will be explored over the next year with the intent of down selecting based on benefits assessments and peer review to a few promising candidates for more detailed investigation. Some of the concepts being considered include:

- 'Meta-airport Operations'—This concept involves examination of the integration of airports in major metropolitan areas into a single meta-airport. Grouping of such airports are to be found in New York (Kennedy, LaGuardia, and Newark) and elsewhere. Given developments in safe, reliable and affordable inter-airport transportation such as tilt-rotors, helicopters and/or surface transportation, can the operations within these clusters of airports be integrated to provide increased regional capacity? Again, if significant benefits from such a concept could be demonstrated by simulation, it could provide the necessary impetus for a research program to develop the necessary high-reliability, affordable short-haul transportation vehicles.

- 'Closely Spaced Aircraft Takeoff and Landing' and 'Dynamically Reconfigurable Runway/Taxiway Location' Operations—These ideas are dependent on a solid paved airfield which could allow simultaneous group landing and takeoff of multiple aircraft, or allow arbitrary redefinition of the runway and taxiway configuration to meet specific demand/capacity requirements.

- 'Automated Zero-visibility Surface Movements' and 'Dynamic Virtual Ramp and Control Towers'—Tower functions would be performed remotely through virtual reality.

- 'Airport Robotics'—A limiting factor on airport capacity is aircraft turn around time. Improved airport operations through robotic baggage handling, fueling, food service, etc. may provide for a dramatic improvement.

- 'Non-Towered Airport Operation'—Under the "Small Aircraft Transportation System" (SATS) Program, NASA is exploring the airborne requirements for a revolutionary personalized air transportation system. AvSTAR will address candidate future air traffic management systems to accommodate this new class of vehicles.

Methodologies and Understanding: Although there are several modeling and simulation tools available to assess technologies for "Tomorrow's ATM System", none have the robustness or fidelity to reliably analyze the implications of the concepts being considered for the "Future Air Transportation System". The "System-Level Simulation" capability discussed above will serve to provide a means to evaluate new concepts, but new analytical tools, system and human performance models will be required to make effective use of such a capability. The genesis of such tools is beginning to emerge within the University community under NASA support, but has not yet reached the maturity required to analyze future air transportation system concepts.

Concluding Remarks [vg 31-32]

In summary, the program is designed to: (a) provide a set of technologies to NASA Technology Readiness Level 6 to meet the needs for "Tomorrow's ATM System" as is defined by the FAA/RTCA Free Flight Program and (b) to provide the foundations that can be used by the country in defining the "Future Air Transportation System". The latter will be achieved by investigating highly innovative concepts to the Technology Readiness Level 4.

The program is critical to the Agency's goal of providing the research and development to guide the nation's air transportation system into the Twenty-First Century. The program will build on the Aviation Systems Capacity Program and will address the country's future air transportation requirements for all vehicle classes including space operations, unmanned air vehicles and revolutionary personalized air transportation systems currently being explored within the SATS Program.

Questions/Answers

Q: Andres Zellweger: What is the relative investment between "Tomorrow's ATM System" and the "Future Air Transportation System"?

A: Dallas G. Denery; The program is still being defined. Based on an initial assessment, approximately 60% of the resources are being allotted to "Tomorrow's ATM System" and 40% to the "Future Air Transportation System". This split could easily change as we go into our next phase of planning based on industry comments/recommendations.

Q: Joseph Jackson: What is the program time frame?

A: Dallas G. Denery: AvSTAR is designed to be a five year program beginning in 2002 and ending in 2007.

Q: Ed Thomas: How does AvSTAR relate to Distributed Air Ground Traffic Management (DAG)?

A: Dallas G. Denery: Many, but not all, of the concepts covered at the DAG workshop are being initiated under the AATT program. The AvSTAR program will propose to accelerate the development of those concepts initiated under AATT that can meet the near-term needs and to initiate other concepts that were omitted from AATT because of funding limitations.

4. Panel 1: Tomorrow's ATM System

Raymond LaFrey (Chair)
Massachusetts Institute of Technology, Lincoln Laboratory

Mr. Raymond LaFrey introduced the panel to discuss "Tomorrow's ATM System" which covers the predictable future. He invited the participants to examine the program goals and provide feedback. He then introduced the panel, which consisted of: Ronald Morgan (FAA), Roger Wall (Federal Express), Aslaug Haraldsdottir (Boeing), and Jim Evans (MIT Lincoln Laboratory). Panel members each spoke for a few minutes and then took questions from the assembly.

Ronald Morgan, Director of Air Traffic Service, FAA, "An FAA Perspective"

The first panel member to speak was Ron Morgan. A copy of Mr. Morgan's presentation is attached as part of Appendix 3 and is available on the web site.

Mr. Morgan discussed many of the challenges facing the current air traffic system, especially those dealing with efficiencies and delays in the system. He stressed that first and foremost, the FAA deals with safety of the system. Getting there safely but maybe late is better than not getting there at all. He showed a chart on operational error rates (for many years it held steady around 0.5 operational errors per 100,000 operations, but in 1998 the error rate started to climb). He pointed out that the resilience in the system is decreasing slightly which to him means that a safety metric is critical for the future system.

Mr. Morgan stated that the ATC system needed better tools to convey information on convective weather information with 30- to 60-minute time horizons. There is a need for continuous weather information. We need to collect, analyze and disseminate weather information. He mentioned that a tool to predict convective fog is also needed.

Mr. Morgan stated that an issue that needs to be addressed is whether or not increasing the capacity only leads to greater operational demand, are we just making the problem worse? He did not see that any consensus on this issue was developing.

Mr. Morgan then talked about the need for a set of expert tools to support ATC separation standards. He discussed that there needed to be accurate weather prediction products with a high level of fidelity. He mentioned that avionics and ground systems need to move toward providing VFR-type procedures in all conditions—the efficiency of the system being very different (better) when VFR is in effect versus IFR. He finished his discussion with a Los Angeles airport haze story—one aircraft turning to follow another aircraft brings one into a situation where the first aircraft cannot see the second because of a hazy background since the airport is located next to the ocean.

Roger Wall, Federal Express, "An Air Cargo Carrier Perspective"

Roger Wall (Chairman of RTCA '03-'05 working group) spoke next. He stated that he liked what he saw on AvSTAR, but he wanted to put it in context. Free Flight Phase 1 was initially a demonstration of a few very mature research efforts. Free Flight Phase 2 is a follow-on that is based on less mature research efforts. He cited the National Airspace System Infrastructure as continuing to be a problem. He mentioned certification continuing to be a problem. He stated that ADS-B technology, particularly the datalink portion, is not yet certified. He mentioned that traffic information is probably the first capability provided by ADS-B that will benefit capacity, but the full capabilities will also be useful. He said that certification is a continuing problem and that everyone needs a clearer, more certain process.

He explained that we all talk about today, tomorrow and the future. He used a 'moving bridge' metaphor…the future never arrives…18 more months and it'll be perfect, but you never get there. He was emphatic that researchers should continue the 'build a little, test a little' process in the operational facilities. He said that NASA has done an excellent job using that process, and that MITRE and Lincoln Laboratory have also done excellent work and their research needs to be leveraged.

Mr. Wall rapidly talked through a series of points about needing an integrated system…we still have a piecemeal approach…and we need procedures to use the individual capabilities…the industry and users will overcome the limitations and continue to improve the system. We need to involve all vehicles including unmanned air vehicles and even space vehicles in defining the future ATM system. Safety in the system…the systems we see today still have the human involved. But we need to go forward and look at using advanced automation. We need to be able to use the avionics onboard the aircraft. We need FMS approaches and the air traffic service provider must be able to accommodate new systems within the ATS system. We have to help the system help itself…Throughput is very important…Do we have a 24 hour/7 day a week system? Not really. Many of the services provided are only on a 10-12 hour availability. The old concept of midnight-8 AM being down is not true. The system does not yet provide full services for 24 hours/7 days a week. He mentioned weather…we need better weather tools and products so we can move from IMC limitations to VMC capabilities. He stated that better surface weather information is needed. We need to fix the interaction of the many systems on the terminal.

Mr. Wall concluded with the point that the problem of looking for the perfect solution revisits the AAS approach and should be avoided. NASA has made a good start achieving a revolutionary change through an evolutionary process.

Aslaug Haraldsdottir, The Boeing Company, "An Airframe Manufacturer Perspective"

The next speaker, Aslaug Haraldsdottir, presented several charts on tomorrow's ATM system. A copy of her presentation is attached as part of Appendix 3 and is available on the web site.

Ms. Haraldsdottir began by making the point that even as we need to increase capacity we cannot overlook safety. The air traffic service provider has safety as the primary objective. However, safety has not always been emphasized in our research to the extent we might think. In 1997, in the first joint EuroControl-FAA Symposium on ATM, there were no papers on safety. In the 1998 seminar in Orlando, only LMI and NLR presented papers on safety. In 1999 there were 5 papers on safety. We are getting better, but still need to do more. The other theme Ms. Haraldsdottir stressed was the direct relationship between the certification issue and the safety challenge.

She stated that to be successful, we must agree on a set of system performance goals and metrics that help us define what it is we are trying to achieve. She pointed out that this is a difficult process because of the many different stakeholder needs, but getting agreement on the goals will move us much further ahead. She indicated that comparative estimates of average delay per flight are difficult because we as an industry do not yet have adequate methodology and tools to predict delays in the significantly changed future system. An internal analysis done by Boeing indicates that FFP1 may provide only modest gains in delay reduction.

She talked about the CNS/ATM Strategic Investment Analysis Problem and the cost/benefit analysis that was performed at Boeing using capacity as the benefit for VDL/2. Implementation of VDL/2, a specific datalink protocol, is not likely to deliver significant benefits without putting many other technology and performance factors into proportional perspective. The performance factors include, but are not limited to, affordability, safety, NAS capacity, NAS efficiency, and sustaining operations. Companion technologies may include air traffic management automation integrated with flight management systems, and potentially improved surveillance performance. She suggested the need for AvSTAR to include development of increasingly mature analysis and integration tools to provide performance predictions to support cost/benefit analysis. She discussed the need to start with a given operational concept (a cohesive picture) of the future with stated performance objectives. There is a need for a comprehensive set of methods, models and tools to be created and implemented to cover the various aspects of the problem.

Ms. Haraldsdottir talked about how the air transportation system involves communications, surveillance, navigation, and air traffic management. She stressed that we need to put the individual pieces together into a realistic system and analyze them as a complete system. Ms. Haraldsdottir then proposed a preliminary design process that began with a statement of goals and ended with the creation of a plan for transitioning from the current system to a desired end-state. Her talk concluded with a proposed hierarchical toolset architecture to assist in the analyses of future capabilities.

Comment: Dr. Robert Rosen made the comment that we really need to come up with a better way of characterizing the benefits and problem than by average minutes of delay. To the general audience, 5 minutes delay is not a problem. This does not properly characterize the true impact of the delay on the system, which is manifested in the delay variance around the mean that threatens the predictability of the schedule and thus the effectiveness of the airline hub.

Dr. James Evans, MIT Lincoln Laboratory, "A Perspective of a Weather Researcher"

A copy of Dr. Evans presentation is attached as part of Appendix 3 and is available on the web site.

Dr. Evans, MIT Lincoln Laboratory, began his discussion by pointing out the continuing under investment in convective weather research and development. He cited how convective weather had a direct impact on the system's capacity and talked about the delays in the system (and their causes) as a result of convective weather. He pointed out that the funding for adding additional capabilities to the FAA's Integrated Terminal Weather System (ITWS) has been zero funded for the current fiscal year. He cited that winds are a large source of delay in the system and stressed the need for a system that could better predict wind information. He made several points that reinforced his assertion that weather is the primary source of delay problems.

Dr. Evans showed a chart that asserted that 70% of delays are due to weather. He stated that historically insufficient IFR capacity has been viewed as the principal cause of delays. He attributed as the principal cause to the rapidly increasing delays we are seeing in the summer months (which can be found in his presentation) to convective weather (e.g., thunderstorms). He indicated that part of problem was the impossibility of predicting convective weather several (2-6) hours in advance but still treating the predictions as certainty.

Dr. Evans pointed out that winter weather, as opposed to summer, does not seem to correlate with the delay numbers, and displayed a chart that showed delay values over several years that distinctively demonstrated this assertion.

He discussed the need for improved "tactical" capability in weather prediction. He talked about flight planning and the need for traffic flow management to make plans 2-6 hours in advance but indicated that highly accurate predictions of convective weather impacts that far ahead are rarely possible. It follows then that excluding aircraft from regions that have relatively low predicted probability of weather being present is not sensible and that instead we need to assume a lower "effective" capacity for regions of predicted weather, provide extra fuel on aircraft and expect that dynamic rerouting may be needed.

Dr. Evans concluded his presentation by stating that the AvSTAR effort needs to:

- Improve tactical (0-2 hour) capability in convective weather prediction
- Determine delay causality and how much delay is "avoidable"
- Extend planned simulation capability to more accurately depict thunderstorms as observed from the cockpit
- Relate pilot preferences/ride quality to en route weather features

Questions/Answers

Q: You mentioned some very impressive numbers for benefits, but this does not translate into funding.

A: Yes, you are right, funding comes from different people than the beneficiaries. There are differences between external versus internal rates of return.

Dr. Donohue made the point that the funding should go to the people actually bringing the costs down.

5. A Vision of the Future

Dr. Heinz Erzberger, Chief Scientist for Air Traffic Management
NASA Ames Research Center

Dr. Erzberger presented his vision of the future ATM system. He made the point that there are many possible visions and this is just one of them. He invited all to comment on his vision. A copy of his presentation is attached as part of Appendix 3 and is available on the web site.

He started by asking the group to assume that large increases in capacity, safety and efficiency will require a new approach different from that used today to provide air traffic management. He stated that the current ATM approach has some of the following characteristics:

- Air traffic growth is increasingly constrained by the capacity limits of sectorized control, wherein a controller is responsible for separation assurance, planning, communications, coordination, etc.
- Capacity gains through re-sectorization and sector size reduction have reached the point of diminishing returns.
- Decision Support Tools provide modest gains but cannot circumvent basic controller workload limits.
- Constraints that limit flight efficiency cannot be reduced at high traffic density because that would further exacerbate the controller's workload problem.
- The inevitability of human error limits further improvements in safety with current procedures.
- Potential of reduced separation cannot be fully exploited because of workload and reaction time limits with controllers performing current duties.

Dr. Erzberger presented a chart that showed a simple relationship amongst a graphical user interface, sector controllers using a voice link to "control" several aircraft, aided by assets including surveillance sensor systems, the host computer, and decision support tools.

He then talked about the possible ATM performance gains that would come from (1) Decision Support Tools (DST's), (2) DST's plus improved sensors, and (3) Automated Airspace (with both current and reduced separation standards). He indicated that today's separation standards are not being fully exploited due to controllers putting an extra margin for operational and safety reasons.

Dr. Erzberger discussed automated airspace operations and made the following points:

- Sector controllers are "liberated" from the responsibility of separation assurance and are "promoted" to the new role of airspace controller.
- Several traditional sectors are combined into super-sectors, each managed by an airspace controller.
- Conflict detection and resolution is fully automated and distributed between ground-based and airborne systems connected via data link.
- Sequencing and spacing control in the terminal area is fully automated on the ground and is executed via data link.
- Voice communications between airspace controller and pilots will be available to handle special needs, i.e., special pilot request, emergencies, loss of data link.
- Access to automated airspace will be restricted to equipped aircraft.
- Automated airspace can revert to conventionally controlled airspace during low demand periods.

He then showed a different plot of the same graphic showing the voice link being less important and the aircraft all communicating with the "Automated Airspace System".

He indicated that getting to such a vision of the future requires facing a number of development challenges:

- Gaining acceptance of concept by operators, controllers and the public
- Designing a system architecture that has multiple safety nets to protect users against various types of failures.
- Automating failure detection and reconfiguration of system to operate in a degraded mode.
- Defining the roles and responsibilities of airspace controllers.
- Designing the interface between airspace controller and system element; retaining the human-centered design while changing the role of the human.
- Transitioning from manual to automated airspace operations
- Providing airspace and runway access for unequipped aircraft
- Updating the CTAS algorithms and software to level of performance required for autonomous operation.
- Establishing the minimum equipment standards for airspace users.
- Verifying, validating and testing of the concept.

Dr. Erzberger discussed three approaches towards automating air traffic control systems: (1) time-based (4D) guidance, (2) self-separation and advanced TCAS, and, (3) automated airspace. In his vision, the first two approaches above, along with highly reliable data links, provide the essential enabling technologies for achieving automated airspace operations.

He indicated that automated airspace can be categorized into the following types:

- self-separation airspace
- high altitude transition airspace: mixing climbing, descending and over-flights

- arrival and departure management airspace
- final approach sequencing and spacing airspace

He then showed examples of Fort Worth Center's traffic flows at flight level 240 and above. He indicated how these flows could be organized into an automated airspace type system and discussed the value of moving toward a "super sector" construct for airspace. The benefits of a super sector could be:

- Making boundaries unconstrained by current center boundaries.
- Eliminating trajectory constraints imposed by conventional sector structure and altitude stratification.
- Reducing handoff coordination.
- Sharing airspace for arrivals, departures and over-flights would increase the flexibility in use of airspace and routes.
- Unifying airspace through use of super sectors thereby increasing the range and effectiveness of conflict resolution.
- Increasing controller productivity.

Dr. Erzberger concluded by making observations on how to step towards such a vision. These steps could include:

- Complete deployment of decision support tools for critical ATM specialties (2010). DST technology is the foundation for automated airspace
- Introduce Distributed Air/Ground procedures and improved sensors (2006). When combined with DST's, this begins the process of changing sector controller roles and responsibilities.
- Build high performance and secure air/ground data link required to support automated airspace operation (2012).
- Evaluate prototype automated airspace system in selected high altitude airspace (2015).
- Install in high-density en route airspace (2017).
- Install in high-density terminal areas (2020).

Questions/Answers

Q: Dr. Andres Zellweger: Some of us have been thinking about this for many years...computer science has not matured enough to deal with many of those issues.
A: Dr. Erzberger: Redundancy will buy you some robustness...we now have some tools in the field showing how to automate some of the ATC functions.
A: Dr. Denery: This is a notional thought and in the breakout sessions we are asking for greater clarity on other thoughts of ATC evolution...

Q: Dr. Jim Evans: What about convective weather? More planes less controllers.
A: Dr. Erzberger--Convective weather will have to be dealt with by the automation.

Q: Marty Pozesky: Aren't you changing the role of the pilot too?
A: Not necessarily.

Q: Marty Pozesky: Does shared decision making improve capacity.
A: The jury is still out on that issue.

6. Panel 2: Future Air Transportation System

John Hansman (Chair)
Massachusetts Institute of Technology

Professor John Hansman then introduced the objectives of the "Future Air Transportation System Panel". He invited the panelists to examine the AvSTAR program goals and to give their view of what was needed in the future.

He then introduced the panel members: George Donohue (George Mason University), Ron Morgan (FAA), Ron Golaszewski (GRA Incorporated), Rocky Stone (United Airlines), Robert Spitzer (Boeing), Joe Jackson (Honeywell), and, Charlie Billings (Ohio State University). Each panel member spoke for a few minutes and then took questions from the assembly.

George Donohue, George Mason University, "A Perspective on Research Requirements"

Dr. Donohue started by saying that when he was with the FAA many ideas were explored. He stated that he had established a systems engineering group that analyzed alternative concepts. Few current concepts offered much increase in capacity or controller productivity. The FAA's NAS Architecture 4.0 is a consensus document and is adequate for the near term but is, at best, a coordinated list of Band-Aids for the problems we are currently facing. He observed that our current development and implementation approach is not going solve the bigger problem. He stated that he supported Dr. Erzberger's concept of the future, as he understood it. He believes that reducing sector sizes only reduces the system capacity. The movement to larger super sectors is an interesting idea that should be explored. He also believes that the primary authority and responsibility for aircraft separation should be transferred from the ATC controller to the pilot and the aircraft system. To some extent, this transfer has already occurred with the introduction of TCAS II in 1990. The responsibility for efficient throughput and flow control should remain on the ground. The current implementation plans simply "kick the can" down the road but do not support the anticipated increase in demand.

Dr. Donohue mentioned that the airline hub and spoke system can be modeled as a network of queues and that the modeling of such a system is straightforward. What Dr. Erzberger is talking about is a 4 dimensional control system. He stated that a time-based approach offers definite efficiencies but a rigid 4D-control system is perhaps too inflexible to use exclusively in the future.

He mentioned that Dr. Haraldsdottir of Boeing has modeled the ATM system as a series of nested feedback control loops. He cautioned that the higher-level loop of central flow control should not try to do the lower-level loop of actual tactical separation. He stressed that the future system will need to have a total systems outlook (driven primarily by a safety analysis).

Dr. Donohue concluded by observing that in order to achieve some of the goals for future air traffic control, the controller and the pilot will need to transition from their current roles to become systems managers. He finished by stating that we all are looking at a major paradigm shift.

Ronald Morgan, Director of Air Traffic Service, FAA, "The Future Air Transportation System"

Mr. Morgan started by stating that the future air transportation must support a number of users including the airlines, General Aviation, Business, □ and Department of Defense. He listed a number of attributes for a future air transportation system. Some of the attributes included access to the system, increased throughput throughout the system, predictability, flexibility, and decreased delays.

Mr. Morgan then reiterated the comments on safety he made during the panel on "Tomorrow's ATM System". He again stressed that first and foremost, the FAA deals with safety of the system. Getting there safely but maybe late is better than not getting there at all. He referred back to the chart he had shown during the "Tomorrow's ATM System" panel on numbers of operational errors. He pointed out that the resilience in the system is decreasing slightly, which to him means that a safety metric is critical for the future system.

He stressed that the system needed to work towards maximizing the efficiency of operation by using all the resources (assets) to the best of the system's ability. Examples of resources that could be better used included: off-hour operations, making use of airports that are currently underused, and providing more flexibility in use of airspace.

He discussed the need to identify who will hold the financial liability in an automated future air transportation system. He talked about the advantages of time-based separation and the need for research to allow the system to move towards time based separation. He stated that we do not have the tools for the controller to actually implement that approach.

Mr. Morgan concluded by stating that whatever the vision turns out to be, the vision must be real and we need to begin moving in that direction.

Rich Golaszewski, GRA, "An Aviation Economist's Perspective"

A copy of his presentation is attached as part of Appendix 3 and is available on the web site.

Mr. Golaszewski from GRA, Inc. started by listing some of the determinants of demand for the future air transportation system. These included economic growth, population size and distribution, aircraft acquisition and operating costs, energy availability and cost, environmental issues such as noise and emissions, vehicle technology, purposes of travel (personal or business), travel modes, global safety/security issues, and evolving air shuttle markets.

Next, he focused on air transportation system issues. He discussed demand distribution, multiple airport systems, roles of hubs and gateways and their impact on frequency of service and the number of non-stop flights in key markets. The number and location of airports and the ability of the air traffic system to handle increasing levels of traffic affect the availability of capacity. The availability of capacity (or lack thereof) contributes to the competitive environment and the creation of alliances/networks, niche carriers, fares.

Next, he went on to cite a series of interrelated demand-capacity-delay issues. Delay problems are concentrated at a small proportion of US airports. To reduce the delay or increase capacity we need to reduce runway occupancy time, alleviate the impact of wake vortex on separations, move towards virtual VMC, and make better use of closely spaced runways. We can also improve the capacity by increasing the number of multiple airport regions and adding new runways, provide incentives to use secondary airports for passengers and carriers, and develop more airspace/routes through dynamic reconfiguration, provide for severe weather avoidance, and provide for one ATC facility to backup another that is overloaded with traffic. However, without institutional or technological change, we will just see more of the same.

Mr. Golaszewski presented a chart of the United States showing the top US commercial airports, identified by forecast annual population growth rate in surrounding areas, 1998 to 2025. Using this chart, he made the point that today the airports near all the major cities are experiencing significant delay. He further stated that from the same chart one could postulate that in 2025 the same congestion problem will exist at our second and third tier airports.

He presented another chart entitled "Detailed Forecast Outputs" which shows the FAA's long-range forecast data for 1999, 2005, 2010, 2015, 2020 and 2025. These figures are for enplanements (Air Carrier and Regionals), aircraft fleet size (Air Carrier/Cargo, Regional/Commuter and General Aviation), and, civil aircraft operations (Commercial and General Aviation). The data show a 3.4% average annual growth rate in the air carrier/cargo fleet, a 2.3% average annual growth rate in the regional/commuter fleet, and a .8% annual growth rate in general aviation. Commercial operations are expected to grow 1.9% annually and general aviation operations are expected to grow at a .7% annual rate. Looking at the numbers he asked the audience if it is it reasonable to ask the National Airspace System to accept 2% growth per year.

There are several scenarios that we need to consider in forecasting the future air transportation system. These include: 1) Pure Airline Driven – where the airlines cater to passenger preferences, the system tries to accommodate, and the airlines price scarcity. This could lead to greater frequency of operation through increased introduction of regional jets; 2) Environmental stringency - noise/emissions standards and taxes could easily affect the growth projections; 3) Congestion/delay – will lead to operations being balanced by FAA Command Center and CDM; 4) Market driven infrastructure – where providers (FAA and airports) price scarcity. This scenario will encounter institutional issues, and probably lead to larger aircraft with less frequency of service; 5) Economic scenarios – where there may be changes in air travel demand. Examples include substitution of communications for air travel, increases in demand as a result of e-Commerce and air travel, changes in the country's economic growth projections, and changes in the competition and industry structure.

He stated that the best metric might be passenger throughput (people throughput instead of aircraft throughput) but that the system needs to change the incentives to achieve this. As long as the current incentives that passengers and carriers face are not changed, then we can expect to see more of the same—a premium on frequency of service with resultant congestion and delays. While we have deregulated the airline industry, infrastructure providers such as airports and the FAA continue to operate in an institutional framework that was designed for the regulated era.

Mr. Golaszewski concluded by observing that we have had the longest period of sustained economic growth in America's history. This translates into continued growth in the demand for airline services and leaves no time for rest for those that must provide capacity to meet this demand.

Rocky Stone, United Airlines, "An Airline Perspective"

Mr. Stone started by observing that there will not be many more runways built in the future. Another commodity that will not grow is new airspace. How can air traffic continue to grow with these finite limitations? The airline industry has enough customer demand to grow, if it can meet that demand without unreasonably increasing delays. Fundamental changes in how we operate the airspace need to be made to meet these demands. He observed that even though we need rapid, revolutionary, and fundamental changes, we have to implement them incrementally.

Mr. Stone concluded by stating that there are many solutions to the ATM capacity problem and we just need to implement them.

Robert Spitzer, The Boeing Company, "An Airframe Manufacturer's Perspective"

A copy of Mr. Spitzer's presentation is included in Appendix 2 and is available on the web site.

Mr. Spitzer described the various work efforts in future ATM in which the Boeing Company is involved. He observed that the demand for people and cargo transport by air will continue to grow. He stated that the current system is at capacity limits and that the system is highly sensitive to disturbances such as weather events. Fifteen years of R&D have brought forth many new technologies and the task is to integrate the best set of technologies into a higher performance system. We need analysis tools to assess the performance of proposed solution sets. We need to focus on the airspace performance, with the appropriate level of modeling fidelity to enable broad concept exploration. We need to understand the feasible performance of a range of new concepts to allow us to lay out the technology research needed to define and transition to the system after next.

He asked "what do passengers want?" He responded by citing: safe and reliable service, direct flights to places they want to go at times that they want to fly, and low air fares and comfortable airplanes.

He asked "how will airlines accommodate air travel growth?" He responded by citing improved airplane capabilities, better government regulation, and improved airline strategies.

He showed a chart illustrating the current and expected growth of air travel in major markets. It is clear that all major markets will have tremendous growth over the next twenty years. The Asia Pacific market shows the greatest growth with air travel in 2018 approaching the levels we expect in North America.

Mr. Spitzer showed another chart that postulates that there are regional differences that drive the priorities for improvements in air traffic management. North America's and Europe's primary need is improvements in capacity. North Pacific, Asia, and the Middle East need to focus on efficiency of operation. Africa and South America need to focus on safety.

He suggested that better air travel is tied to global security and prosperity.

He talked about Boeing's vision of ATM as including a modern, global, interoperable ATM system by 2016 that is: safe, affordable and supports free market growth. Also, it includes all Boeing aircraft equipped for the new environment and that the equipage is based on a strategic investment case.

Mr. Spitzer joked that we need to clone Dr. Erzberger and have 6 different concepts and look at them all. He said that there is no model that will allow us to compare the merits of various concepts. He expanded on his point and stated that without such a model, there is no realistic path for choosing between the various approaches. He observed that it takes really fundamental work and better understanding to achieve robust concepts.

He briefly mentioned the NASA benefits assessment process and stated that more work needed to be done that reinforces the analysis of programs and technologies, advanced concepts against baselined objectives and metrics.

He discussed the NAS architecture phase-in approach with phase 1 covering 2000-2002, phase 2 covering the mid-term, 2003-2007, and phase 3 covering the far-term, 2008-2020. The presentation material has more details.

Mr. Spitzer concluded by seeking to encourage the group to come up with the better ideas and showed the following list of long-range research needs:

- A safe, affordable transportation system to 2025
- Adequate system capacity for most weather operations
- Multi-modal operations concepts to support passenger transit time requirements
- Radical operations, vehicle and infrastructure concepts
- Tools & Methods to synthesize system solutions and to assess their effectiveness over a range of future scenarios
- Meaningful research to help the transportation of people and goods

Joe Jackson, Honeywell, "An Avionics Manufacturer's Perspective"

A copy of his presentation is attached as part of Appendix 3 and is available on the web site.

Dr. Joe Jackson, Honeywell, started by stating that by 2030 there will be wonderful technologies available for the cockpit. These technologies will include: highly integrated systems, very reliable, mega-processing power, gobs and gobs of memory, air/ground digital communications allowing the aircraft to be a node in the internet, high-integrity 4-D Flight Management Systems, GPS systems totally integrated into the cockpit, and next generation TCAS capability.

The avionics industry is being pressured by shareholder value and user benefits. We need to synchronize technology readiness with overall system readiness.

Dr. Jackson talked about the attributes of ATM in 2030:

- Safety of operations will be the #1 priority for the ATM owner and users
- ATM safety and capacity will be global and national priorities
- Global considerations will strongly influence NAS ATM enhancements
- Evolutionary (versus revolutionary) introduction of new ATM capabilities will continue to be the norm.

He stated that the ATM Infrastructure should incorporate new technologies and procedures (a/g) expeditiously and efficiently, based on:

- World class ATM system architecture and personnel
- World class simulation/design/deployment/regulatory processes and tools
- Streamlined funding allocation process
- Collaboration with industry and other ATM providers

Dr. Jackson finished his presentation by discussing how capacity bottlenecks can be addressed by:

- Continued investment in ATM assets
- New procedures and capabilities responsive to user needs
- Distributed airborne/ground stations and decision-making
- Multi- and inter-modal transportation solutions

Charlie Billings, Ohio State University, "A Human Factors Perspective"

A copy of his presentation is attached as part of Appendix 3 and is available on the web site.

Dr. Billings started his presentation by stating that the future is still notional and that no one is conducting the research to support the far-term concepts, technologies and methods. He described the goal of providing research and development by 2007 needed to provide the foundations for the future (beyond free flight). He pointed out the AvSTAR goals of achieving a 3 times increase in throughput at high-density airports and a 50% reduction in the rate of missed/canceled flights. He also cited the AvSTAR plans for developing an ATM system-level definition, design, functions, architecture, and interfaces. He quoted "Tomorrow's technologies provide the building blocks; Information systems technologies provide the mortar". He emphasized that these were all headed in the right direction but the first need is the far-term concepts.

He pointed out that the best way to forecast the far-term requirements is to study the evolution of our near-term problems. He pointed out that the ATM system and the people who operate it must evolve gradually, because they must handle production pressures throughout its evolution.

Dr. Billings cited several difficult problems in the present system. These include:

- Traffic demand and complexity are escalating. Delays are soaring, and passenger rage is skyrocketing.
- Information management has not kept pace
- It has become increasingly difficult to accommodate user goals and priorities.

He observed that a system continuous re-planning capability is an obvious tool that needs to be done now. He said that we have been thinking about such a tool for decades and that now is the time to actually implement one.

Dr. Billings described an approach for identifying and assessing operations concepts and system designs for a Unified Air Transportation System. These include:

- Identify and develop system-level <u>operations concepts</u>. We need to ensure participation by and incorporation of stakeholder knowledge and goals.
- Define <u>information management</u> and presentation to support those concepts.
- Define the <u>potential human and team roles</u> in the future system.
- Evaluate the implications of a novel system for <u>human operators</u>.
  - Human roles in direction and management of automated ATM systems
  - Monitoring state and functionality of automated systems
- Define the <u>architectures necessary to support distributed work</u> in these systems
  - Planning processes and integration
  - Tactical processes to meet real-time conditions and demands
- Then define the <u>requirements for tools</u> to support operations in this system.
  - Reliability, robustness and failure handling
  - Automation roles in automated systems
  - Maintenance of user flexibility in more automated systems
- Evaluate transition from current to future infrastructure as a major issue.

Dr. Billings concluded by talking about how we need to believe that the technological building blocks of the future system rest upon a solid foundation of concepts and architectures.

The information systems technologies in the future system should be designed to assist human operators to implement the policies and procedures by which the system is governed.

7. Breakout Sessions

After the break, the workshop participants were divided into three groups - two that focused on the near-term aspects of the program, "Tomorrow's System", and one that focused on the far-term aspects of the program, "The Future Air Transportation System". The two "Tomorrow's ATM System" Breakout Sessions covered the terminal/surface area and the en-route/TFM/ATM-TFM Weather Integration areas respectively. These breakout sessions developed a set of recommendations regarding program content and prioritization.

Breakout Session Summaries

Tomorrow's ATM System
Chair, Mr. Raymond LaFrey (Lincoln Laboratory); Co-Chair, Thomas Davis (NASA)
"Terminal/Surface", Chair, Mr. Roger Wall (Federal Express)
"En-Route/Traffic, Flow Management/ Weather", Chair, Mr. Randy Kelly (UAL)

Chair Comments

General Reactions:

- There is enthusiasm for AvSTAR and appreciation to NASA for involving the community in the program planning process
  - — The seven "Tomorrow's System" elements appear to encompass the needed steps to fill gaps and augment efforts to achieve the goals of Free Flight
  - — There did not appear to be any missing elements in the AvSTAR program
- There is interest in having additional opportunities to learn more about the program and to help plan AvSTAR

General Recommendations:

- The safety implications of new automation tools and procedures must be assessed so that safety margins are not eroded
- New automation tools need to be compatible with the evolving ATC system
- The FAA certification process needs to be more definitive, otherwise it may hinder the introduction of new technology

Other General Recommendations

- Continue the development of a strong business case for AvSTAR:
  - — State an overall investment strategy
  - — Provide explanations for continuing with TAP/AATT initiated work (e.g. AVOSS, SMS, aFAST)
  - — Establish realistic expectations of AvSTAR benefits
  - State the potential impact on top-50 airports (a stop-light chart)
  - Insure that AvSTAR addresses delay causality and how much of this delay can be avoided through improved procedures and automation

- Insure that AvSTAR addresses decision making under the uncertainties in weather predictions
- The ATC system can be viewed as an information exchange problem and NASA should examine application of information technologies
- NASA should conduct research into the design strategies, test strategies, etc. to assure safety and fault tolerance in ATM software
- Tool integration is vital
  - — NASA, working with the FAA, must take a responsibility for how each tool fits into the FAA architecture.
    - Human factors
    - Systems engineering
- NASA should develop a simulation/modeling capability as a basis for understanding needed improvements in ATC operations
- NASA should consider taking ATM tools to a higher TRL level to help close the transition gap
- Flight deck human factors needs must be a part of the program
- ATM should be considered for the smaller airports
- The growing regional airports should be considered
- Environmental issues should be addressed in all program elements
- FAA Regulation and Certification involvement should begin earlier

<u>Surface Congestion Alleviation</u>

- Assure AvSTAR developments in surface automation are integrated and properly account for current and emerging industry surface tools
- Take advantage of Safe Flight 21 findings
- Cockpit systems need to be included as part of the surface congestion solution
- The surface congestion solution must include the integration of arrival, departure, and surface automation tools and procedures

<u>Runway Productivity Technologies</u>

- Continued Wake Vortex Work is needed
  - — Departure and arrival wake vortex spacing requirements significantly limit traffic flow
  - — Continued development of sensors and systems that can safely reduce current limits is highly desired
- A cockpit display that enables "Virtual" VMC for reduced separation ("enhanced visuals") should be considered
- The development of technologies that will allow improved utilization of closely spaced or converging runways should be continued

<u>Enhanced Arrival/Departure Tools</u>

- Need tools that help controllers maintain separation
- Operations of DSTs should include input and coordination with other ATS initiatives

- Need to integrate AvSTAR developments with industry tools
- 2010: Time-based separation should be a goal

Integrated Airspace Decision Support Tools

- Time based scheduling must be the guiding philosophy for all research and decision support tool development. Note: The AvSTAR activities are consistent with time-based scheduling and are supported as essential building blocks
- Developments within AvSTAR must be integrated and compatible with other tools being deployed by the FAA.
- Conduct research on how best to use data link in ATC automation

National Traffic Flow Management

- Develop a rapid modeling tool that provides forecast capabilities (what if?) for all users
  — FAA/AOC
- Produce optimal solutions based on shared information to enable decision makers to:
  — Incorporate triggering mechanisms for initiatives
  — Define exit mechanisms for every initiative
- A unified TFM system is needed
  — Must move from an open-loop SCC TFM to one that has interaction between strategic and local TFM activities
- Need to develop technology that will better predict sector overload and allow us to move towards dynamic resectorization
  — Develop metrics for controller workload and feasible sector throughput
  — Develop the means to handle dynamic resectorization across TRACON and Center boundaries
  — Improve the reliability of sector monitor alerts

Runway Independent Operations

- The business case for investment in runway independent operations needs clarification
  — What is its future role in the US air transportation system
- The operational concept needs more clarity

ATM/TFM Weather Integration

- Ensure weather hazards are accounted for in new automation initiatives and policies
  — Consider use of artificial intelligence methods to interpret weather obstacles. Note: Several FAA Aviation Weather products now incorporate machine intelligence (AKA A.I.) to fuse data from various sources into a forecast.
- Ensure the flight deck has access to weather information and the automation to assist the pilot in using this information. Note: There are a variety of initiatives, government and industry, that are, or will soon, provide weather information directly to the cockpit.
  — Build a tool to help pilots in the diversion decision and contingency planning
  — Provide complete NAS (weather?) status for the pilots

Terminal Weather

- Provide better predictions of convective weather and ceiling/visibility
- FAA Aviation Weather Research has developed a 60 minute convective weather forecast tool, but
  - — Accurate forecast more than 2 hours will be hard to accomplish in next 10 years
- However, merging weather with ATM DSTs can improve safety

The Future Air Transportation System
Chair, Professor John Hansman (MIT); Co-Chair, Dr. Karlin Roth (NASA)

Overview

- AvSTAR future system effort critically important
  - — Challenge is real
  - — Need to deliver
  - — Already time critical
- Investment in the future
  - — Protect from encroachment due to near term pressures
- Need to follow a systems engineering process
  - — System must be integrated from the start
  - — Tasks must be linked in the system concept
- Efforts need to be worked in a worldwide context

Areas

- Policy issues
- System Attributes
- Concepts
- Metrics
- Research Issues

Policy Issues (General)

- Political and business commitment to action and implementation
- Adopt versus specifically develop technologies and methodologies
  - — Examine other similar efforts – avoid duplication
- ATN issues and spectrum availability
- Harmonize air transportation with other transportation modes. Define the boundary of the system?
  - — Integrated multi-modal
  - — Door-to-door or gate-to-gate
- Information management + system architecture
  - — Do we have the national competency to do this job?

System Attributes

- System Guidelines/Scope
  - Mission/goal driven research
    - Set realistic expectations
    - Account for differing views of system requirements
      - Passenger-centric vs. aircraft-centric vs. airline-centric vs. airport centric
  - System Characteristics/design constraints
    - Transitional and revolutionary
      - Concurrent transition planning
    - Layered system
      - Must be robust to sub-system failure/changing conditions
- System Performance Parameters
  - Safety
  - Reliability
  - Availability
  - Affordability
  - Adaptable to all aircraft types

Concepts

- Concurrence on need for greater automation/movement away from current approach to sectorization of airspace as a means of improving traffic throughput
  - Automated Airspace (Erzberger)
    - Remove human as separation assurance monitor
    - Tactical control loop
    - Implications for automation
  - 4-D Dispersed Control
    - Computer strategic checking
    - Aircraft tactical separation
  - Separation based on collision risk management
  - Sector-less flight-based ATM
    - Same controller handles all flight phases
  - Highly Distributed Control
- Airport/Runway Technologies
  - Runway Independent Operations
- System-level considerations
  - System-level information management (emphasized)
  - Modeling must account for up to a "300,000" IAC (Instantaneous Airborne Count) system
  - New airline business approaches
  - Review of prior concepts of operations
    - Impact of new technologies

- Weather
  - — Future system automation must properly account for weather and uncertainty in its predictability

Metrics

- Safety
  - — Target level of safety (TLOS)
- Environment impact
- Fleet coverage
- Door-to-door
- Passenger Throughput
- Efficiency
- Capacity
- Etc...

Research Issues

- Modeling and Understanding
  - — Methodology for evaluating concepts
    - Economic feedback loops
    - Reality test
    - Models
  - — Benchmarking and understanding of current system
    - Dynamic behavior
    - Non-normal events (e.g., weather)
    - Inefficiencies
    - System-level modeling
    - Economic feedback
    - Controller limits
  - — Safety analysis (emphasized)
    - Barrier to transition
    - System design issues
    - Partition and allocation of risk and responsibility
  - — Understanding transition dynamics
    - Barriers
  - — Robustness of large, distributed, highly-automated systems
    - Validation and certification
    - Software

Technology Developments

- Multiple objective-function optimization
- Airborne conflict management
- Intent
- Weather integration in systems and research
- Communications issues
- Sensor issues

Operational Issues

- Develop confidence for re-allocation of separation responsibility to automation
- Robustness and fall-back modes

Detailed Research Example - Automated Airspace (Erzberger)

- Size of super-sector
  - — How big is the biggest?
- Psychological impact on pilots
  - — Dealing with automation-provided ATC clearances
- Mixed operations in automated airspace
  - — Transitional design issue
- Communications infrastructure
  - — Not ATN? UMTS? Satellite-based?

8. Next Steps/Discussion

Dr. Denery then offered the workshop participants to make any final comments on the Breakout Session Summaries and the workshop in general.

The ensuing discussion demonstrated a very strong consensus regarding the need for AvSTAR. The workshop participants expressed their appreciation in being involved in the planning process and expressed strong interest in staying involved in the future.

Mr. Robert Pearce (NASA Headquarters) stated that NASA was very interested in establishing a National Partnership that would guide the research within AvSTAR to assure that the work would meet the needs of the air transportation system.

Dr. Denery then thanked the workshop attendees for their participation. He stated that the primary purpose of the current workshop was to understand the requirements for the evolving air transportation system from the perspective of the user community. It was for this reason that the invitations were limited. As a result of the discussion and comments, we are now in a much better position to lay out a more detailed program. The NASA and FAA will be conducting an internal workshop in early December to put together a revised plan based on these recommendations. In early 2001, we will be conducting a second industry workshop to reengage industry in the planning. Whereas the current workshop focused on requirements, the next workshop will also focus on implementation and will be opened to the supplier as well as the user community.

The workshop was officially adjourned at 12 PM, September 22, 2000.

Appendix 1 — Participants List

Paul Abramson	System Resources Corp.
Frank Aguilera	NASA Ames Research Center
Ed Aiken	NASA Ames Research Center
Al Albrecht	Consultant
Terry Allard	NASA Ames Research Center
John Andrews	MIT Lincoln Laboratory
P. Douglas Arbuckle	NASA Langley Research Center
Rose Ashford	NASA Ames Research Center
Steve Atkins	NASA Ames Research Center
Dev Banerjee	Boeing Commercial Airplane Group
Karl Bilimoria	NASA Ames Research Center
Charles Billings	The Ohio State University
Wayne Bryant	NASA Langley Research Center
John Cavolowsky	NASA Ames Research Center
Kenneth Cobb	TRW
Gregory Condon	Raytheon Corp.
Sharon Darnell	Federal Aviation Administration
Tom Davis	NASA Ames Research Center
Joseph Del Balzo	JDA Aviation Technology Solutions
Dorsey DeMaster	UPS Advanced Flight Systems
Dallas Denery	NASA Ames Research Center
George Donohue	George Mason University
Paul Drouilhet	M.I.T. Lincoln Labs
Vu Duong	Eurocontrol - EEC
Mike Durham	NASA Langley Research Center
Thomas Edwards	NASA Ames Research Center
Paul Erway	Federal Aviation Administration
Heinz Erzberger	NASA Ames Research Center
Jim Evans	MIT Lincoln Laboratory
Skip Fletcher	NASA Ames Research Center
David Foyle	NASA Ames Research Center
Yuri Gawdiak	NASA Ames Research Center
Richard Golaszewski	GRA Incorporated
Steve Green	NASA Ames Research Center
George Greene	Federal Aviation Administration
Karl Grundmann	NASA Ames Research Center
Jon Guice	USRA-RIACS
Charles Hall	American Airlines
John Hansman	Massachusetts Institute of Technology
Aslaug Haraldsdottir	Boeing Commercial Airplane Group
Bruce Holmes	NASA Langley Research Center
Albert Homans	ARINC, Inc.
John Hopkins	Volpe National Transportation Systems Center

Joseph Jackson	Honeywell Inc.
Robert Jacobsen	NASA Ames Research Center
ChuckJohnson	NASA Ames Research Center
David Jones	United Airlines
Randy Kelley	United Airlines
Robert Kerczewski	NASA Glenn Research Center
Seth Kurasaki	NASA Ames Research Center
Raymond LaFrey	MIT Lincoln Laboratory
Michael Landis	NASA Ames Research Center
J. Victor Lebacqz	NASA Ames Research Center
Jack Levine	NASA Headquarters
William Leber, Jr.	Northwest Airlines
Sandra Lozito	NASA Ames Research Center
Wayne MacKenzie	Federal Aviation Administration
Hugh McLaurin	Federal Aviation Administration
David McNally	NASA Ames Research Center
Donald Mendoza	NASA Ames Research Center
George Meyer	NASA Ames Research Center
Larry Meyn	NASA Ames Research Center
Ron Morgan	Federal Aviation Administration
Rich Nehl	Federal Aviation Administration
John O'Neill	USRA-RIACS
Lynne O'Rourke	TRW
Judith Orasanu	NASA Ames Research Center
Richard Page	Federal Aviation Administration Hughes Tech Center
Russ Paielli	NASA Ames Research Center
Everett Palmer	NASA Ames Research Center
Steve Pansky	Federal Aviation Administration
Robert Pearce	NASA Headquarters
Frank Petroski	MITRE/CAASD
Denise Ponchak	NASA Glenn Research Center
Martin Pozesky	NASA Ames Research Center
George Price	NASA Ames Research Center
Thomas Proeschel	Federal Aviation Administration
Roy Reichenbach	NASA Ames Research Center
Ron Reisman	NASA Ames Research Center
Roger Remington	NASA Ames Research Center
Donald Richardson	SAIC
Robert Rosen	NASA Ames Research Center
Vernon Rossow	NASA Ames Research Center
Karlin Roth	NASA Ames Research Center
Bennie Sanford	Federal Aviation Administration
Christine Scofield	NASA Ames Research Center
Barry Scott	Federal Aviation Administration
Bob Simpson	Flight Transportation Associates
David Smith	NASA Ames Research Center

Dave Snyder	Bell Helicopter and Technology
Robert Spitzer	The Boeing Company
Banavar Sridhar	NASA Ames Research Center
Rocky Stone	United Airlines
Harry Swenson	NASA Ames Research Center
Edwin Thomas	United Airlines/WHQVF
Leonard Tobias	NASA Ames Research Center
George Tucker	NASA Ames Research Center
Bill Voss	Federal Aviation Administration
Roxana Wales	QSS at NASA Ames Research Center
Roger Wall	Federal Express
Chris Wargo	Computer Networks & Software, In.
Del Weathers	NASA Ames Research Center
Jonathan Whittle	QSS Group, Inc. at NASA Ames Research Center
Eugene Wilhelm	MITRE/CAASD
Richard Wright	Volpe National Transportation Systems Center
Andres Zellweger	Embry Riddle Aeronautical University
John Zuk	NASA Ames Research Center

Appendix 2 — Acronyms

4D	Four Dimensional
AAS	Advanced Automation System
AATT	Advanced Air Transportation Technologies
AOC	Airlines Operations Center
ATC	Air Traffic Control
ATM	Air Traffic Management
ATN	Aeronautical Telecommunications Network
AvSTAR	Aviation System Technology Advanced Research
CDM	Collaborative Decision Making
CTAS	Center TRACON Automation System
DST	Decision Support Tool
FAA	Federal Aviation Administration
FFP1	Free Flight Phase 1
FFP2	Free Flight Phase 2
FMS	Flight Management System
GPS	Global Positioning System
HQ	Headquarters
IAC	Instantaneous Airborne Count
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
ITWS	Integrated Terminal Weather System
LMI	Logistics Management Institute
MIT	Massachusetts Institute of Technology
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NLR	Netherlands Research Laboratory
R&D	Research and Development
SATs	Small Aircraft Transportation System
SCC	Systems Command Center
TAP	Terminal Area Productivity
TCAS	Threat Collision Avoidance System
TLOS	Target level of safety
TRACON	Terminal Radar Approach Control
TRL	Technology Readiness Levels
TFM	Traffic Flow Management
UAL	United Airlines
UTMS	Universal Time Management System
VDL/2	VHF Date Link Mode 2
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
vg	View Graph

Appendix 3 — Presentations

Conf paper /S, / IN/03

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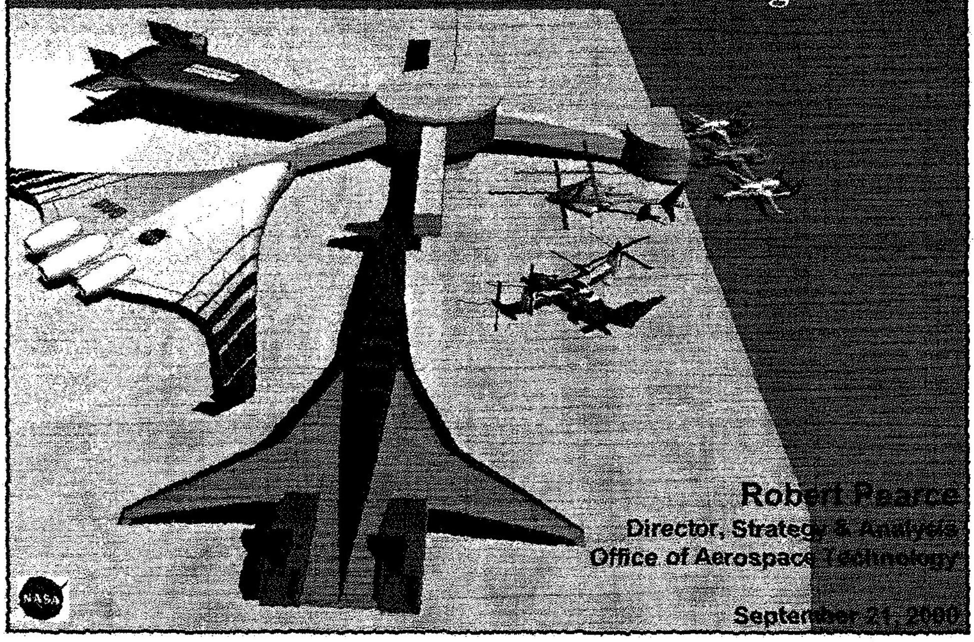
Transportation System After Next & Comments on AvSTAR Planning



Transportation System After Next

Mission

Define how transportation will meet the requirements of mobility in the future so that we can initiate R&D programs today that will allow us to achieve that future state.

The future IS mobility - - moving people, goods, and ideas

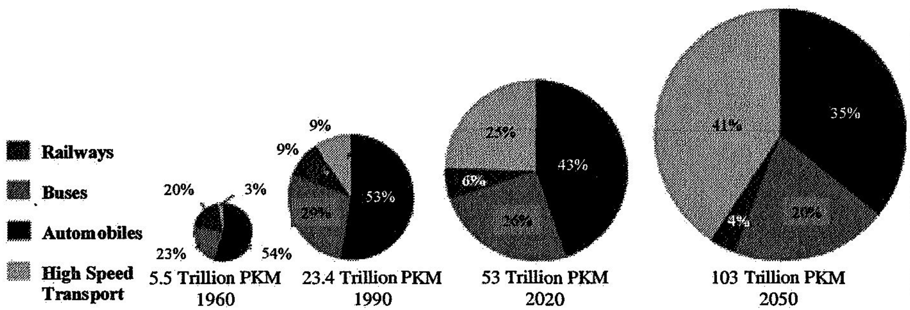
Purpose

To define and identify:

- Role of transportation in supporting future US needs
  - economic
  - security
  - quality of life of its people
- Trends
  - What is the problem?
  - Where are we going and growing?
- System *after next*
  - a vision of
  - requirements for New concepts and technologies
- Supporting research and education
- Priority investments
  - Government
  - Industry
  - Academia
- Barriers
  - Institutional
  - Cultural
  - Political
  - Global

Forecasts

World Traffic Volume



WORLD TRAFFIC VOLUME, measured in passenger-kilometers (PKM), will continue to balloon, with higher-speed transport gaining market share. By 2050, automobiles will supply less than two fifths of global volume.

Scientific American, The Past and Future of Global Mobility; October 1997
http://www.sciam.com/1097issue/1097schaferbox1.html

Challenges

To deal with:

- Aging population
- Population pattern shifts (e.g. mega-cities)
- Increasing trade
- Increasing tourism
- Globalization
- Environmental concerns
- Explosion of new technology

  (IT, Bio, nano, physics, chemistry, genetics, robotics, tele-communication ...)

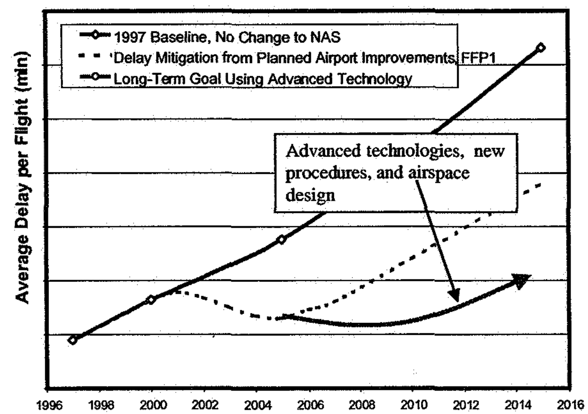
White Paper

- Content
  - Description of transportation trends, and definition of problem -nature of constraints to growth and demand verses supply mismatch
  - Identify solution space (technical/operational leverage) and barriers/issues to unlocking leverage for issues outlined above
  - Matrix of options for consideration, major uncertainties, questions, future requirements or constraints. "Hooks" to expand discussion to other modes for complete systemic view
- Status
  - In preparation
  - First draft for review and comment by October 2000
  - NASA-FAA draft can be used by other mode's as a model for their white papers

AvSTAR Planning

Urgency

- All analyses indicate that with continued growth, delay within the system will remain at unacceptable levels - *even when we implement everything that is in the pipeline*



MITRE/CAASD
August, 2000

Complexity

- At the same time, the air transportation system is extremely complex
  - The operational system displays the behavior of a non-linear, dynamic system
  - A large number of stakeholders within the system

From the Washington Post -- September 13, 2000
Hundreds of travelers who thought they were just passing through O'Hare International Airport were forced to spend Monday night on cots and on the floor after storms canceled dozens of flights.

From the Washington Post -- September 10, 2000
The airlines blame the FAA for not having improved the system for 20 years ago as promised; the FAA blames the airlines for overscheduling; and the same local citizens who, as passengers, may complain about poor airline service also oppose expanding airports. As a result, at a time when we most need airport expansion, we are left with an institutional gridlock that weakens our ability to get anything accomplished.
Darryl Jenkins, Director of the Aviation Institute, George Washington University

Dealing with an urgent & complex problem

- Many potential outcomes in trying to solve an urgent and complex problem, *most of them are not good*
- Need to continue evolutionary technology development and implementation in the near-term while working more fundamental research and advanced concepts for the long-term
- Requires high fidelity testing to prove out concepts and technology
- All key stakeholders must buy-in
- For advanced concepts, need to protect the effort from tendency to pull back to nearer-term, incremental solutions

Strategies for Moving Forward

- Continue to support Free Flight implementation and the development of automation aides
- Aggressively pursue system concept studies to develop overall system architecture options that can operate at higher capacities
- Develop a large-scale, non-linear simulation capability for the air transportation system to better understand and perform trade-offs for technology and advanced concepts
- Pursue a partnership model that integrally includes all key stakeholders

Conclusion

- Growing recognition for the need for renewal of transportation to meet the mobility needs of the Nation
- Air transportation is the key for the growing demand for high speed transportation
- Advanced aviation system concepts and supporting technology is the cornerstone for continuing to advanced air transportation

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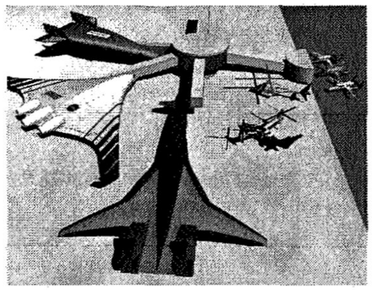
AvSTAR

September 21, 2000



Dr. Dallas G. Denery
Deputy, Aviation Systems Division
Ames Research Center

1

Planning Team

Chair: Dallas G. Denery (ARC)

Core Planning Team: W. Bryant (LaRC), J. Shin (GRC), T. Edwards (ARC), T. Allard (ARC), H. Erzberger (ARC), K. Roth (ARC), H. Schlickenmaier (HQ), H. McLaurin (FAA)

Associates:
- ARC:
  - S. Atkins ,T. Davis, B. Sridhar, S. Green, K. Bilimoria , R. Remington ,Y. Gawdiak, Jon Guice, J. Zuk
- LaRC:
  - K. Willshire, S. Johnson, D. Hinton
- GRC:
  - D. Ponchak, Bob Kerczewski

FAA :
- W. Mackenzie, S. Bradford, B. Sanford, J. Recstad, T. Proeschel, S. Pansky, G. Green, S. Moore, G. Kulesa, J. Merkle, D. Ford, C. Rapport

2

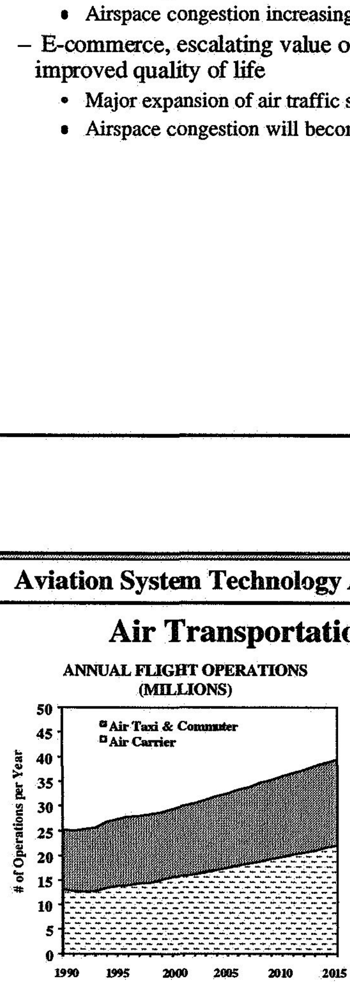
Background

Air transportation delays/congestion continue to grow

- Airline traffic is predicted to grow at 4.3%/year
  - Significant increase in number of delays at busy airports
  - Increasing number of secondary airports experiencing major delays
  - Airspace congestion increasingly becoming major contributor to schedule reliability
- E-commerce, escalating value of property in major commerce centers, search for improved quality of life
  - Major expansion of air traffic services at smaller airports
  - Airspace congestion will become dominant

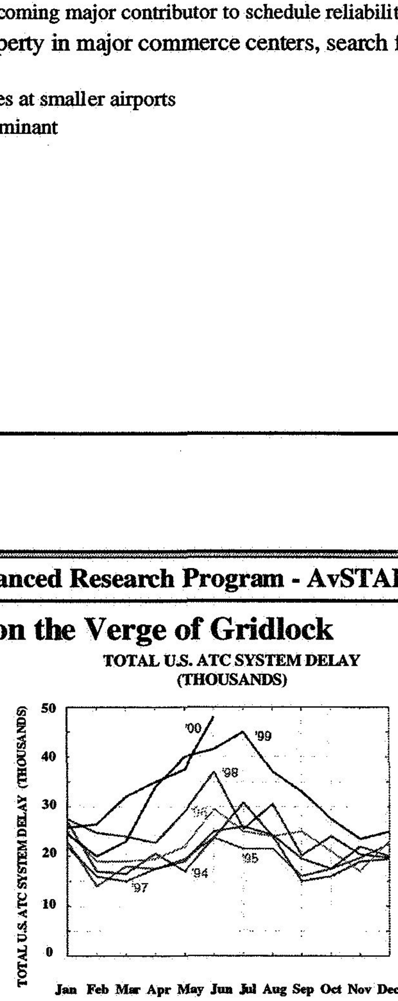
Air Transportation, on the Verge of Gridlock

ANNUAL FLIGHT OPERATIONS
(MILLIONS)



Sources: FAA 1999 Terminal Area Forecast Report

TOTAL U.S. ATC SYSTEM DELAY
(THOUSANDS)



Source: Aviation Week & Space Technology, October 25, 1999

Demand is escalating faster than the general economic growth

Delays are soaring and passenger rage is skyrocketing

"Washington, we have a problem"

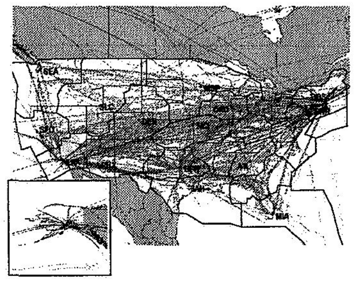
Source: Avoiding Aviation Gridlock: A Consensus for Change, National Civil Aviation Review Commission, Sept 10, 1997, N. Mineta, Chair

Aviation System Technology Advanced Research Program - AvSTAR

Constraining Factors on Today's Air Transportation System

Today's System

- Over 2000 sectors -
- 18,000 ATC personnel -
- Limited runway construction -



- Inability to further reduce separations between aircraft
  - Technology limitations
  - Human limitations
  - Sectorization of airspace has reached its limit
- Inability to make best use of available information to optimize traffic flow

Aviation System Technology Advanced Research Program - AvSTAR

The Problem and Solution Options

Without new technology the results are unacceptable

Maintain Current Capabilities
(System on Verge of Gridlock)

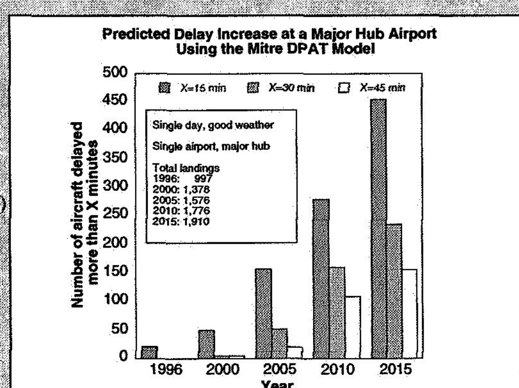
- Restrict Growth
- Expand Hours of Operation
- Open New Airfields

(This will lead to increased airspace congestion)

Insert New Technologies within Current Paradigm - Tomorrow's System (free-flight)

- FFP1, FFP2, & FFP3
- (Provides Relief Over Next 10-12 Years)

A Revolutionary Change in Airspace Operations- The Future System
(The only real solution for the long-term)



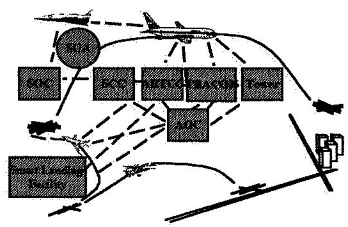
Source: Donohue, G., "Investing in Air Transportation Research," *Aerospace America*, Sept. 2000, pp. 28-31

Aviation System Technology Advanced Research Program - AvSTAR

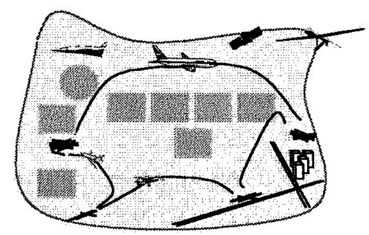
Air Transportation Vision

Seamless operations for all vehicle classes across all airspace to provide vast increases in movement of people/cargo through

- integrated airspace operations
- sharing of information from distributed sources including weather
- advanced automation
- human interactive system monitoring and goal setting capabilities



Today's ATM System
Distinct facilities/segregated airspace
- Procedure based coordination across facility/airspace boundaries -



The Future Air Transportation System
Unified
- Seamless operations for all vehicle classes across all airspace -

7

Aviation System Technology Advanced Research Program - AvSTAR

The Status

Tomorrow's Air Transportation System definition is clear ("Free Flight") and is supported by all constituents

- First implementation has started (NASA products = TMA, pFAST and SMA)
- BUT, significant R&D required to complete Goal/Vision
- The Free-Flight Program will not solve the long-term problem

The Future Air Transportation System is still notional

- *No one* is conducting the research to support the far-term concepts, technologies and methods

The capability required for evaluating future concepts at the requisite degree needs to be available

8

Aviation System Technology Advanced Research Program - AvSTAR

Program Goals and Objectives

Objectives:

Provide the research and development by 2007 necessary to:

- Complete the development of technology for tomorrow (Free-Flight)
- Provide the foundations for setting the direction for the future (Beyond Free-Flight)

Goals (Air transportation as one component of a fully integrated multi-modal transportation system):

Tomorrow's Air Transportation System*

- 20% increase in throughput at high density airports
- 25% reduction in today's missed/canceled flights due to traffic problems

The Future Air Transportation System*

- 3X increase in throughput at high density airports
- 50% reduction in rate of missed/canceled flight

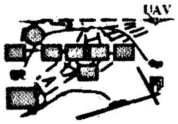
* Systems studies have been initiated to validate goals against program elements

9

Aviation System Technology Advanced Research Program - AvSTAR

The Program

Program Integration



System-Level Operations Concepts

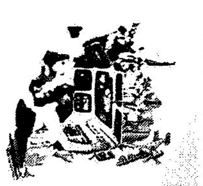
Tomorrow's ATM Vision
- Align with FAA/Industry Concept of Operations

The Future Air Transportation Vision

Coordinate with FAA and industry
- Functional definition
- Architectural implications
- Interfaces with local transportation

System-Level Simulation

Tomorrow's ATM System - *Technologies for Tomorrow*

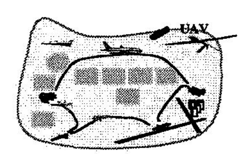


- Surface congestion alleviation
- Runway productivity technologies
- Technology enhanced arrival/departure decision support tools
- Integrated airspace decision support tools
- National traffic flow management
- Runway Independent Aircraft operations
- ATM/TFM weather

Full vehicle-class coverage

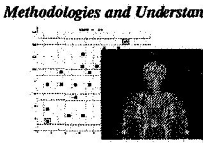
Future Air Transportation System - ***Foundations for the future***

System Level Definition
- ATM system level definition/design
- Design for integrity/reliability/graceful degradation



Breakthrough Concepts
- ATM automation
- CNS and System Architecture(software/hardware)
- Airport/constrained airspace technologies
- Integration of all vehicle classes

Methodologies and Understanding



- System analysis and simulation methods including multi-modal transportation
- Human-system modeling and understanding

10

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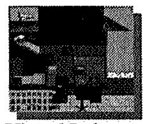
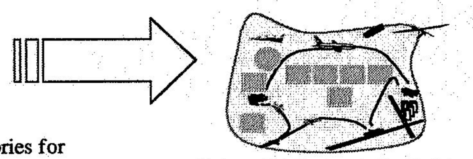
Validate Through System-Level Simulation

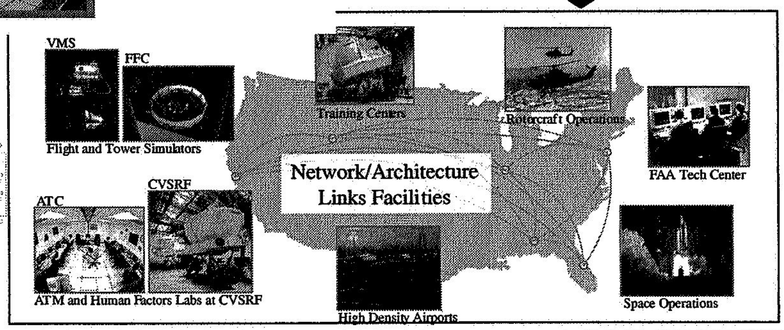
Collaborative Tools for System Level Assessments



Virtual Laboratories for Command and Control



Future Air Transportation System



Seamless integration of national simulation facilities into a virtual validation environment enables rapid prototyping of future ATM concepts and high-fidelity, human-in-the-loop demonstrations

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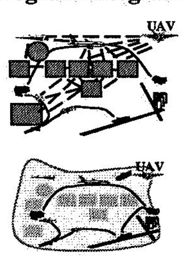
Aviation System Technology Advanced Research Program - AvSTAR

The Program

Program Integration



System-Level Operations Concepts

Tomorrow's System

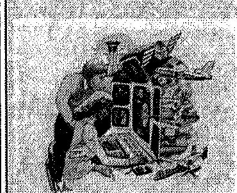
- Align with FAA/Industry Concept of Operations

The Future Air Transportation Vision

Coordinate with FAA and industry
- Functional definition
- Architectural implications
- Interfaces with local transportation

System-Level Simulation

Tomorrow's ATM System - *Technologies for Tomorrow*



- Surface congestion alleviation
- Runway productivity technologies
- Technology enhanced arrival/departure decision support tools
- Integrated airspace decision support tools
- National traffic flow management
- Runway Independent Aircraft operations
- ATM/TFM weather

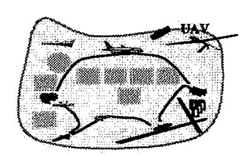
Full vehicle-class coverage

Future Air Transportation System -

Foundations for the future

System Level Definition

- ATM system level definition/design
- Design for integrity/reliability/graceful degradation



Breakthrough Concepts

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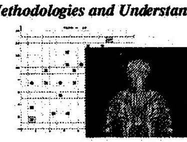
Methodologies and Understanding



- System analysis and simulation methods including multi-modal transportation
- Human-system modeling and understanding

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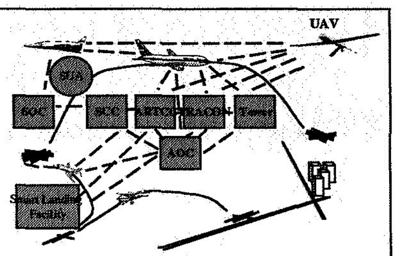
Tomorrow's Air Transportation System

Defined in FAA/RTCA Concept of Operations



Tomorrow's ATM System
Interoperable
- Intelligent advisories for interoperability -

Technology Challenges

Improved traffic flow management predictions and decision making
- Collaboration between users and computer assisted re-routing
- Improved prediction of traffic patterns and weather

Remove restrictions across facility/sector boundaries
- Introduction of decision support tools such as CTAS integrated with weather for dynamic re-routing

Reduce separation requirements in the terminal area
- Monitoring of trailing vortices
- Technologies for relative positioning of aircraft

Eliminate surface congestion
- Sharing of information on arrivals, departures, gate status
- Taxi guidance
- Intelligent decision making/cueing to eliminate runway incursions
- Optimized taxiway/runway designs/improvements

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Aviation System Technology Advanced Research Program - AvSTAR

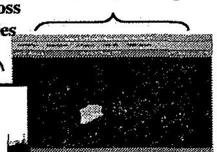
Tomorrow's Air Transportation System (The Program)

Improved predictions and decision making

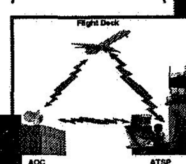
Remove restrictions across facility/sector boundaries

Reduce separation in the terminal area

Eliminate surface congestion

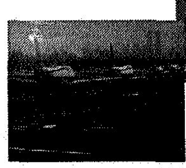


National Traffic Flow Management



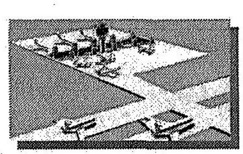
Integrated Airspace Decision Support Tools

Arrival/Departure Decision Support Tools

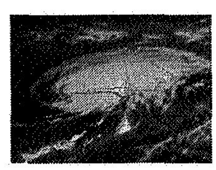


Surface Congestion Alleviation

Runway Productivity



Runway Independent Aircraft Operations



ATM/TFM Weather Integration

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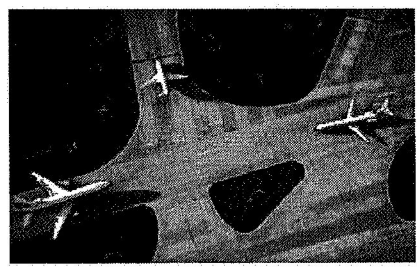
Aviation System Technology Advanced Research Program - AvSTAR

Surface Congestion Alleviation



Objective

Airport congestion is rapidly becoming the limiting factor in airport throughput. Incidents of runway incursion in today's system are threatening current airport throughput. Develop traffic management automation, and required technologies, to alleviate surface congestion.

Activities

- Develop & field test near-term advances (early deliverables). Initiate joint activity as a team member in identifying and developing procedures to safely reduce runway/taxiway congestion, making use of the Future Flight Central tower simulator.
- Develop technologies to enable automation aids that will alleviate runway congestion in IMC and VMC while eliminating runway incursions. Investigate solutions that require more substantial changes in the NAS including integration of arrivals, departures and surface operations (field tests toward end of project).

Benefits

- Increased airport throughput (by coordinating taxi occupancy of runways with arrivals & departures)
- Reduced taxi delays (due to queuing for active runway crossings)
- Increased taxi route conformance
- Reduced controller and pilot workloads

Issues

Procedures for "holding short" and "crossing active runways" need to be improved and integrated with an overall surface management strategy to provide improved airport throughput.

- Predictive algorithms to plan runway occupancy (arrivals, departures, and crossings)
- Advisories and displays for controllers and pilots
- Supporting procedures
- Employ datalink to connect flight deck and ATC tower
- Integrated with arrival and departure tools

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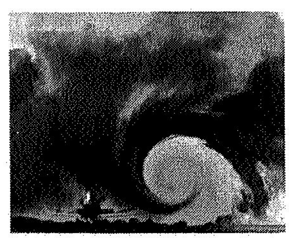
Runway Productivity



Objectives:

Develop and test new aircraft and sensor technologies and associated procedures including safety assurance information/assessments for increased capacity within the terminal area

Activities:

Building on AVOSS and AILS, develop technologies and procedures critical to achieving increased capacity

- **Develop aircraft technologies for closely spaced parallel/converging runway approaches**
  Advanced traffic alerting/detection and avoidance systems and pilot interface devices using high update surveillance capabilities integrated with digital terrain/TERPS databases and traffic information
- **Wake vortex sensor technology**
  Develop and evaluate wake vortex sensor system technology for arrivals to parallel/converging runways and departures in operational environment

Key Issues:

Parallel/converging runways

- Design for reliability/robustness
- Interaction with other traffic in the event of an alert
- Integration of mixed equipage
- Shared picture between ground and air

Wake Vortex

- Stability of vortex predictions
- Reliability of predictive vortex decay modeling
- Procedures for integrating into routine operations
  - Clear/concise information
- Vortex sensor placement

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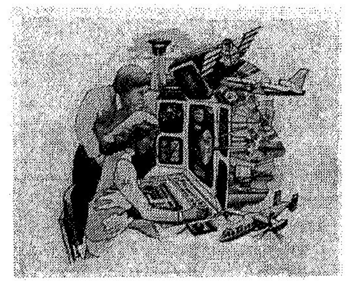
Aviation System Technology Advanced Research Program - AvSTAR

Technology Enhanced Arrival/Departure Decision Support Tools

Objectives:

Optimize throughput through the introduction of new technologies and the maturation of emerging technologies.



Activities:

Terminal arrival/departure/surface planning advisory system
Building on CTAS, SMS, existing tower capabilities and advances in data-link, weather and vortex sensing technologies, develop and demonstrate interdependent arrival, departure, and surface tools to maximize throughput

- **Dynamic spacing/routing based on weather/vortex**
  Accelerate aFAST and enhance to include weather/vortex constraints/opportunities for dramatic increase in capacity while maintaining safety
- **Expedite departure path planner (EDP)**
  Develop path planning tools that are compatible with FAST to aid the controller in safely merging departure traffic into en route streams
- **Environmentally compatible operations**
  Enhance FAST and EDP with capabilities to support reduced noise arrival and climb-out routes
- **Interdependent arrival/surface advisory system**
  Develop the automation to assist in airport-centric flow control for interdependent arrivals and departures

Key Issues:

- Human/DST interaction for safety of operations
- Design for robustness
- Integration of mixed equipage
- Air/ground integration via data-link

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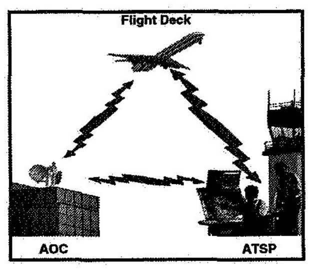
Aviation System Technology Advanced Research Program - AvSTAR

Integrated Airspace Decision Support Tools

Objectives:

Develop flight deck and ground technologies aimed at removal or reduction of restrictions through collaboration between regional/local traffic management coordinators, sector controllers, airline operations center personnel, and flight crew



Activities

Time-based scheduling for regional/local traffic flow management

- **Constrained Airspace Tool**
  Assist TMC's in making flow changes in congested sectors by techniques such as dynamic re-sectorization, re-routing, and metering
- **Regional Metering Tool**
  Distribute metering delays to Centers upstream of the flow constraint problem

Controller advisory tools for achieving flow conformance

- **En route Spacing Tool**
  Assist sector controllers trial-plan and execute conflict-free flight deck compatible trajectories that efficiently conform to spacing restrictions
- **En route Descent Advisor**
  Advise sector controllers on how to achieve conflict-free flow-rate conformance to spacing restrictions or metering times that are flight-deck compatible.
- **Direct-To Tool integrated with TFM tools**
  Ensure compliance of Direct-To advisories with downstream TFM constraints

ATC/AOC/Flight Deck Integration

- Facilitate collaboration between AOC, local flow control, sector controllers and flight deck as a function of equipage (FMS, data-link)

Key Issues:

- Affecting flights to meet flow rate in a way that minimizes impact on AOC and is compatible with aircraft performance and crew procedures
- Mixed equipage
- Integration with complementary decision support tools for CDM and en route flow control being developed by FAA and companion organizations

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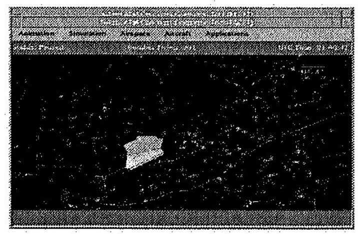
Aviation System Technology Advanced Research Program - AvSTAR

National Traffic Flow Management



Objectives:

Develop technologies for planning NAS-wide TFM initiatives through collaboration between system command center managers, regional/local traffic management coordinators, and flight operations center personnel.

Activities:

- **Traffic Flow Automation System**
  TFAS will run multiple instances of CTAS to create a 'National' CTAS functionality. TFAS will provide aircraft prediction data to the FAA System Command Center's Enhanced Traffic Management System (ETMS) to increase the reliability of ETMS Sector-Overloading and Monitor-Alert tools.

- **System-level Traffic Re-routing Tool**
  Automation to assist SCC managers collaborate with AOC personnel to balance airspace demand across the NAS by implementing an appropriate mix of traffic re-routing and ground delays at the national level.

- **National Traffic Flow System Analysis/Assessment**
  Assess performance of National Traffic Flow to identify primary factors that lead to delay, errant rerouting, effective strategies

Key Issues:

- Accuracy in predicting traffic flows in actual operations given fidelity in weather, aircraft performance and intent information
- Optimizing system-level performance while allowing airspace users to manage their fleet
- Shared awareness between all parties
- Integration of weather prediction capabilities
- Integration with complementary decision support tools for CDM and National Traffic Flow Management being developed by FAA and companion organizations

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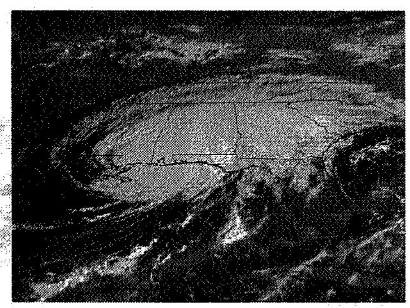
Aviation System Technology Advanced Research Program - AvSTAR

ATM / TFM Weather Research



Objective:

Develop requirements for weather products tailored towards ATM/TFM applications and invest in existing mid/long-term weather research to develop these products and integrate with ATM Decision Support Tools

Activities:

The ATM Meteorology Research Team
NASA will form a small interdisciplinary team that bridges the gap between the ATM/TFM and meteorology communities. This team will identify, instigate and coordinate cooperative weather research that serves ATM/TFM weather information needs. By utilizing small, targeted research investments, innovative solutions can be developed for a wide variety of ATM/TFM prediction needs. Potential research includes:

- Definition of ATM/TFM Relevant Weather Information
- Validation ATM/TFM Weather Predictions
- Development of Prediction Probability/Uncertainty Models for ATM Application
  User Deviation Probability & Impact Assessment/estimation of pilot willingness to penetrate bad weather and the impact on traffic flows.

Key Issues:

Enables Revolutionary Advances

By utilizing expert knowledge in both ATM and meteorology, new and innovative solutions can be identified and developed.

Highly Leveraged Investment

NASA can steer or expand the scope of research performed in the meteorology community to address ATM needs for a fraction of the cost of doing in-house research. (A strategy successfully used by NASA's "Wind Research Team.")

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Runway Independent Aircraft Operations

Objectives:

- **Develop technologies & criteria database that will:**
  - **Enable simultaneous non-interfering (SNI) A/C ops**
  - **Allow V/STOL aircraft to operate at airports under Cat IIIA**
  - **Establish ops requirements for future powered lift A/C**

Activities:

- **SNI Criteria Database Development**
  - **Ops Concept**
  - **Adverse weather / low noise ops**
- **ATM / Aircraft Systems Integration**
  - **Human Centered Cockpit**
  - **ATM tools**
- **V/STOL A/C Performance / Airspace Requirements Database**
- ***Demonstrations***

Benefits:

- **Air traffic growth without enlarging airports**
- **Aviation System throughput increase & delay reduction**
- **Airspace safety & reliability improvement**
  - **Vehicles use unused & underutilized space**
- **National mobility & accessibility increased**

Key Issues:

- **Air & and infrastructure requirements**
- **Level I handling qualities**
- **Non-interfering missed approaches & guided departures**
- **Low noise flight paths**
- **SNI ops concept acceptance**

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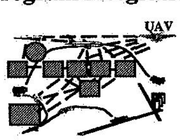
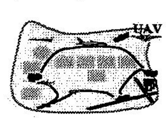
Aviation System Technology Advanced Research Program - AvSTAR

The Program

Program Integration





System-Level Operations Concepts

Tomorrow's System

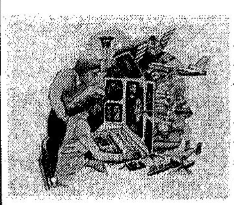
- Align with FAA/Industry Concept of Operations

The Future Air Transportation Vision

Coordinate with FAA and industry
- Functional definition
- Architectural implications
- Interfaces with local transportation

System-Level Simulation

Tomorrow's ATM System - *Technologies for Tomorrow*



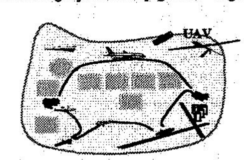
- Surface congestion alleviation
- Runway productivity technologies
- Technology enhanced arrival/departure decision support tools
- Integrated airspace decision support tools
- National traffic flow management
- Runway Independent Aircraft operations
- ATM/TFM weather

Full vehicle-class coverage

Future Air Transportation System - *Foundations for the future*

System Level Definition

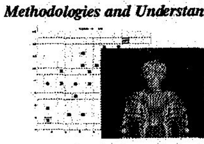
- ATM system level definition/design
- Design for integrity/reliability/graceful degradation



Candidate Breakthrough Concepts

- ATM automation
- CNS and System Architecture(software/hardware)
- Airport/constrained airspace technologies
- Integration of all vehicle classes

Methodologies and Understanding



- System analysis and simulation methods including multi-modal transportation
- Human-system modeling and understanding

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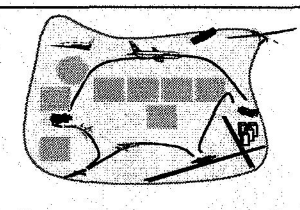
Aviation System Technology Advanced Research Program - AvSTAR

The Future Air Transportation System

Notional - Concept of Operations Does not Exist



The Future Air Transportation System
Unified
- Seamless operations for all vehicle classes across all airspace -

Technology Challenges

Candidate Breakthrough Concepts
- ATM automation
  - -Eliminate sector-based control of traffic
  - -Elevate controller to system-level manager
  - -Remove controller from tactical control of traffic
  - - Automated conflict detection and resolution
  - -Real-time system -wide optimization
  - -Probabilistic decision making
  - -Integration of airspace resources
  - -Planning over continuum of time horizons
  - -Human interactive model-based monitoring and goal setting
- New technologies for quantum leaps in capacity/throughput
  - - Airports
  - - Weather
- Infrastructure concepts
- Full vehicle class coverage

Methodologies and Understanding
- Systems analysis and simulation methods
- Human System Modeling and Understanding

System Level Definition
- Functions, architecture, interfaces with local transportation
- Design to allow for sub-system failure
  - -Levels of automation for system planning/separation assurance
    - - Ground based
    - - Airborne based
- Transition from today
- Validate through system level simulation

The Enablers
- Tomorrow's technologies provide the building blocks
- Information systems technologies provide the mortar (Automated reasoning, human centered computing, intelligent data understanding, revolutionary computing)

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Aviation System Technology Advanced Research Program - AvSTAR

The Future Air Transportation System (The Program)

System Level Definition

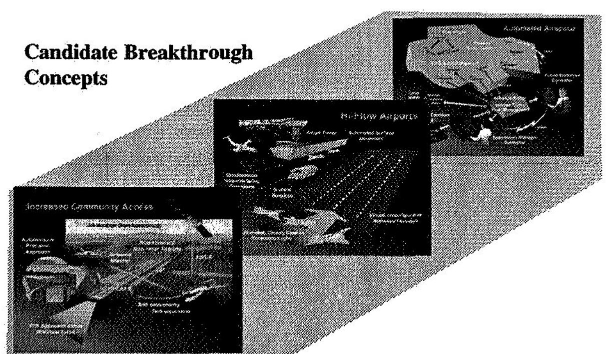
Functions, architecture, interface with local transportation

Design to allow sub-system failure

Transition from today

Validate through system level simulation

Candidate Breakthrough Concepts



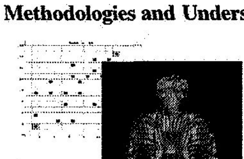
ATM automation
- **Super-sector**
- **Real-time system wide optimization**
- **Interactive model-based monitoring and goal setting**

Quantum leaps in capacity/throughput

Infrastructure concepts

Full vehicle class coverage

Methodologies and Understanding



Systems modeling/analysis and simulation

Human modeling and understanding

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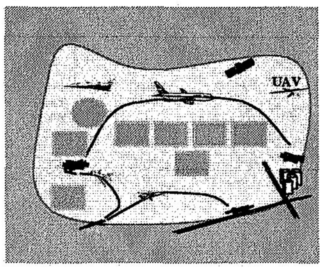
Aviation System Technology Advanced Research Program - AvSTAR

The Future Air Transportation System

System-level Definition



Objective:

Identify and assess overall operations concepts/system designs for Unified Airspace System and integrate with concepts from the elements.

Activities:

- ATM System Level Definition/Design
  - Identify and further develop system-level operations concepts
  - Define overall architectural designs satisfying the operational concepts
  - Assess candidate operations concepts through systems analysis and modeling
  - Define interfaces with other transportation entities
- Design for reliability/integrity/ graceful degradation
  - Conduct failure modes and affect analysis
  - Investigate model-based reasoning tools and other methods for system monitoring/warning
  - Conduct analysis and simulation to validate system robustness to failure
- Transition from today
- Validation with high-fidelity, human-in-the-loop simulation

Key Issues:

- Very complex and heterogeneous environment to visualize
- Very difficult task to build a consensus
- System level modeling lacks credibility
- Implications on the human operator of novel approaches is difficult to assess

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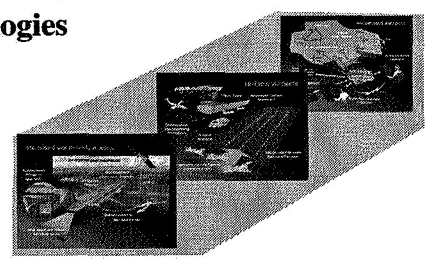
Aviation System Technology Advanced Research Program - AvSTAR

The Future Air Transportation System

Breakthrough Concepts &Technologies



Objective:

Conduct exploratory research to identify novel concepts and technologies for enabling the unified airspace vision

Activities (Candidates):

- **ATM Automation Concepts**
  - Real-time system wide optimization
  - Eliminate sector-based control of traffic
    - Elevate controller to system-level manager
    - Automated conflict detection and resolution
  - Human interactive model-based monitoring and goal setting
- **New technologies for capacity/throughput**
  - Airports
  - Weather
- **Infrastructure Concepts**
  - CNS technologies
  - Architecture/software
- ***Integration with all Vehicle Classes***
  (Space operations, unmanned air vehicles)

Key Issues:

- Acceptance of major paradigm shifts
- Modeling benefits and safety of revolutionary concepts
- Future vision continually changes with new technologies and societal needs
- Transition path to implement revolutionary changes

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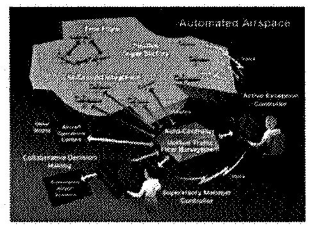
Aviation System Technology Advanced Research Program - AvSTAR

ATM Automation Concepts



Objective:

Develop advanced ATM concepts and human automation technologies to enable major increases in the NAS capacity

Activities:

- Real-time system-wide optimization
  - Innovative ATM processes to meet real-time market demand
  - Integrated planning across across all the NAS timeframes
- Eliminate sector-based control of traffic
  - Automated aircraft separation while meeting flow control constraints
- Interactive model-based monitoring and goal setting
  - Human role in direction of automated ATM/C systems
  - Monitoring state of automated systems

Key Issues:

- Human role in automated systems
- Reliability, robustness and failure handling of automated systems

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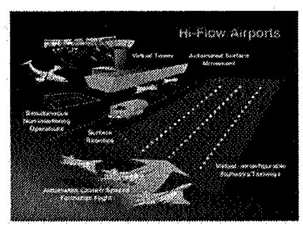
Aviation System Technology Advanced Research Program - AvSTAR

Quantum Leaps in Capacity/Throughput



Objective

Develop advanced concepts and technologies to enable quantum leaps in throughput at airports and in enroute weather

Activities

- **Airport Operations**
  - Meta-airport operations
  - Closely spaced aircraft take-off and landing
  - Dynamically reconfigurable runway location
  - Automated zero-visibility surface movement
  - Dynamic virtual ramp and control towers
  - Airport robotics
  - Non-towered airport automation to support high-density operations
- **Weather Operations**
  - Coupling of weather prediction with ATM:
    - Precise aircraft movement around weather cells in enroute airspace
    - Accurate airport runway/airspace reconfiguration

Key Issues

- Accuracy and confidence of weather prediction
- System reliability and safety of closely spaced aircraft operations
- Wake vortex prediction system accuracy and confidence

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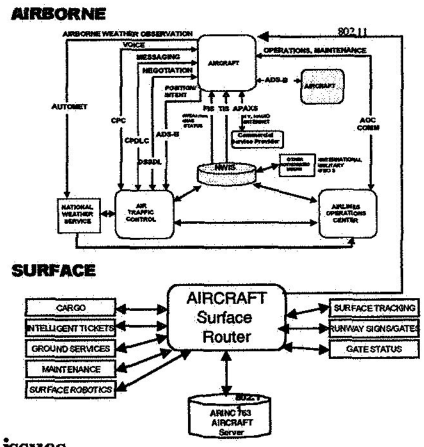
Infrastructure Concepts

Objectives

Develop concepts for high-capacity, integrated communications/navigation/surveillance infrastructure for gathering and disseminating information in the air and on the ground to support highly-automated air traffic management.

Activities

- Derive requirements for future air traffic management information flow – quantity, accuracy, integrity, reliability.
- Develop and assess candidate architectures for a highly integrated global aviation system information infrastructure.
- Validate infrastructure concepts through high fidelity simulations.
- Develop and demonstrate key technologies.



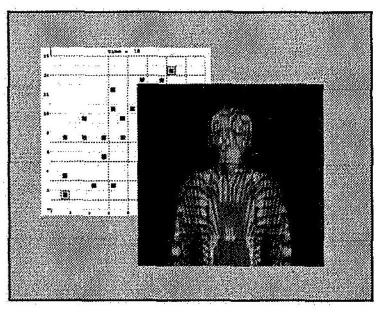
Key issues

- A quantum leap in information flow is required.
- Information accuracy, integrity, reliability, and security must be sufficient to support complex, highly integrated global systems.
- Global standards and interfaces are required.
- Transition from current to future infrastructure is a major impediment.

2

The Future Air Transportation System

Methodologies and Understanding



Key Issues:

- Design for robustness and safety
- Analysis methods for human-directed automated systems
- Human role in highly automated systems

Objective:

Develop the methods and fundamental understanding needed to support systems analysis and design of future unified airspace operations

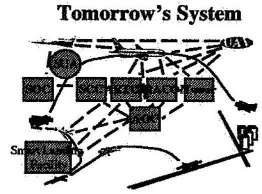
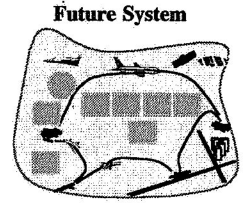
Activities:

- **Novel methodologies and design tools**
- **Advanced systems analysis, design and simulation methods**
  - Total system models for systems analysis
  - Analytic methods for hybrid systems
  - Simulation methods
  - Common trajectory models
- **Human System Modeling and Understanding**
  - Computational models of human teams
  - Human interaction with distributed systems
  - Mathematical models of human/system performance

3

Aviation System Technology Advanced Research Program - AvSTAR

Products

	Tomorrow's System	Future System
		
	Technologies by 2007 for Tomorrow's System	**Foundations by 2007 for Future System**

System-level Integration	• Improved National Flow Control
	  • Traffic Flow Automation System for system-wide flow predictions
	  • User/system automated re-routing tool
	• User compliant local flow control automation
	  • Automation for metering in congested airspace
	  • Aircraft compatible sector advisories
	  • Collaborative AOC, Flight deck, ATC
	• Weather integration for TFM/ATM
		• Validated set of future ATM concepts
		  - Design for safety/graceful degradation
		• Tools for analyzing and designing a unified system
		  • Systems analysis
		  • Performance/safety analysis and design
		  • Common trajectory prediction methodology
		• Understanding of human attributes/limitations in highly integrated/distributed systems
		• Candidate CNS /architectural concepts
		• Implications of full vehicle-class coverage

Local Optimization	• Technology-enhanced arrival/departure/surface advisory systems
	  • Dynamic spacing/routing
	  • Integrated departure/surface operations
	  • Surface congestion alleviation
	• Wake vortex sensor technology for arrivals and departures
	• Technology for approaches to closely spaced parallel and converging runways
	• Validation of runway independent operations
		Feasibility established for
		• Use of information technologies for improved airport operations
		• High flow airport concepts
		• Virtual runways/taxi-ways
		• Virtual tower and remote-airport sensor system
		• Smart landing facilities for non-towered airports
		• Airport automation

31

Aviation System Technology Advanced Research Program - AvSTAR

Progression Towards the Future

Aviation System Technology Advanced Research - AvSTAR
- Development of core component technologies for quantum improvements in capacity/throughput and seamless operations across all airspace
  - Development and integration of active air traffic management automation tools with advanced technologies (wake vortex sensor system, ADS-B, weather)
  - Breakthrough air traffic management concepts beyond today's Free-Flight Program
- Development of a virtual airspace simulation environment for testing advanced concepts
- Evaluation of advanced air traffic management concepts

Small Aircraft Transportation System - SATS
- Airborne technologies for revolutionary personalized transportation system to non-towered airports

Aviation Systems Capacity - ASC
- First generation technologies for early capacity increases
  - Passive controller/TMC automation decision aids
- Concept exploration for distributed air/ground traffic management
- Continued support for the FAA's Free-Flight Program

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Conf Paper / 03 / IN / 03 2001057102 525153 pgs 14

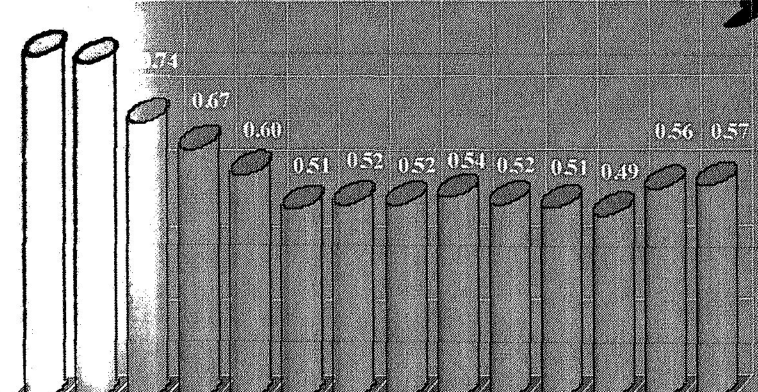
Tomorrow's System

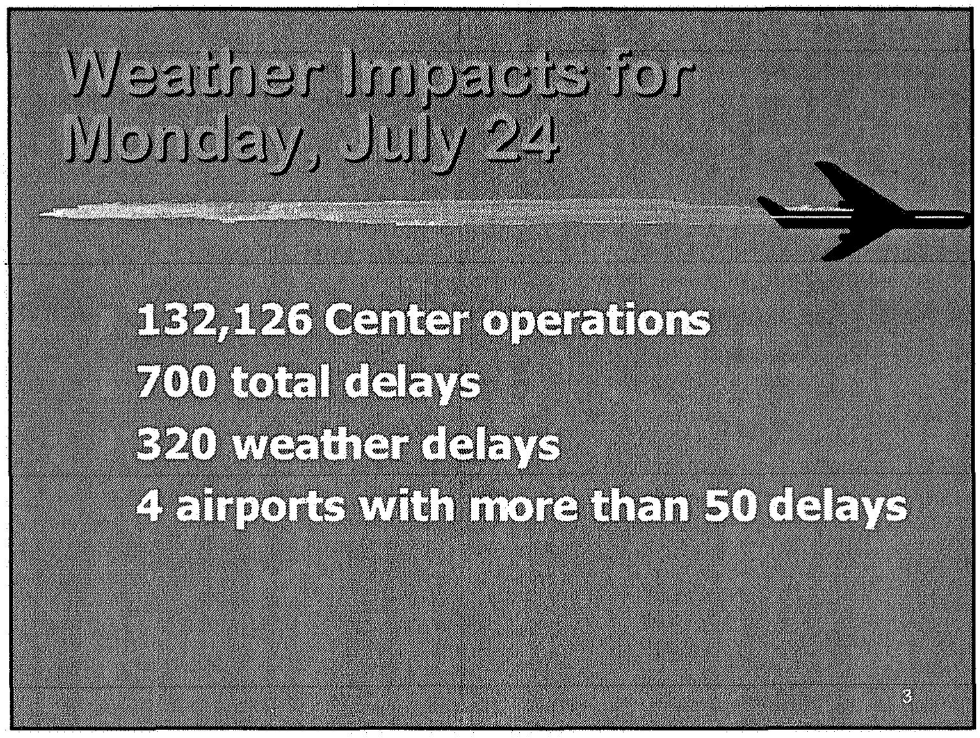
Ron Morgan, FAA Director of Air Traffic

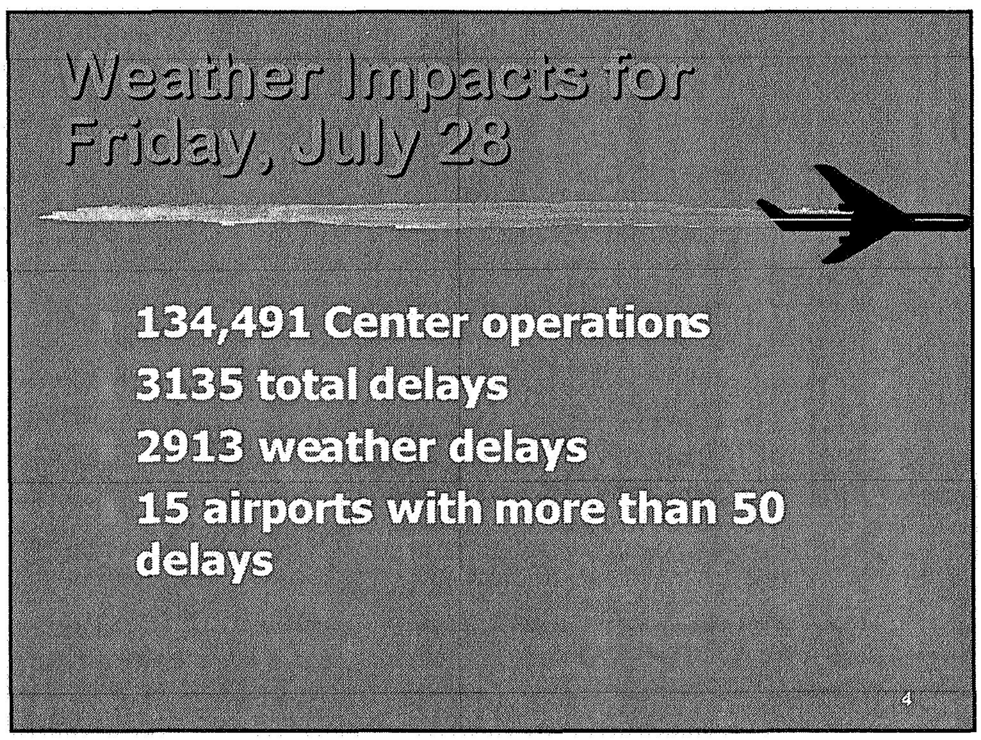
Aviation Systems Technology Advance Research Workshop

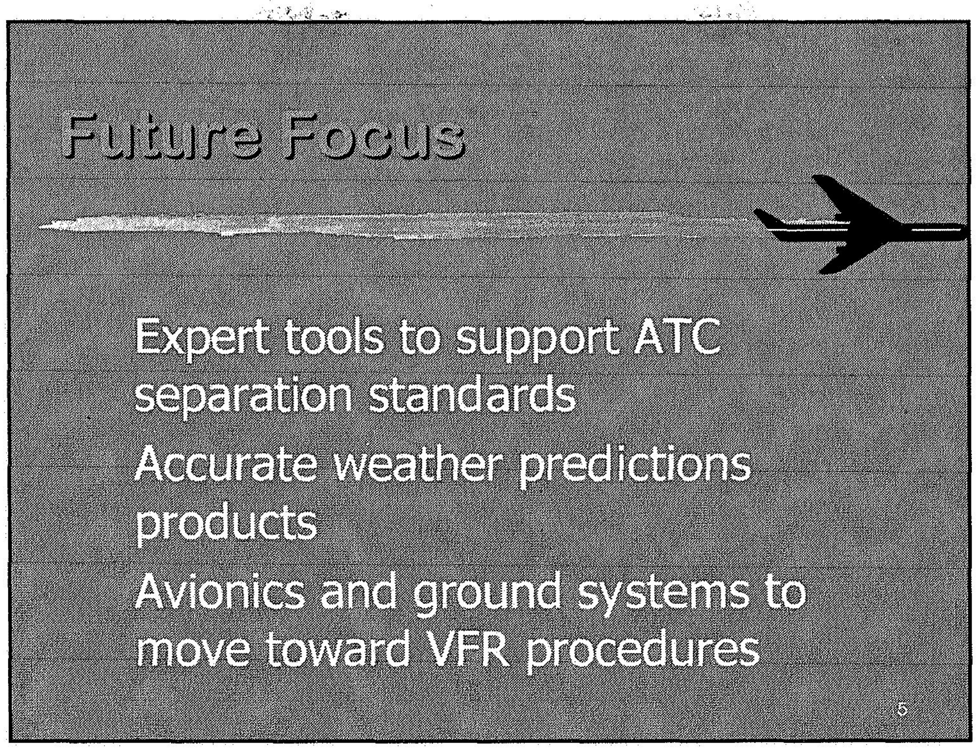
September 21, 2000

SAFETY: Operational Error Rate




Weather Impacts for Monday, July 24
132,126 Center operations
700 total delays
320 weather delays
4 airports with more than 50 delays
3


Weather Impacts for Friday, July 28
134,491 Center operations
3135 total delays
2913 weather delays
15 airports with more than 50 delays
4


Future Focus
Expert tools to support ATC separation standards
Accurate weather predictions products
Avionics and ground systems to move toward VFR procedures
5

Comments on the NASA AvSTAR Program
Tomorrow's ATM System

NASA Ames
September 21, 2000
Robert Schwab, Aslaug Haraldsdottir
The Boeing Company

ATM_Overview 1

NAS Architecture Evolution

Strategic Goals

- ATM 2000+
- FAA
- NASA Goals
- ICAO

Options for the NAS
- NAS Growth & Constraints
- Emerging Technologies
- Alternative Futures
- Globalization

Phase 3
- Far Term (2011-2025)
- Concept Architecture
- Technology Exploration

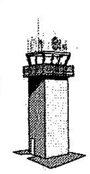
Modernizing the NAS
- NAS Performance
- NAS Safety Enhancement
- NAS Affordability

Phase 2
- Mid Term (2003-2010)
- Modernization Architecture
- New Functionality

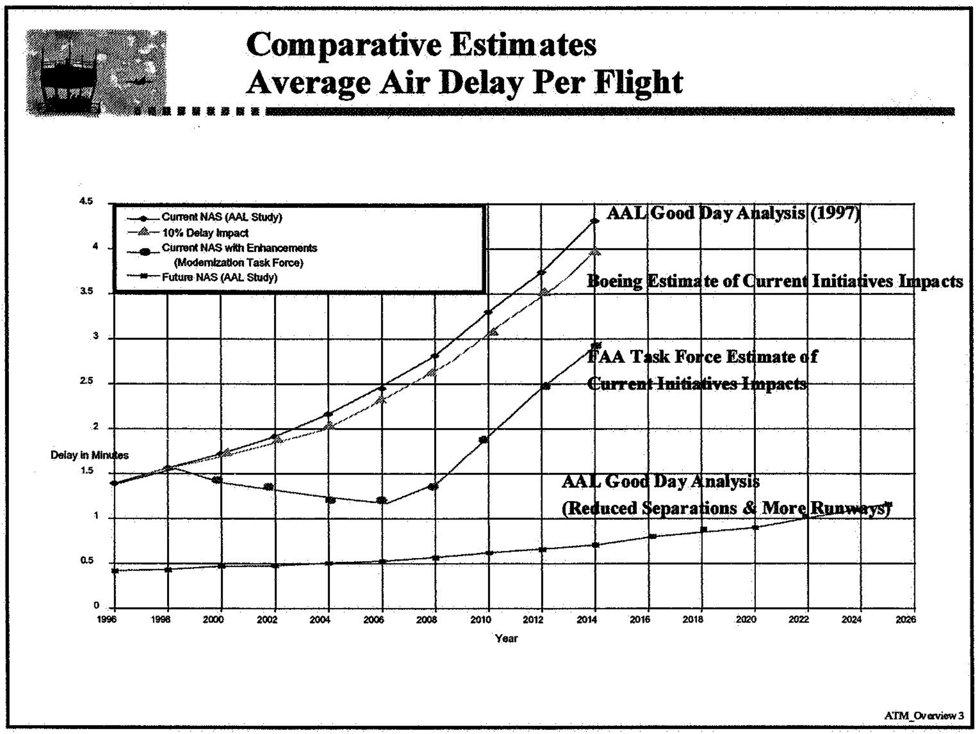
Sustaining the NAS
- NAS Sustaining
- Funding Profiles
- Limited User Benefits
- Risk Management

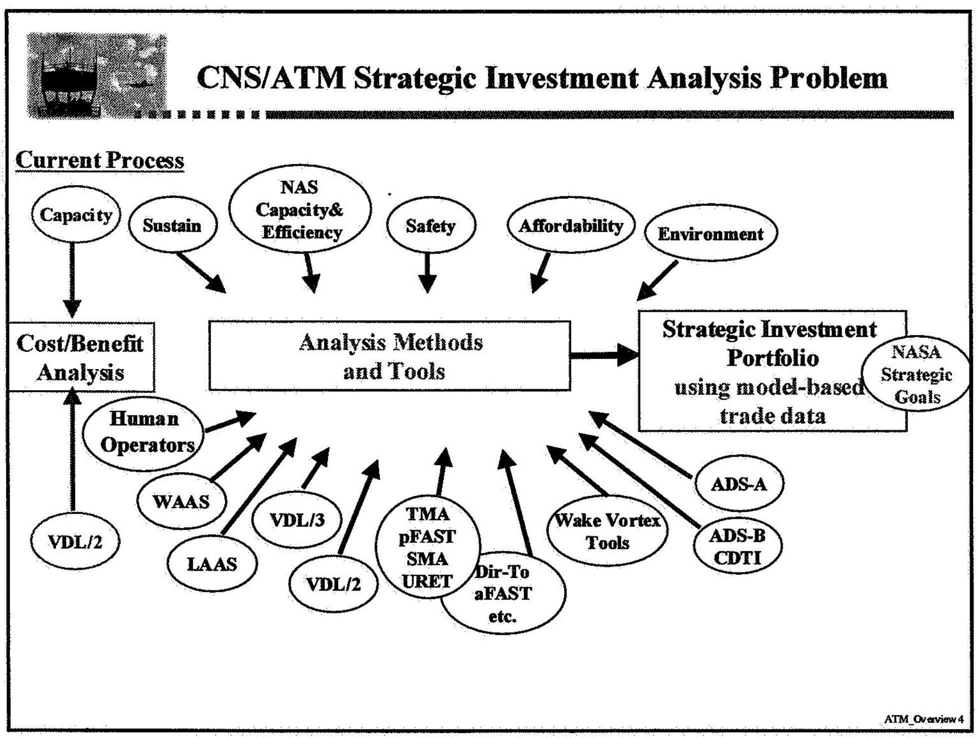
Phase 1
- *Near Term (2000-2002)*
- Sustaining Architecture
- Committed Deployment

Today's Installed Base



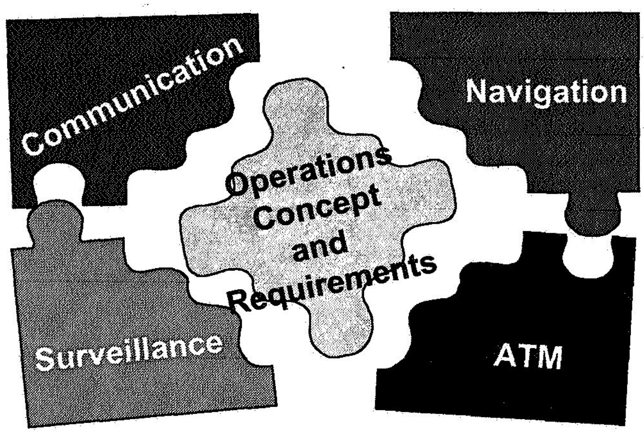
ATM_Overview 2


Comparative Estimates
Average Air Delay Per Flight
Current NAS (AAL Study)
10% Delay Impact
Current NAS with Enhancements
(Modernization Task Force)
Future NAS (AAL Study)
AAL Good Day Analysis (1997)
Boeing Estimate of Current Initiatives Impacts
FAA Task Force Estimate of
Current Initiatives Impacts
AAL Good Day Analysis
(Reduced Separations & More Runways)
Delay in Minutes
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
2022
2024
2026
Year
ATM_Overview 3


CNS/ATM Strategic Investment Analysis Problem
Current Process
Capacity
Sustain
NAS Capacity& Efficiency
Safety
Affordability
Environment
Cost/Benefit Analysis
Analysis Methods and Tools
Strategic Investment Portfolio using model-based trade data
NASA Strategic Goals
Human Operators
WAAS
VDL/2
LAAS
VDL/3
VDL/2
TMA
pFAST
SMA
URET
Dir-To
aFAST
etc.
Wake Vortex Tools
ADS-A
ADS-B
CDTI
ATM_Overview 4

The Challenge

The components of CNS-ATM include Communications Navigation, Surveillance, ATM and their Integration with an Operational Concept and Technical Requirements.



Tomorrow's System Research Needs

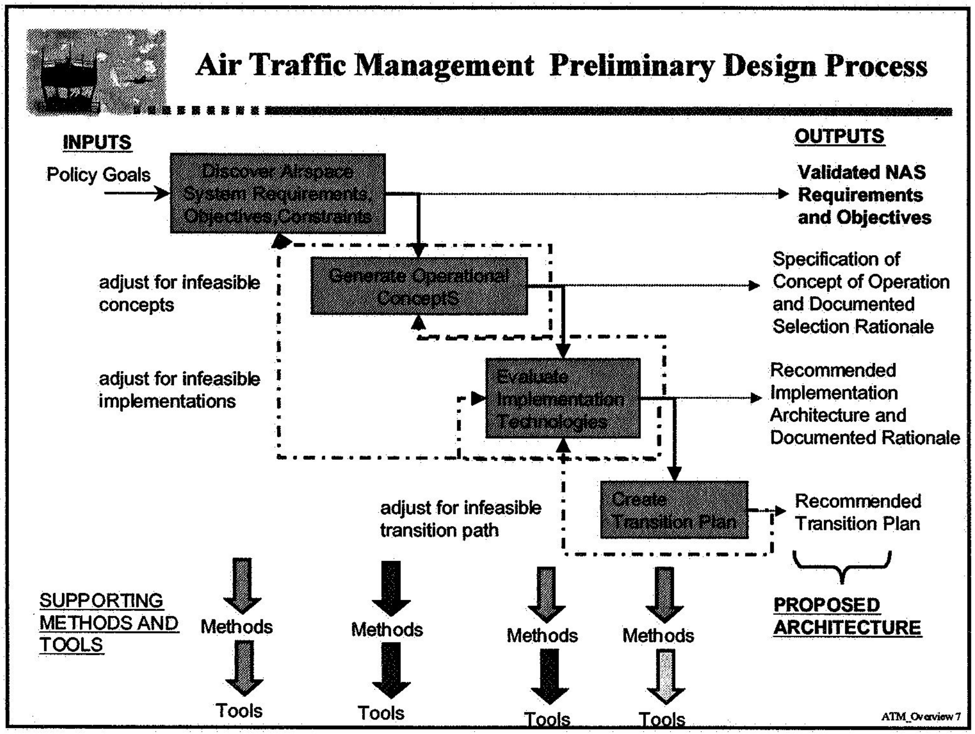
2010 Goal: A Safe, Affordable Air Transportation that Accodomates Growth

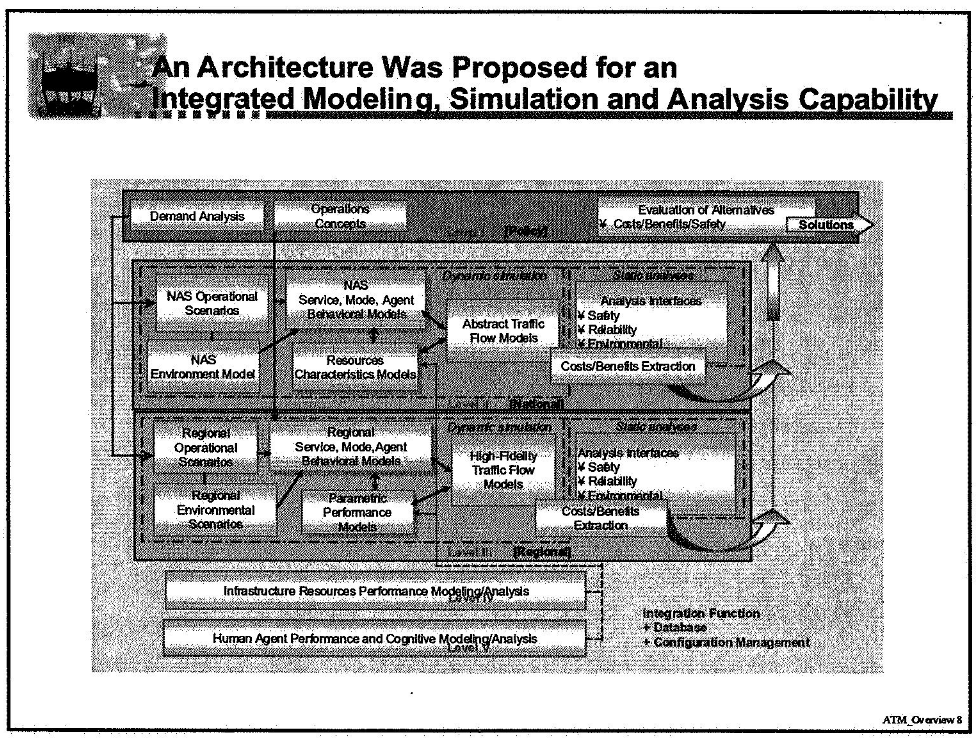
Elements of the Solution

- **Key Capacity Technologies**
  - **Wake Vortex Systems, Weather Forecasting, ...**
- **Terminal / Airport Productivity Technologies**
  - **CTAS, RNAV/RNP, Data Link, Surveillance, ATM Coordination Tools**
- **Sector Productivity Tools**
- **Flow Management - Clean Sheet Approach to Operational Concept**

Supporting Methodology to Enable Operational Change

- **System Metrics and Baselining**
- **Airspace and Procedures Design Criteria**
- **System Tools and Methods including Human Performance Modeling & Safety Modeling**


Air Traffic Management Preliminary Design Process
INPUTS
OUTPUTS
Policy Goals
Discover Airspace System Requirements, Objectives,Constraints
Validated NAS Requirements and Objectives
adjust for infeasible concepts
Generate Operational ConceptS
Specification of Concept of Operation and Documented Selection Rationale
adjust for infeasible implementations
Evaluate Implementation Technologies
Recommended Implementation Architecture and Documented Rationale
adjust for infeasible transition path
Create Transition Plan
Recommended Transition Plan
PROPOSED ARCHITECTURE
SUPPORTING METHODS AND TOOLS
Methods
Tools
Methods
Tools
Methods
Tools
Methods
Tools
ATM_Overview 7


An Architecture Was Proposed for an Integrated Modeling, Simulation and Analysis Capability
Demand Analysis
Operations Concepts
[Policy]
Evaluation of Alternatives
¥ Costs/Benefits/Safety
Solutions
Dynamic simulation
Static analyses
NAS Operational Scenarios
NAS Service, Mode, Agent Behavioral Models
Abstract Traffic Flow Models
Analysis Interfaces
¥ Safety
¥ Reliability
¥ Environmental
NAS Environment Model
Resources Characteristics Models
Costs/Benefits Extraction
[National]
Dynamic simulation
Static analyses
Regional Operational Scenarios
Regional Service, Mode, Agent Behavioral Models
High-Fidelity Traffic Flow Models
Analysis Interfaces
¥ Safety
¥ Reliability
¥ Environmental
Regional Environmental Scenarios
Parametric Performance Models
Costs/Benefits Extraction
[Regional]
Infrastructure Resources Performance Modeling/Analysis
Human Agent Performance and Cognitive Modeling/Analysis
Integration Function
+ Database
+ Configuration Management
ATM_Overview 8

Reducing NAS delays

James E. Evans

Senior Staff, MIT Lincoln Laboratory

Visiting Scholar, Univ. of Calif. Berkeley

<u>Outline</u>

- *Delays in the NAS and the role of convective weather*
- The FAA/airline "Spring 2000" plan to reduce convective weather induced delays
- What went wrong in "Spring 2000" (convective weather cannot be predicted accurately 2-6 hrs in advance)
- What can AvSTAR do to reduce delays due to convective weather

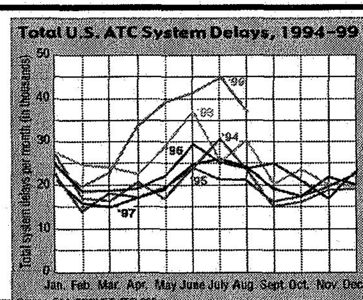
JEE/000028-1
jee 2/9/01

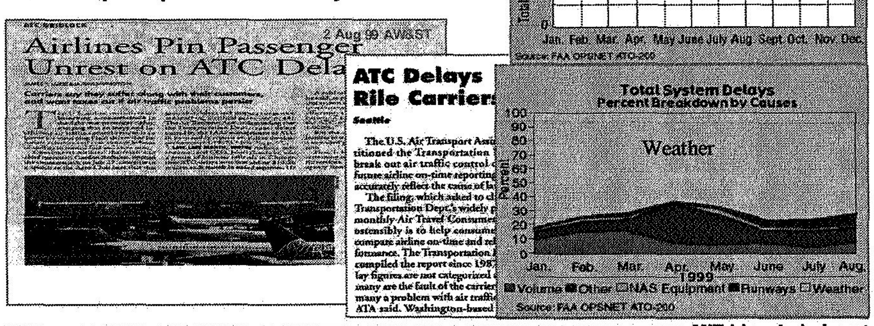
MIT Lincoln Laboratory

1999 Air Traffic Delays

Over 70% of delays are due to weather

Historically, insufficient IFR capacity has been viewed as the principal cause of delays. However, the rapidly increasing delays in the summer months shows that convective weather (e.g., thunderstorms) are now the principal cause of delays





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jee 2/9/01

MIT Lincoln Laboratory

Convective Weather is Low Priority Despite ITWS/TCWF Success

- Free Flight Phases 1 and 2 have minimal convective weather capability
  - CTAS near term does not explicitly handle convective wx
  - CDM has some
- ITWS pre planned product improvements to extend current 20 predictions to 60 minutes was zeroed in FAA FY01 and 02 budgets
- However, ITWS and TCWF have demonstrated delay reduction benefit to cost ratio > 100:1 at NY airports
- New York is a harbringer of the future -megaplex metropolitan airport complexes are becoming more common

JEE/000028-3
jee 2/9/01

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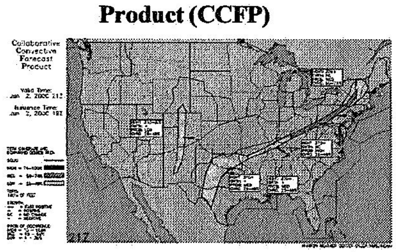
FAA/Airline Spring 20 00 Plan

Collaborative Convective Forecast Product (CCFP)



2, 4 and 6 hour predictions generated by FAA/NWS/airline meteorologist collaboration group every 4 hours

Each region of predicted convective activity has estimates of:
Thunderstorm coverage (median)= 100, 87, 62 or 37%
Probability of occurence (median)=85, 55 or 22%

(note: probability of weather being encountered on a route~ probability of occurrence X thunderstorm coverage)

Strategic Planning

CCFP

"Playbook" → FAA/Airline Strategic Planning Team

Strategic Plan

Teleconference
Every 2 hours

JEE/000028-4
jee 2/9/01

MIT Lincoln Laboratory

Escalation in Aviation System Delays

Flying Into a Storm of Delays

By Don Phillips and Neil Irwin
Washington Post Staff Writers
Monday, July 17, 2000; Page A01

Last Monday began with a bang. An awesome line of thunderstorms formed out over Wisconsin before dawn and churned into Chicago just as the first flights of the day would normally be taking off from O'Hare Airport. The airport, the second-busiest in the country, started the day already shut down.

Ed Gannon, a severe weather specialist at the Air Traffic Control System Command Center in Herndon, works the phones in an effort to reroute a number of flights around bad weather in the midwest. (Michael Lutzky - The Washington Post)

Under the Weather

Efforts to Ease Delays In Summer Air Travel Also Produce Snarls

FAA's Centralized Controls, New Radar Screens Are Cited for Lost Efficiency

'Things Really Got Hairy'

By Scott McCartney
Staff Reporter of The Wall Street Journal

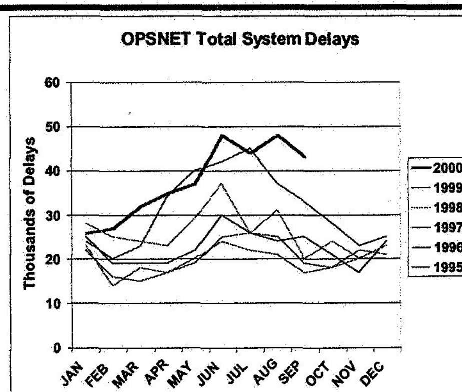
The passengers at Newark International Airport found themselves in an all-too-familiar situation: Delayed. All flights were being held for an hour because of thunderstorms.

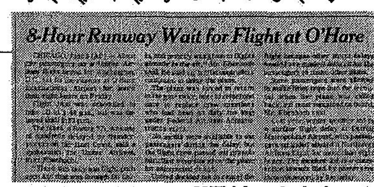
But on this clear August afternoon, the only thunderstorms in the country were hundreds of miles away, in a corner of Oklahoma.

Another day, flights from Chicago to New York were grounded because of thunderstorms—in Florida.

How could this be?

The summer of 2000 was a painful low point for airline delays. Throughout the long months, as hundreds of thousands of passengers simmered on tarmacs and in ...





8-Hour Runway Wait for Flight at O'Hare

MIT Lincoln Laboratory

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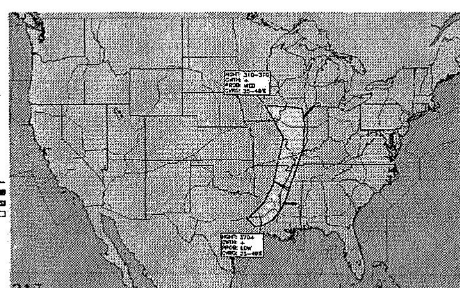
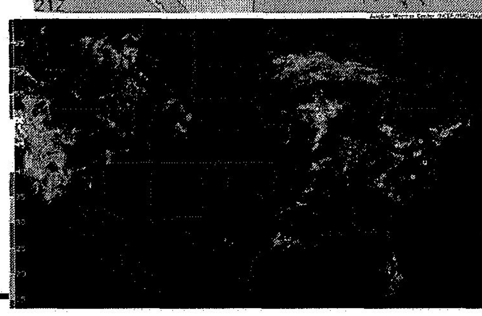
jee 2/9/01

April 16, 2000 - New York Delay Case



Forecast Weather 21Z



Actual Weather 21Z

Note that actual weather was in upper portion of of forecast region.

Significant weather occurred north of forecast region and near New York City

MIT Lincoln Laboratory

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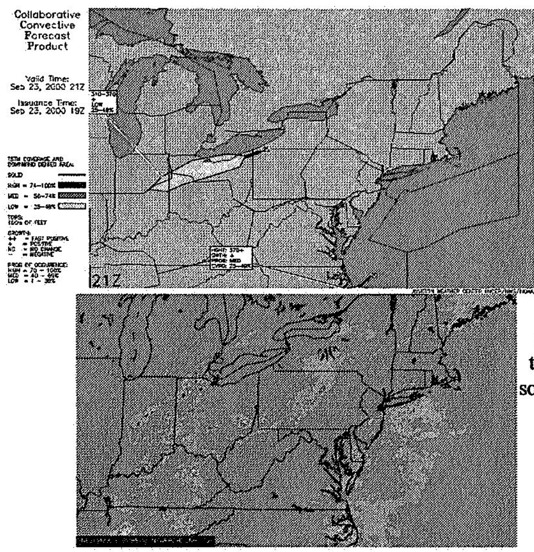
jee 2/9/01

ZOB Weather on 23 Sept. 2000 Illustrating Need for Tactical Agility



Predicted convective weather at 21Z issued at 19 Z. Predicted coverage in ZOB is 25-49% with "low" probability of occurence (1-39%)

Actual weather at 2045Z. Note that coverage extends well to the south and north of predicted region and that coverage along a NS axis is more than 50%.

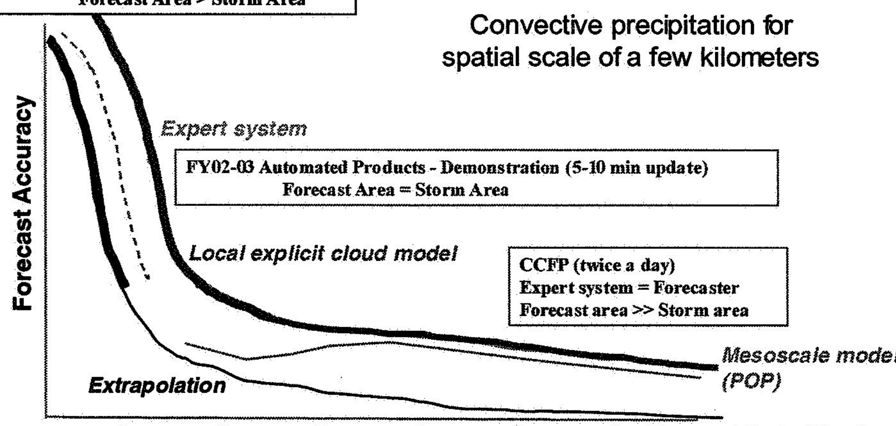
JEE/000028-7
jee 2/8/01

MIT Lincoln Laboratory

Automated Products (5-10 min update)
TCWF (1km) and
NCWF (4 km)
Forecast Area = Storm Area
Forecaster Products (60 min update)
Convective SIGMET
Forecast Area > Storm Area

Projection of near term capability by FAA Av. Weather Research Convective Weather Product Development Team

Convective precipitation for spatial scale of a few kilometers



Modified from Browning, 1980

Role of Improved Tac tical Ca pability

Although flight planning and traffic flow management must make plans 2-6 hours in advance, highly accurate predictions of convective weather impacts will rarely be possible

Excluding aircraft from regions that have relatively low predicted probability of weather being present* is not sensible. Instead:

— assume a lower effe ctive ca pacity for regions of predicted weather

— load extra fuel on planes

— expect that dynamic rerouting may be needed

The effective capac ity depends on the facility tactical capability:

— confidence in depiction of current and short term predicted weather

— ability to re route planes with minimal controller/AOC/TFM workload

— traffic flow management impact assessment of re routes

* = (predicted coverage) times (probability of wx occuring)

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jee 2/9/01

Suggestions for AvSTAR Program

- Improve tactical (0-2 hour) capability in convective weather
  - Make better use of tactical weather decision support systems such as ITWS in systems such as CTAS
  - Develop real time "what if" traffic flow management decision support tools to aid in determining traffic routing strategies
  - Extend tools such as "Direct To" to reduce workload for controllers,pilots, and dispatch when dynamically rerouting
- Determine delay causality and how much delay is "avoidable"
- Research decision making on routes and traffic flow under uncertainty. Tailor weather product uncertainty estimates to ATM decision support system features
- Extend planned simulation capability to more accurately depict thunderstorms as observed from cockpit
- Relate pilot preferences/ride quality to en route weather features

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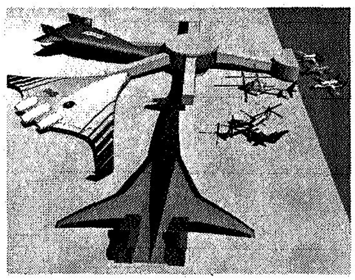
Aviation System Technology Advanced Research Program - AvSTAR

A Vision of the Future ATM System

September 21, 2000

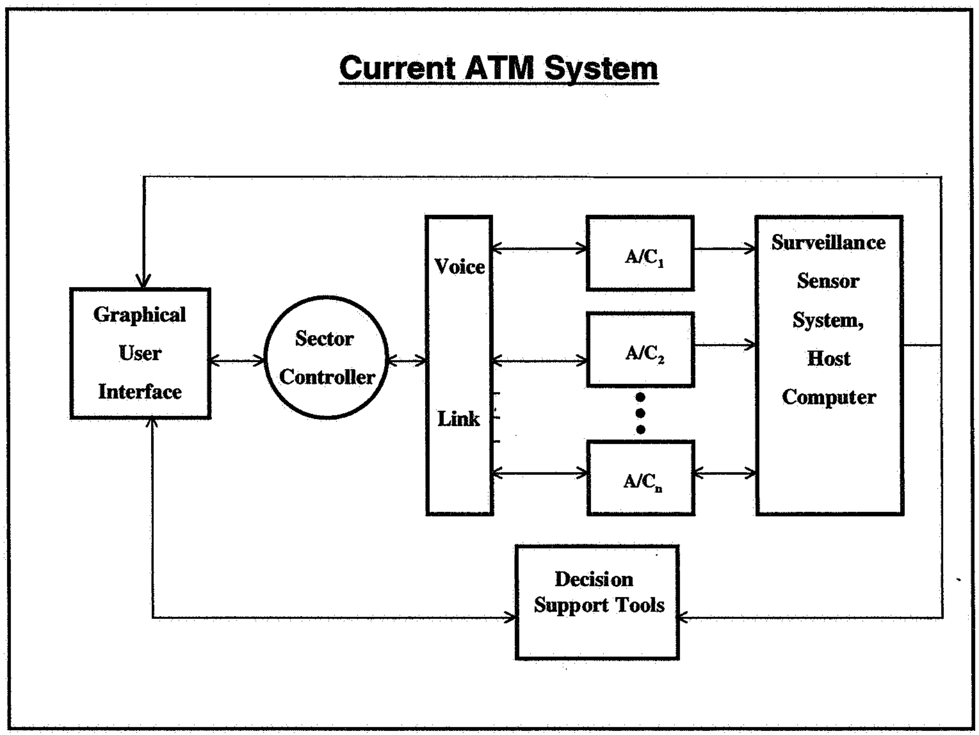


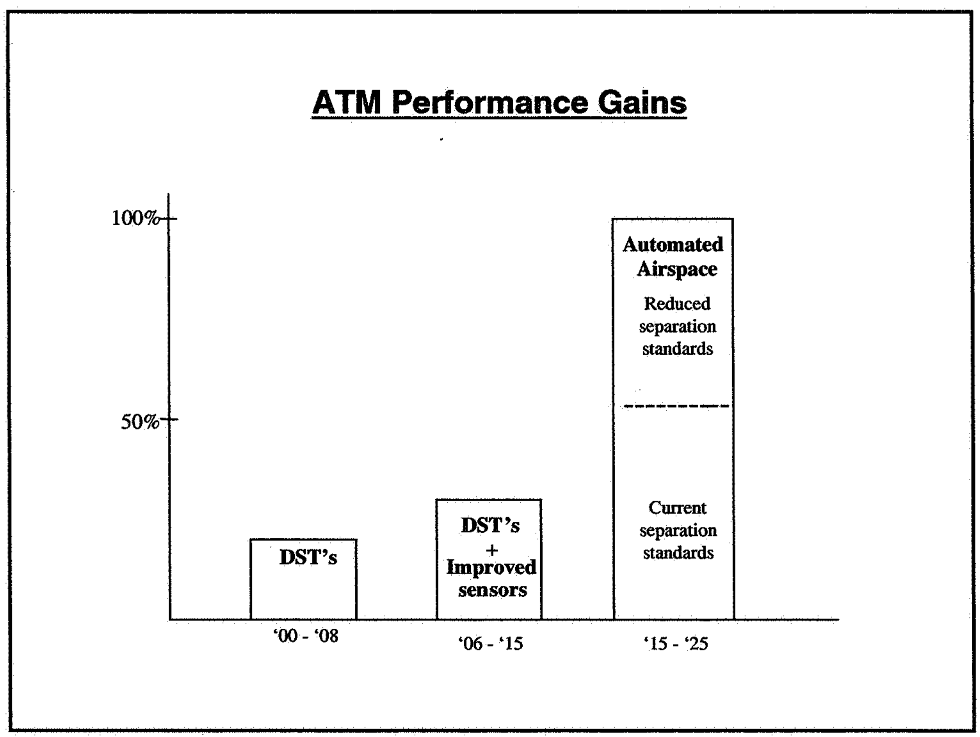
Dr. Heinz Erzberger
Senior Scientist for ATM
Ames Research Center

1

Large Increases in Capacity, Safety and Efficiency Require a New Approach

- Air traffic growth is increasingly constrained by the capacity limits of sectorized control, wherein a controller is responsible for separation assurance, planning, communications, coordination, etc.
- Capacity gains through re-sectorization and sector size reduction have reached the point of diminishing returns.
- Decision Support Tools provide modest gains but can't circumvent basic controller workload limits.
- Constraints that limit flight efficiency can't be reduced at high traffic density because that would further exacerbate the controllers workload problem.
- The inevitability of human error limits further improvements in safety with current procedures.
- Potential of reduced separation can't be fully exploited because of workload and reaction time limits with controllers performing current duties.

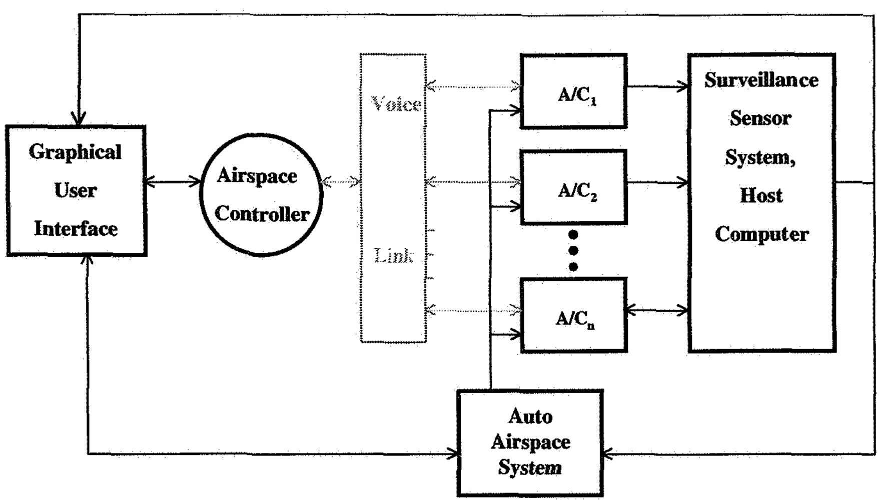

Current ATM System
Graphical
User
Interface
Sector
Controller
Voice
Link
A/C$_1$
A/C$_2$
A/C$_n$
Surveillance
Sensor
System,
Host
Computer
Decision
Support Tools


ATM Performance Gains
100%
50%
DST's
DST's
+
Improved
sensors
Automated
Airspace
Reduced
separation
standards
Current
separation
standards
'00 - '08
'06 - '15
'15 - '25

Automated Airspace Operations

- Sector controllers are "liberated" from the responsibility of separation assurance and are "promoted" to the new role of airspace controller.
- Several traditional sectors are combined into super-sectors, each managed by an airspace controller.
- Conflict detection and resolution is fully automated and distributed between ground-based and airborne systems connected via data link.
- Sequencing and spacing control in the terminal area is fully automated on the ground and is executed via data link.
- Voice communication between airspace controller and pilots will be available to handle special needs, i.e. special pilot request, emergencies, loss of data link.
- Access to automated airspace will be restricted to equipped aircraft.
- Automated airspace can revert to conventionally controlled airspace during low demand periods.

Automated Airspace System



Development Challenges

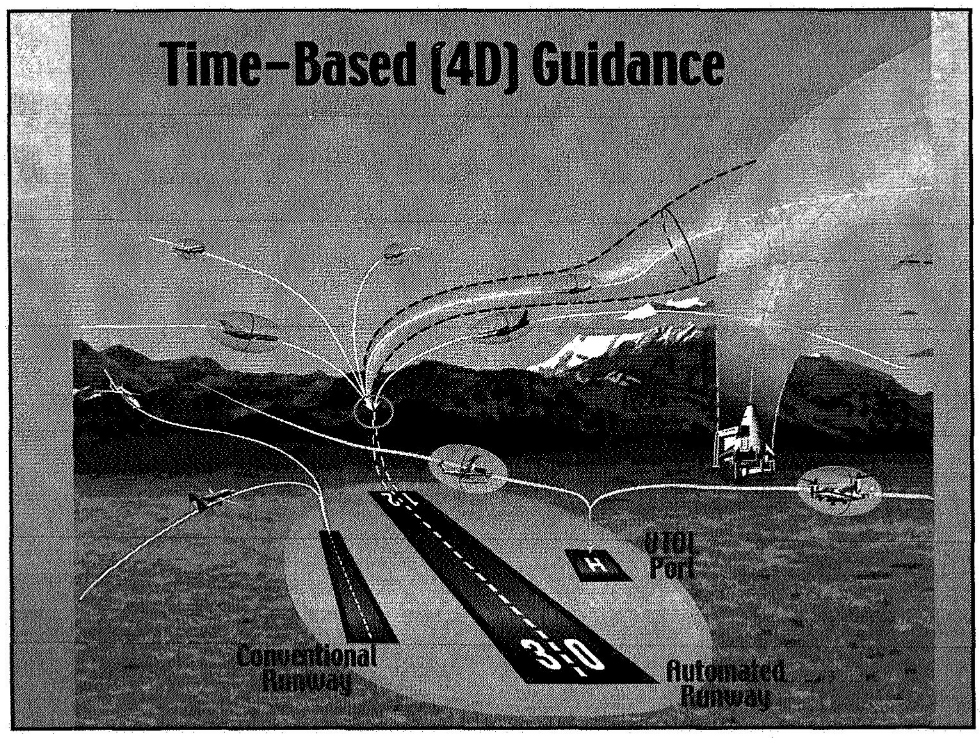
- Gaining acceptance of concept by operators, controllers and the public.
- Design of system architecture that has multiple safety nets to protect users against various types of failures.
- Automated failure detection and reconfiguration of system to operate in a degraded mode.
- Roles and responsibilities of airspace controllers.
- Design of the interface between airspace controller and system element; retaining the human-centered design while changing the role of the human.

Development Challenges (cont.)

- Transitioning from manual to automated airspace operations.
- Providing airspace and runway access for unequipped aircraft
- Upgrading the CTAS algorithms and software to level of performance required for autonomous operation.
- Establishing minimum equipment standards for airspace users.
- Verification, validation and testing of concept.

Approaches to Automated ATC

- Time-based (4D) Guidance
- Self-Separation and advanced TCAS
- Automated Airspace

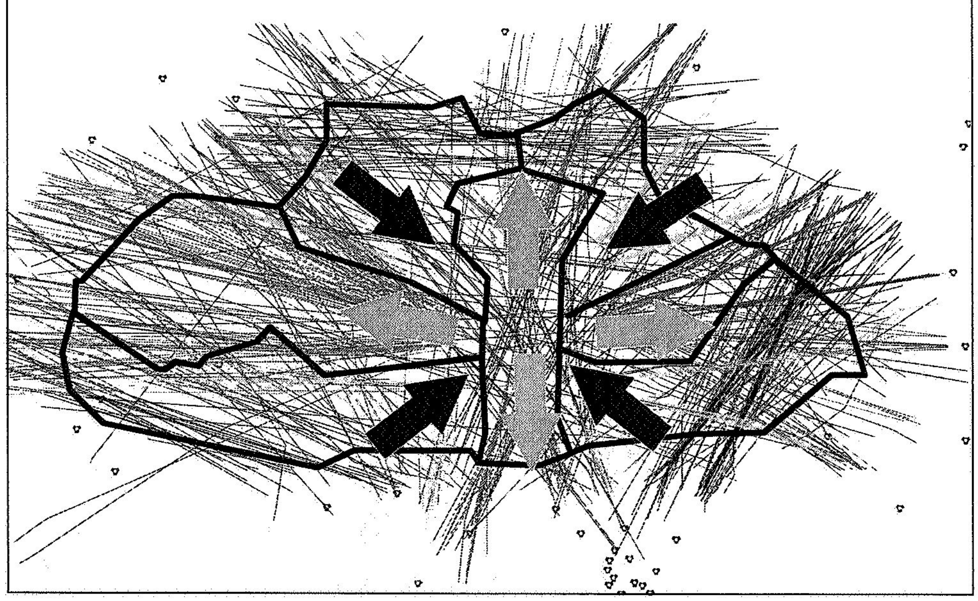


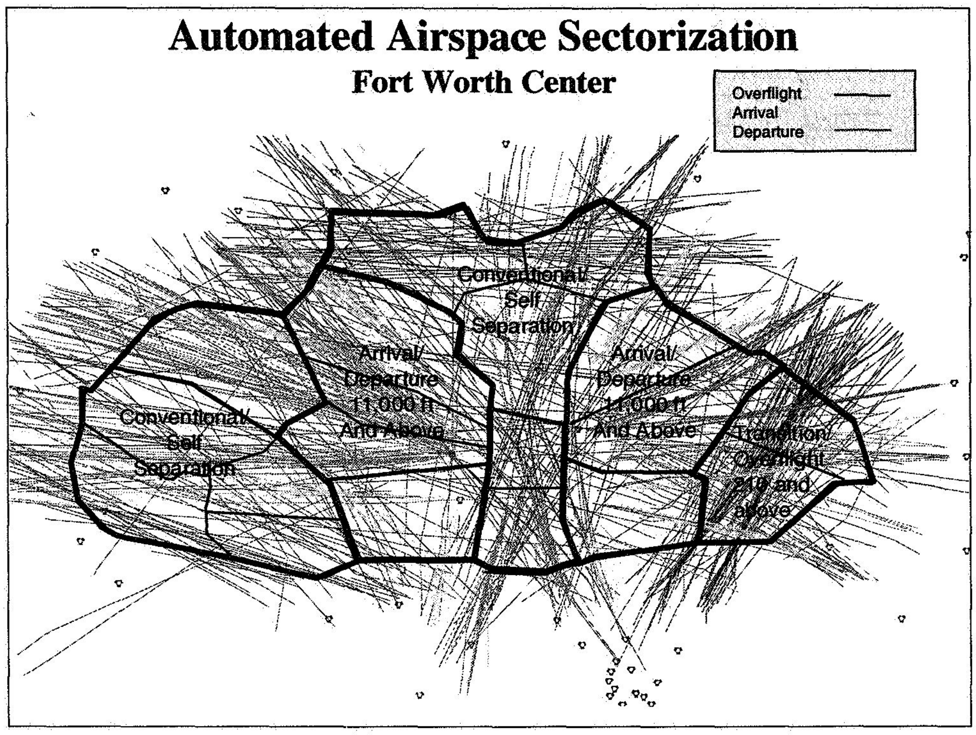
Types of Automated Airspace

- Self separation airspace
- High altitude transition airspace: mixed climbing, descending and over-flights
- Arrival and departure management airspace
- Final approach sequencing and spacing airspace

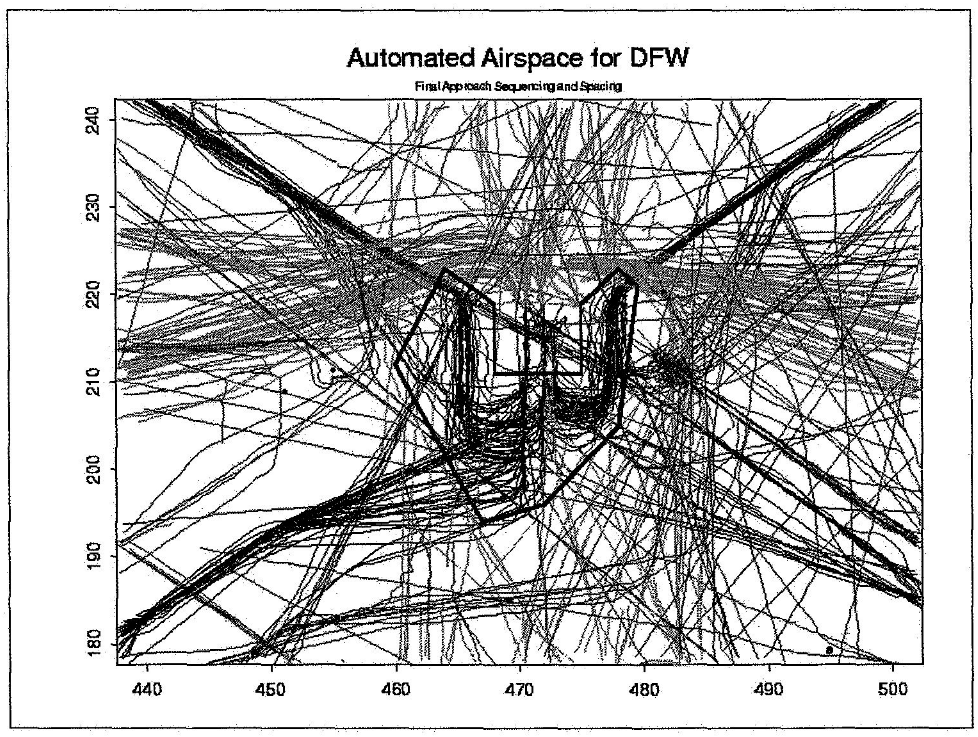
Fort Worth Center Traffic Flows

FL240 and above





Automated Airspace Sectorization
Fort Worth Center
Overflight
Arrival
Departure
Conventional/
Self
Separation
Arrival/
Departure
11,000 ft
And Above
Conventional/
Self
Separation
Arrival/
Departure
11,000 ft
And Above
Transition/
Overflight
210 and
above



Automated Airspace for DFW
Final Approach Sequencing and Spacing
240
230
220
210
200
190
180
440
450
460
470
480
490
500

Benefits of Super Sector

- Boundaries unconstrained by current center boundaries.
- Elimination of trajectory constraints imposed by conventional sector structure and altitude stratification.
- Reduction of handoff coordination.
- Shared airspace for arrivals, departures and overflights allows flexibility in use of airspace and routes.
- Unified airspace of super sectors enables increasing the range and effectiveness of conflict resolution.
- Increased controller productivity.

Steps Toward Automated Airspace

- Complete deployment of decision support tools for critical ATM specialties (2010).
  - DST technology is the foundation for Automated Airspace.
- Introduce Distributed Air Ground procedures and improved sensors (2006).
  - When combined with DST's, this begins the process of changing sector controller roles and responsibilities.
- Build high performance and secure air-ground data link required to support automated airspace operation (2012).
- Evaluate prototype automated airspace system in selected high altitude airspace (2015).
- Install in high density on route airspace (2017).
- Install in high density terminal areas (2020).

Conf Paper /55/1N/03   2001057104   525156 pgs 16

AVIATION SYSTEMS TECHNOLOGY ADVANCED RESEARCH (AvSTAR) WORKSHOP

Panel 2 Future Air Transportation System

September 21-22, 2000

Richard Golaszewski
Executive Vice President
GRA, Incorporated

115 West Avenue C Jenkintown, PA 19046 C USA
Telephone: 215-884-7500 C Fax: 215-884-1385
E-mail: richg@gra-inc.com

SOME DETERMINANTS OF THE FUTURE AIR TRANSPORTATION SYSTEM

Economic growth

Population size and distribution

Aircraft acquisition and operating costs

Energy availability and cost

Environmental issues
- Noise
- Emissions

Vehicle technology

Substitutes
- Personal travel
- Business travel
- Modes

Global safety/security issues

Evolving air shuttle markets

Note NASA/ASEB scenario-based planning studies examine some of these issues.

AIR TRANSPORTATION SYSTEM ISSUES

Aerospace
NASA Ames Research Center

Demand distribution
- ❑ Multiple airport systems
- ❑ Role of hubs and gateways
  - ❑ Frequency
  - ❑ Non-stops

Capacity availability/growth
- ❑ Airports
- ❑ Terminal ATM
- ❑ En route ATM

Competitive environment
- ❑ Alliances/networks
- ❑ Niche carriers
- ❑ Fares

Institutional issues related to increasing capacity or managing demand

GRA, Incorporated 3 September 21-22, 2000

DEMAND-CAPACITY-DELAY ISSUES

Aerospace
NASA Ames Research Center

Delay problems concentrated at a small proportion of U.S. airports
- ❑ Aggregate demand
  - ❑ Reduced Runway Occupancy Time
  - ❑ Wake vortex alleviation/control
  - ❑ Virtual VMC
  - ❑ Runway independent operations
- ❑ IMC/VMC capacity differences
  - ❑ More precise flight tracks
  - ❑ Runway construction/relocation

Increase in multiple airport regions to add runways
- ❑ Terminal ATM needs
- ❑ Incentives to use secondary airports for passengers and carriers

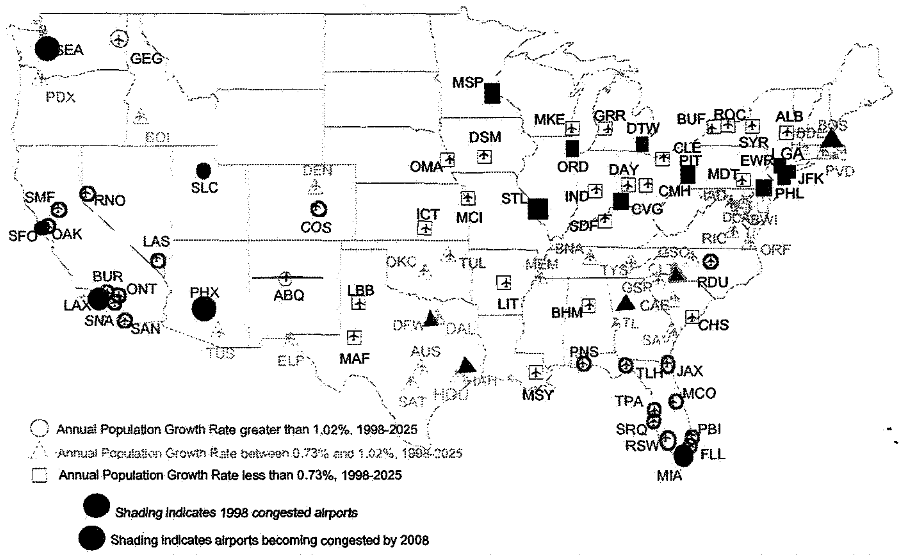
En Route
- ❑ Use of more airspace/routes
- ❑ Dynamic reconfiguration
  - ❑ Severe weather avoidance
  - ❑ Facility backup

GRA, Incorporated 4 September 21-22, 2000

PROJECTED (2008) CONGESTED AIRPORTS

Aerospace NASA Ames Research Center

Top US Commercial Airports, Identified by Forecast Annual Population Growth Rate in Surrounding Area, 1998 to 2025



DETAILED FORECAST OUTPUTS

Aerospace NASA Ames Research Center

FAA LONG RANGE FORECAST

	1999	2005	2010	2015	2020	2025	Total Growth	Average Annual Growth
Millions of Enplanements								
Air Carrier (U.S. Domestic/International)	708.1	876.7	1075.8	1294.7	1544.9	1841	160%	3.8
Regionals	72.3	103.00	131.7	165.7	203.5	244.1	238%	4.8
Fleet in Thousands								
Air Carrier/Cargo	5.3	6.4	7.8	9.2	10.9	12.5	136%	3.4
Regional/Commuter	2.2	2.9	3.1	3.5	3.7	4	82%	2.3
General Aviation	184.3	195.3	203.2	211.5	218.8	226.1	23%	0.8
Millions of Civil Aircraft Operations								
Commercial	28.9	32.6	36	39.5	43.2	46.9	62%	1.9
General Aviation	90.8	95	98.6	102.4	105.1	107.6	19%	0.7

Source: FAA Long-Range Aerospace Forecasts Fiscal Years 2015, 2020 and 2025 FAA-APO-00-5, p. 14.

SOME AIR TRANSPORTATION SYSTEM GROWTH SCENARIOS

Aerospace
NASA Ames Research Center

Pure Airline Driven Airl ines cater to passenger preferences, system tries to accommodate, airlines price scarcity
- More frequency
- Regional Jets

Environmental Stringency Ne gative aviation impacts controlled
- Noise/emissions standards
- Noise/emissions taxes

Congestion/Delay Ope rations balanced by FAA Command Center and CDM
- Service quality becomes limiting factor
- Continue first come-first served (?)

Market Driven Infrastructure Pro viders (FAA and airports) able to price scarcity
- Institutional issues
- Larger aircraft
- Less frequency

Economic Scenarios Cha nges in air travel demand
- Substitute communications for air travel
- e-Commerce and air travel
- Economic growth projections
- Competition and industry structure

GRA, Incorporated 7 September 21-22, 2000

Comments on the NASA AvSTAR Future System Research

NASA AMES
September 21, 2000

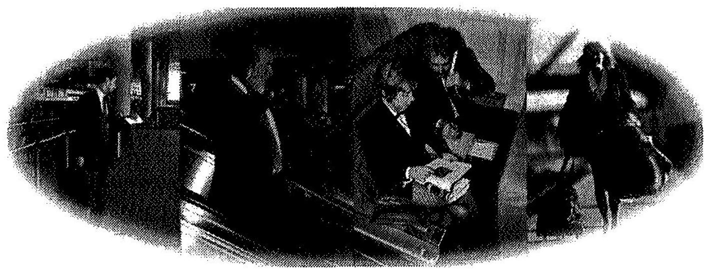
Robert E. Spitzer

Introduction

- Demand for people and cargo transport by air will continue to grow.
- The current system is at capacity limits.
  - Highly sensitive to disturbances such as weather events.
- Fifteen years of R&D have brought forth many new technologies.
  - The task is to integrate the best set of technologies into a higher performance system.
- Need analysis tools to assess the performance of proposed solution sets.
  - Airspace performance focused, appropriate level of fidelity to enable broad concept exploration.
- Understanding the feasible performance of a range of new concepts will allow us to lay out the technology research needed to define and transition to the system after next.

What Do Passengers Want?

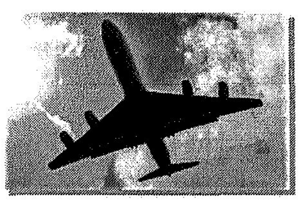
- Safe and reliable service
- Direct flights to places they want to go at times they want to fly
- Low air fares and comfortable airplanes



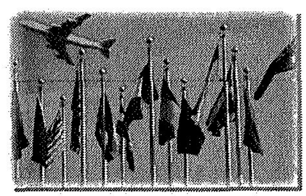
ATM_Overview 3

BOEING

How Will Airlines Accommodate Air Travel Growth?



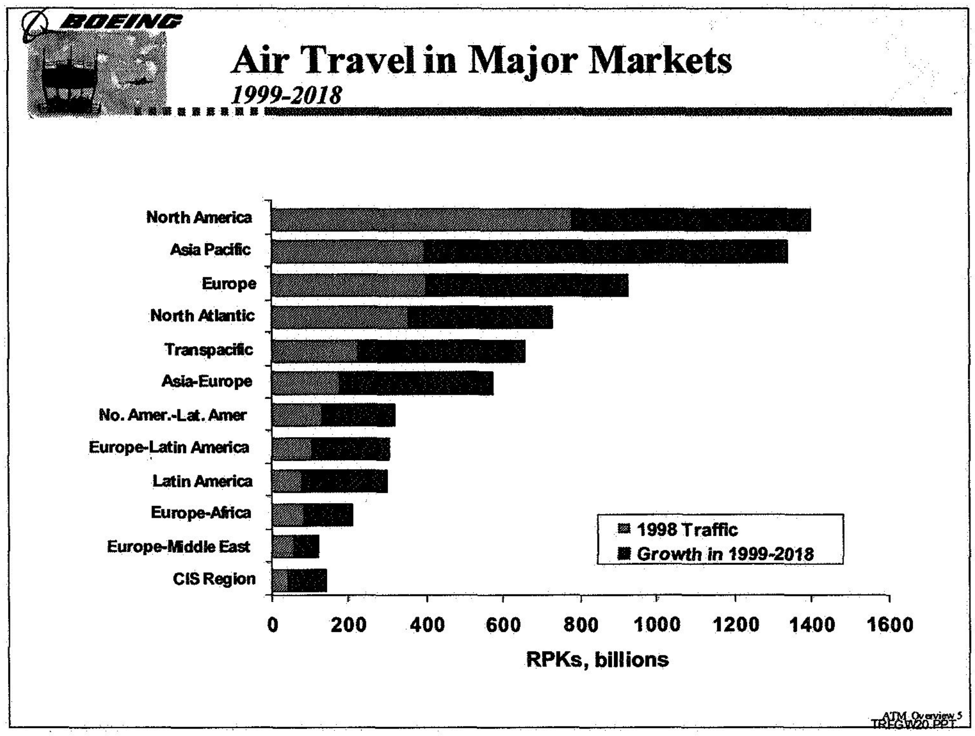
Airplane capabilities

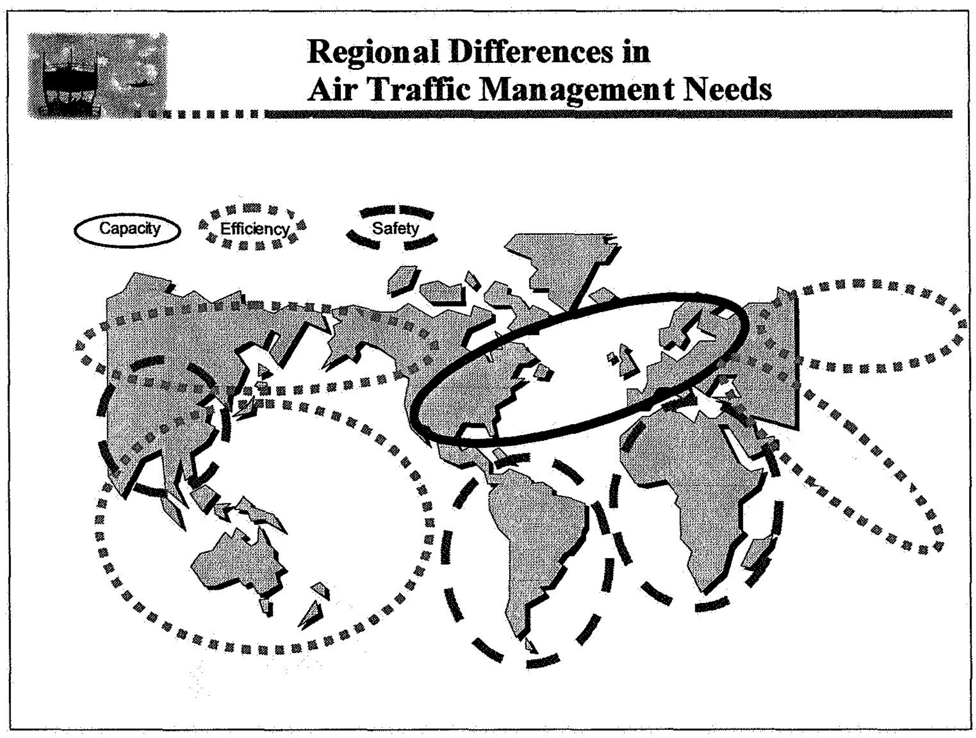


Government regulation

Airline strategy

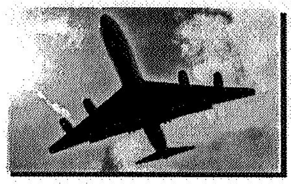
ATM_Overview 4


BOEING
Air Travel in Major Markets
1999-2018
North America
Asia Pacific
Europe
North Atlantic
Transpacific
Asia-Europe
No. Amer.-Lat. Amer
Europe-Latin America
Latin America
Europe-Africa
Europe-Middle East
CIS Region
1998 Traffic
Growth in 1999-2018
0 200 400 600 800 1000 1200 1400 1600
RPKs, billions
ATM Overview 5
TRFGW20.PPT

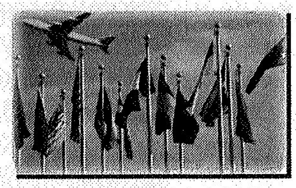

Regional Differences in
Air Traffic Management Needs
Capacity
Efficiency
Safety

BOEING

Will The Infrastructure Constrain Future Growth?

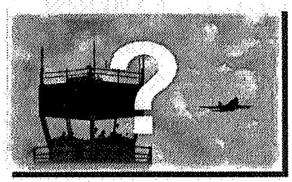


Airplane capabilities



Government regulation

Airline strategy

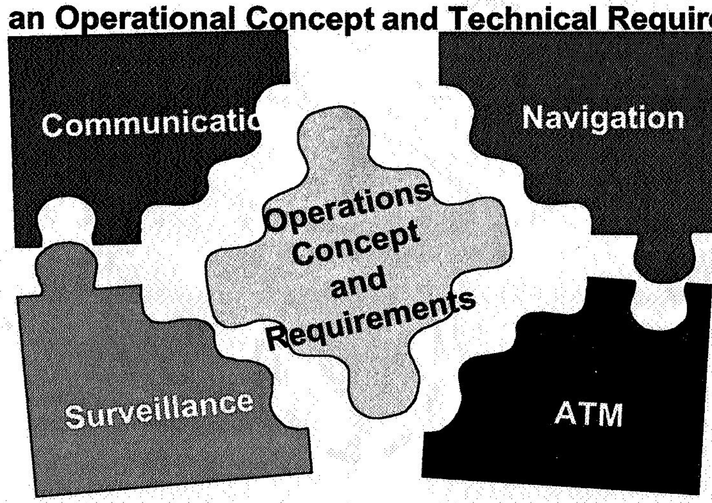


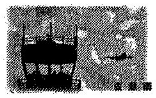
Airports and air traffic control

ATM Overview 7
3INTRDEP.PPT

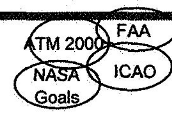
The Challenge

The components of CNS-ATM include Communications Navigation, Surveillance, ATM and their Integration with an Operational Concept and Technical Requirements.

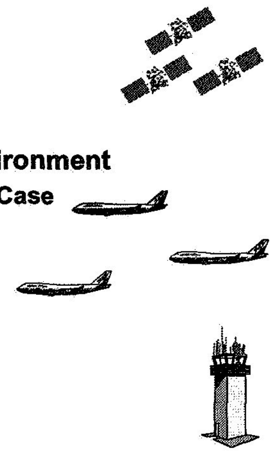




BCAG Air Traffic Management Vision



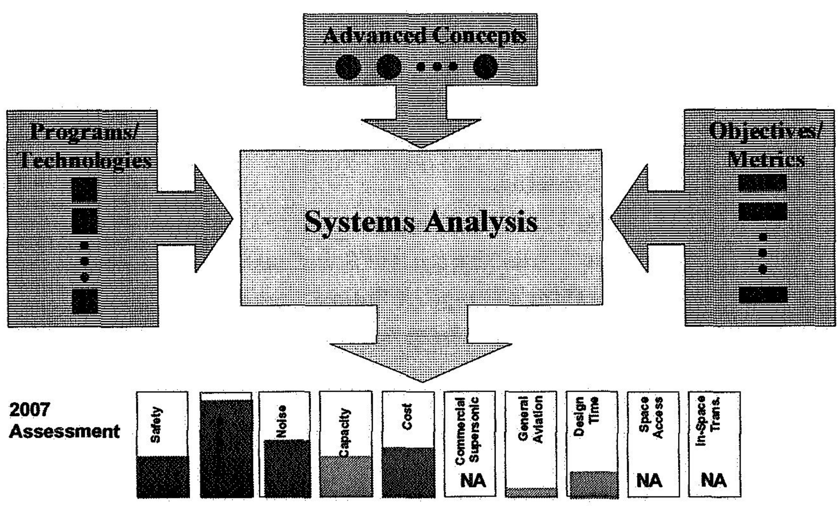
- A modern, global, interoperable ATM system by 2016 that is:
  — Safe
  — Affordable
  — Supports Free Market Growth
- All Boeing aircraft equipped for new environment
  — Equipage based on Strategic Investment Case



ATM_Overview 9

AT

NASA Assessment Process



NAS Architecture Phase In

Strategic Goals

- ATM 2000+
- FAA
- ICAO
- NASA Goals

Options for the NAS
- NAS Growth & Constraints
- Emerging Technologies (Today)
- Alternative Futures
- Globalization

Modernizing the NAS
- NAS Performance
- NAS Safety Enhancement
- NAS Affordability

Sustaining the NAS
- NAS Sustaining
- Funding Profiles
- Limited User Benefits
- Risk Management

Phase 1
- Near Term (2000-2002)
- Sustaining Architecture
- Committed Deployment

Phase 2
- Mid Term (2003-2007)
- Modernization Architecture
- New Functionality

Phase 3
- Far Term (2008-2020)
- Concept Architecture
- Technology Exploration

Today's Installed Base

ATM_Overview 11

Long Range Research Needs

- A Safe, Affordable Transportation to 2025
- Adequate System Capacity for Most Weather Operations
- Multi-Modal Operations Concepts to Support Passenger Transit Time Requirements
- Radical Operations, Vehicle and Infrastructure Concepts
- Tools & Methods to Synthesize System Solutions and to Assess Their Effectiveness Over a Range of Future Scenarios
- Meaningful Research that can help People and Goods Transportation

ATM_Overview 12

Attributes of ATM 2030

Dr. Joseph Jackson
Honeywell

NASA AVSTAR Conference September 21, 2000

Attributes of ATM in 2030

- **Safety of Operations #1 priority for the ATM owner and users.**
- **ATM Safety and Capacity are Global and National priorities.**
- **Global considerations strongly influence NAS ATM enhancements.**
- **Evolutionary (vs. revolutionary) change continues to be the norm to introduce new ATM capabilities.**
- **ATM infrastructure able to incorporate new technologies and procedures (air and ground) expeditiously and efficiently, based on:**
  - "World Class" ATM System Architecture and Personnel
  - "World Class" Simulation/Design/Deployment/Regulatory Processes and Tools
  - Streamlined Funding Allocation Process
  - Collaboration with Industry and other ATM Providers ...
- **Capacity bottlenecks addressed by:**
  - Continued Investment in ATM Assets
  - New Procedures and Capabilities Responsive to User Needs
  - Distributed Airborne / Ground Solutions and Decision-Making
  - Multi- and Intermodal Transportation Solutions ...

NASA AVSTAR Conference September 21, 2000

Comments on the Future Air Transportation System

Philip J. Smith
Charles E. Billings
Institute for Ergonomics
The Ohio State University
Columbus, Ohio 43210

21 September 2000

The Future Air Transportation System is still notional

- *No one* is conducting the research to support the far-term concepts, technologies and methods

Goal: Provide R&D by 2007 necessary to:

- Provide the foundations to set the direction for the future (beyond free flight):
  - •• 3X increase in throughput at high density airports
  - •• 50% reduction in rate of missed/canceled flights

Needed: ATM system level definition/design, functions, architecture, interfaces

"Tomorrow's technologies provide the building blocks; Information systems technologies provide the mortar"

But what is needed <u>first</u> is the far-term concepts.

To forecast far-term ATM needs: study likely evolution of our near-term problems.

- Aircraft will not be qualitatively different–there will just be more of them.

- The ATM System and the people who operate it must evolve gradually, because they must handle production pressures throughout its evolution.

What are the difficult problems in the present system?

- Traffic demand and complexity are escalating. Delays are soaring, and passenger rage is skyrocketing.

- Information management has not kept pace:

  •• Processing capability and tools are inadequate.

- It has become increasingly difficult to accommodate user goals and priorities.

Approach: Identify & assess operations concepts/system designs for Unified System

- Identify and develop system-level operations concepts. Insure participation by and incorporation of stakeholders' knowledge and goals.
- Define information management and presentation to support those concepts.
- Define potential human and team roles in the future system.
- Evaluate the implications of a novel system for human operators.

  •• Human roles in direction and management of automated ATM systems
  •• Monitoring state and functionality of automated systems

- Define the architectures necessary to support distributed work in these systems.

  •• Planning processes and integration
  •• Tactical processes to meet real-time conditions and demands

- *Then* define requirements for tools to support operations in this system.

  •• Reliability, robustness and failure handling
  •• Automation roles in automated systems
  •• Maintenance of user flexibility in more automated systems

- Evaluate transition from current to future infrastructure as a major issue.

We believe that

The technological building blocks of the future system must rest upon a solid foundation of *concepts and architectures*.

The information systems technologies in the future system should be designed to *assist human operators* to implement the policies and procedures by which the system is governed.

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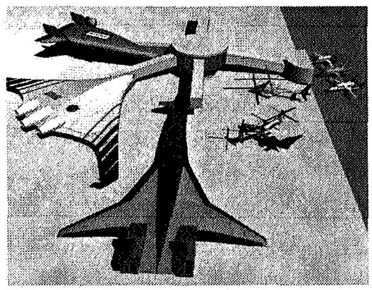
AvSTAR Workshop

Tomorrows' Air Transportation System



Breakout Session Report

Ames Research Center

10/18 AvSTAR – Tomorrow's ATM System 1

Outline

- Chair Comments
- General Comments
- Comments on the Seven Research Elements

Ames Research Center

10/18 AvSTAR – Tomorrow's ATM System 2

Chair Comments

- General Reactions
  - There is enthusiasm for AvSTAR and appreciation to NASA for involving the community in the program planning process
    - The seven "Tomorrow's System" elements appear to encompass the needed steps to fill gaps and augment efforts to achieve the goals of Free Flight
    - There did not appear to be any missing elements in the AvSTAR program
  - There is interest in having additional opportunities to learn more about the program and to help plan AvSTAR

Chair Comments

- General Recommendations
  - The safety implications of new automation tools and procedures must be assessed so that margins are not eroded
  - New automation tools need to be compatible with the evolving ATC system
  - The FAA certification process needs to be more certain as it may hinder the introduction of new technology

Other General Comments

- Continue the development of a strong business case for AvSTAR:
  - State an overall investment strategy
  - Provide explanations for continuing with TAP/AATT initiated work (e.g. AVOSS, SMS, aFAST)
  - Need to have realistic expectations of AvSTAR benefits
    - State the potential impact on top-50 airports (a stop-light chart)
    - Insure that AvSTAR addresses delay causality and how much of this delay can be avoided through improved procedures and automation
- Insure that AvSTAR addresses decision making under the uncertainties in weather predictions
- The ATC system is an information exchange problem and NASA should examine application of information technologies
- NASA should conduct research into the design strategies, test strategies, etc. to assure safety and fault tolerance in ATM software

Ames Research Center

10/18 AvSTAR – Tomorrow's ATM System 5

Other General Comments – 2

- Tool integration is vital
  - NASA, working with the FAA, must take a responsibility for how each tool fits into the FAA architecture.
    - Human factors
    - Systems engineering
- NASA should develop a simulation/modeling capability as a basis for understanding needed improvements in ATC operations
- NASA should consider taking ATM tools to a higher TRL level to help close the technology transfer gap
- Flight deck human factors needs must be a part of the program
- ATM should be considered for the smaller airports
  - The growing regional airports should be considered
- Environmental issues should be addressed in all program elements
- Recommend early FAA Regulation and Certification involvement

Ames Research Center

10/18 AvSTAR – Tomorrow's ATM System 6

Surface Congestion Alleviation

- Assure AvSTAR developments in surface automation are integrated and properly account for emerging industry surface tools
- Take advantage of Safe Flight 21 results/knowledge
- Cockpit systems need to be included as part of the surface congestion solution
- The surface congestion solution must include the integration of arrival, departure, and surface automation tools and procedures

Runway Productivity

- Continued Wake Vortex Work is needed
  - Departure and arrival wake vortex spacing requirements significantly limit traffic flow
  - Continued development of sensors and systems that can safely reduce current limits are highly desired
- A cockpit display that enables "Virtual" VMC for reduced separation ("enhanced visuals") is needed
- Need to continue development of technologies that will allow improved utilization of closely spaced or converging runways

Enhanced Arrival/Departure Tools

- Need tools that help controllers maintain separation
- Operations of DSTs should include input and coordination with other ATS initiatives
- Integrate AvSTAR decision support tool output data with airline operational decision tools/systems
- 2010: Time-based separation should be a goal

Integrated Airspace Decision Support Tools

- Time based scheduling must be the guiding philosophy for all research and decision support tool development
- Developments within AvSTAR must be integrated and compatible with other tools being deployed by the FAA.
- Conduct research on how best to use data link in ATC automation

National Traffic Flow Management

- Develop a rapid modeling tool that provides forecast capabilities (what if?) for all users
  - FAA/AOC
- Produce optimal solutions based on shared information to enable decision makers to-
  - Incorporate triggering mechanisms for initiatives
  - Define exit mechanisms for every initiative
- A unified TFM system is needed
  - Must move from an open-loop SCC TFM to one that has interaction between strategic and local TFM activities
- Need to develop technology that will better predict sector overload and move towards dynamic resectorization
  - Develop metrics for controller workload and feasible sector throughput
  - Develop the means to handle dynamic resectorization across TRACON and Center boundaries
  - Improve the reliability of sector monitor alerts

Runway Independent Operations

- The business case for investment in runway independent operations needs clarification
  - Future role in US air transportation system
- Operational concept needs more clarity

ATM TFM Weather

- Ensure weather hazards are accounted for in new automation initiatives and policies
  - Consider use of artificial intelligence methods to interpret weather obstacles
- Ensure the flight deck has access to weather information and the automation to assist the pilot in using this information
  - Build a tool to help pilots in the diversion decision and contingency planning
  - Provide complete NAS (weather?) status for the pilots

Terminal Weather

- Provide better predictions of convective weather and ceiling/visibility
- FAA Aviation Weather Research has developed a 60 minute convective weather forecast tool, but
  - Accurate forecast greater than 60 minutes will be hard to accomplish in next 10 years
- However, merging weather with ATM DSTs can improve safety

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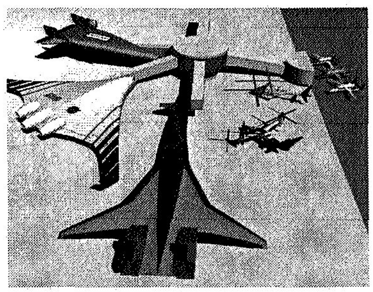
Conf Paper /54/IN 03 P356

AvSTAR Workshop

Future Air Transportation System



Breakout Session Report

Ames Research Center

09/22/00 AvSTAR – Future Air Transportation System 1

Overview

- AvSTAR Future System Effort Critically important
  - Challenge is real
  - Need to deliver
  - Already time critical
- Investment in the future
  - Protect from encroachment due to near term pressures
- Need to follow a systems engineering process
  - System must be integrated from the start
  - Tasks must be linked in the system concept
- Efforts need to be worked in worldwide context

Ames Research Center

09/22/00 AvSTAR – Future Air Transportation System 2

Areas

- Policy Issues
- System Attributes
- Concepts
- Metrics
- Research Issues

Policy Issues

- General
  - Political and business commitment to action and implementation
  - Adopt vs. specifically develop technologies & methodologies
    - Examine other similar efforts – avoid duplication
  - ATN issues and spectrum availability
  - Harmonize air transportation with other transportation modes. Define the boundary of the system?
    - Integrated multi-modal
    - Door-to-door or gate-to-gate
  - Information management + system architecture
    - Do we have the national competency to do this job?

System Attributes

- System Guidelines/Scope
  - Mission/goal driven research
    - Set realistic expectations
    - Account for differing views of system requirements
      - Passenger-centric vs. aircraft-centric vs. airline-centric vs. airport centric
  - System Characteristics/design constraints
    - Transitional and revolutionary
      - Concurrent transition planning
    - Layered system
      - Must be robust to sub-system failure/changing conditions
- System Performance Parameters
  - Safety
  - Reliability
  - Availability
  - Affordability
  - Adaptable to all aircraft types

Concepts

- Concurrence on need for greater automation / movement away from current approach to sectorization of airspace as a means of improving traffic throughput
  - Automated Airspace (Erzberger)
    - Remove human as separation assurance monitor
    - Tactical control loop
    - Implications for automation
  - 4-D Dispersed Control
    - Computer strategic checking
    - Aircraft tactical separation
  - Separation based on collision risk management
  - Sector-less flight-based ATM
    - Same controller handles all flight phases
  - Highly Distributed Control
- Airport/Runway Technologies
  - Runway Independent Operations
- System-Level Considerations
  - System-level information management (emphasized)
  - Modeling must account for up to a "300,000" IAC (Instantaneous Airborne Count)
  - New airline business approaches
  - Review of prior concepts of operations
    - Impact of new technologies
- Weather
  - Future system automation must properly account for weather and uncertainty in its predictability

Metrics

- Safety
  - Target level of safety (TLOS)
- Environmental impact
- Fleet coverage
- Door to Door
- Passenger Throughput
- Cargo Throughput
- Efficiency
- Capacity
- Etc…

Research Issues (1)

- Modeling and Understanding
  - Methodology for evaluating concepts
    - Economic feedback loops
    - Reality test
    - Models
  - Benchmarking and understanding of current system
    - Dynamic behavior
    - Non-normal events (eg weather)
    - Inefficiencies
    - System-level modeling
    - Economic feedback
    - Controller limits
  - Safety analysis
    - Barrier to transition
    - System design issues
    - Partition and allocation of risk and responsibility
  - Understanding transition dynamics
    - Barriers
  - Robustness of large, distributed, highly-automated systems
    - Validation/certification
    - Software

Research Issues (2)

- Technology Developments
  - Multiple objective-function optimization
  - Airborne Conflict Management
    - Intent
  - Weather integration in systems and research
  - Communications issues
  - Sensor issues
- Operational Issues
  - Develop confidence for re-allocation of separation responsibility to automation
  - Robustness and fall-back modes

Detailed Research Example

- Automated Airspace (Erzberger)
  - Size of super-sector
    - » How big is the biggest?
  - Psychological impact on pilots
    - » Dealing with automation-provided ATC clearances
  - Mixed operations in automated airspace
    - » Transitional design issue
  - Communication infrastructure
    - » Not ATN? UMTS? Satellite-based?

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13. ABSTRACT *(Maximum 200 words)*

This Conference Proceedings documents the results of a two-day NASA/FAA/Industry workshop that was held at the NASA Ames Research Center, located at Moffett Field, CA, on September 21-22, 2000. The purpose of the workshop was to bring together a representative cross section of leaders in air traffic management, from industry, FAA, and academia, to assist in defining the requirements for a new research effort, referred to as AvSTAR (Aviation Systems Technology Advanced Research). The Conference Proceedings includes the individual presentations, and summarizes the workshop discussions and recommendations.

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