AVIATION MODELING AND SIMULATION NEEDS AND REQUIREMENTS WORKSHOP

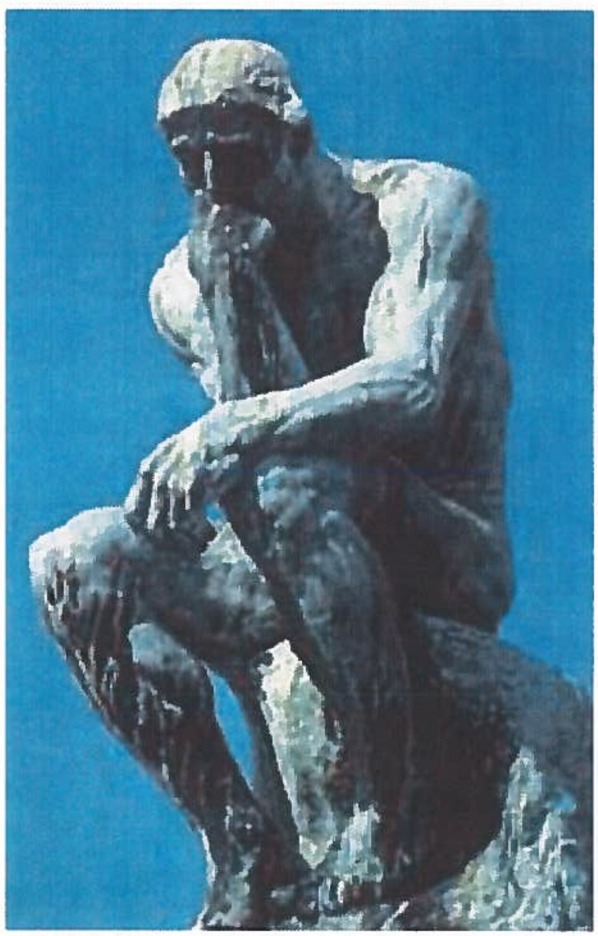
U.S. Department of Transportation

Research and Special Programs Administration

John A. Volpe National Transportation Systems Center

January 27-28, 1999

Robert Wiseman, Editor



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WORKSHOP AGENDA

Wednesday, January 27, 1999

9:00-10:30 **Opening Remarks: Setting the Stage** — **Richard R. John, Volpe Center**; **Kevin Corker, NASA/Ames**; **Steve Bradford, FAA**

Conceptual framework for identifying, assessing, and enhancing: 1) analytical and planning tools that give decision makers insight into the capacity, safety, environmental, economic, and security consequences of alternative air transportation system futures; and 2) alternative approaches to overcoming barriers to aviation system transition to new technologies and operating procedures.

10:30-10:45 Break

10:45-11:3 **Focus Area 1**
Capacity and Delay Analysis and Simulation — **Amedeo Odoni, MI**, *Discussion Facilitator*

Capacity and delay models are the most advanced in terms of being able to meet user needs. Major deficiencies are the lack of information on the part of potential model users on what models are available and what models are best to use for a particular situation. (Ref. 3/97 MIT Report, AATT Research)

Current Status of Analytical,
Modeling and Simulation Tools

Group Discussion

11:30-1:00 **Focus Area 2**
Safety and Security Analysis — **Charlie Huettner**, *Discussion Facilitator*

Conflict generation, detection, and resolution models are particularly relevant to propose new air traffic management concepts, e.g., Free-Flight. No single existing model provides enough flexibility and capability to perform a complete in-depth study of conflict detection and resolution (Ref. 3/97 MIT Report, AATT Research). *Analytical planning tools are needed to assess the vulnerability of the air transportation system to natural and man-made physical and information system disruption.*

Current Status of Analytical,
Modeling and Simulation Tools

Group Discussion

1:00-2:00	Lunch

2:00-2:45 **Focus Area 3**
Environmental Analysis — **Wes Harris, MIT**, *Discussion Facilitator*

Procedures and new technologies that increase through-put in a congested terminal area may not be enthusiastically received by environmentalists who are already concerned about aircraft noise and air pollution.

Current Status of Analytical,
Modeling and Simulation Tools

Group Discussion

2:45-3:00 Break

Focus Area 4
Human Automation Analysis and Modeling Capabilities — **Kevin Corker, NASA/Ames**, *Discussion Facilitator*

Many of the basic principles and issues in this area are not yet fully understood at the conceptual level. As humans become the limiting element in the critical systems of air transportation, automation must be used to support critical human performance. Given the immense importance of human/automation interaction in proposed advanced air transportation system concepts, e.g., shared pilot-air traffic controller decisionmaking, this category of modeling deserves urgent attention.

Current Status of Analytical,
Modeling and Simulation Tools

Group Discussion

4:30 *Adjourn*

Thursday, January 28, 1999

9:00-10:30 **Focus Area 5**
User and Provider Economics — **Steve Bradford, FAA**
Discussion Facilitator

Cost/benefit analysis and simulations of new air system technologies and procedures are needed for each of the participants, i.e., service providers, aircraft operators, passengers, and shippers. Technology and procedural upgrades to the air transportation system will only be voluntarily adopted if the economic benefits are apparent to all the stakeholders.

Current Status of Analytical,
Modeling and Simulation Tools

Group Discussion

10:30-10:45 *Break*

10:45-12:15 **Focus Area 6**
Barriers to Aviation System Transition — **Bob Simpson**
Discussion Facilitator

Current understanding of multi-stakeholder decision process and means of overcoming barriers to air transportation system transition.

Current Status

12:15 *Lunch*

1:15-3:00 **Open Session:** — **Kevin Corker, NASA/Ames**

Prioritization of analytical, modeling, and simulation research initiatives

Development of a common understanding of roles, responsibilities, and resource requirements.

3:00-3:15 *Break*

3:15-4:00 **Concluding Remarks** — **Richard R. John, Volpe Center**
Kevin Corker, NASA/Ames
Steve Bradford, FAA

4:15 *Adjourn*

EXECUTIVE SUMMARY

A two-day workshop was held at the Volpe Center on January 27-28, 1999. The purpose of the workshop was to:

1) identify and understand the requirements for analytical and planning tool initiatives that will give decision makers insight into the capacity, safety, security, environmental, and economic consequences of and transition constraints to alternative air transportation futures;

2) formulate a common understanding of the capabilities and gaps of current analytical, modeling, and simulation tools;

3) address the requirement that different model and simulation focus areas be compatible and capable of integration; and

4) establish priorities for an air transportation system analysis, modeling and simulation research agenda and develop a common understanding of roles, responsibilities, and resource requirements.

Federal and academic aviation experts with extensive modeling and simulation experience attended the workshop. Concern was expressed that the workshop was titled inappropriately and that modeling and simulation needs and requirements had to be expressed in terms of the total air transportation enterprise, since such efforts have little meaning outside the context of the total system. It was agreed that the primary goal of the workshop was to provide a framework for generating a knowledge base to improve decision making by the users (air carriers, general aviation, military, general public) and providers (air traffic controllers, airport operators) of the air transportation system.

In addition to a knowledge base, it was agreed that a process for analysis to provide information in an appropriate and consistent form to the policy makes and program directors is a shared need across the national agencies and private sector organizations involved in NAS infrastructure and development decisions. Simulation and modeling of the various facets of the air transportation enterprise are not an end in themselves, but rather are a means to provide the knowledge base required for system design and transition decisions.

Refinement and development of new tools for analysis, simulation, and modeling were seen as needed to support three areas:

1) Enhanced understanding of the role of the aviation system in the total economy and its resulting impact on the public good.

2) Tools and analysis to evaluate future global air transportation system requirements (e.g., institutional, economic, environmental, safety), operational concepts (e.g., centralized versus decentralized control) to meet these requirements, and processes, procedures, and

technology (e.g., shared decision making, space-based communication, navigation, and surveillance) to respond to the operational concepts .

3) Tools and analysis to evaluate the benefits of near-term (one to five years) changes in processes, procedures, and technologies (e.g., passive final approach spacing tool, P-FAST, and collaborative decision-making, CDM).

Considerable emphasis was placed on identifying and summarizing potential issues that would benefit from an improved knowledge base for decision-makers. It was agreed that the direction of modeling and simulation research had to be driven by the need to respond to a series of pressing issues and problems and was most effectively addressed in an integrated manner, one that takes into consideration issues related to safety, security, environment, institutions, economics.

The final determination of the feasibility of introducing new procedures, processes, and technologies must involve an understanding the role of multi-stakeholders in the air transportation system transition decision process. The value of an integrated approach to simulation and analysis is found in an ability to propagate the effects of decisions in one area of NAS operations to other and in the ability to leverage on the full body of analyses undertaken in response to specific point-design problems, to provide a framework for knowledge.

Workshop participants reached agreement on the need to establish problem-specific knowledge bases designed to support decision making in the following six areas:

1) Institutional

- Equity and efficiency impacts of the proposed semi-public/semi-private air traffic system (case studies from overseas should be considered)
- Increased concerns regarding the rapidly emerging requirement to achieve international standard operating procedures, processes, and technologies.

2) Safety

- Long-term safety implications of moving from central to decentralized air traffic control and shared decision making between the pilot and the air traffic controller.

3) Security

- Trade-off between level of security and schedule predictability.
- Major public policy concerns regarding. roles, responsibilities, and funding of physical and information aviation security.

4) Economic

- Evaluation of proposed air system changes in terms of benefits and costs to providers (i.e., aviation authorities which must acquire new services and the pilots and controllers that must be retrained); and benefits and costs to users (i.e., national and international airlines, military, business and commercial operators, general aviation, passengers and shippers).

5) Environmental

- Implications of changing the air traffic mix (i.e., size of airplanes, changing air traffic operating procedures, and increased throughput and delays, and the impact on local noise and air pollution).

6) Operational

- Integrated assessment of air system efficiency (i.e., throughput, predictability, and delays) with moving from centralized to decentralized air traffic control and shared decision making between the pilot and automated decision making transition

- Understanding and awareness of the multi-stakeholders who may provide constraints and barriers to the transition

INTRODUCTION TO THE MINUTES OF THE WORKSHOP

The minutes of the workshop follow this introduction. The viewgraph material used by all of the presenters is contained in the last part of the minutes on page 48 in files that are in the same chronological order as their corresponding presentations. The file names are listed in parentheses next to the speaker's name at the beginning of each presentation description. A paper provided by Dr. Robert Simpson and the workshop attendees are respectively in the last two sections of this document.

MINUTES OF THE WORKSHOP

Opening Remarks: Setting the Stage

Dr. Richard John, the Director of the Volpe Center, opened the workshop, thanking everyone for coming and encouraging them to be active participants in the discussions. (See pages 51-54 of these proceedings). He showed an abbreviated version of the agenda, covering the topic titles and mentioning that ample time had been planned to allow extensive discussion after the presenters in each focus area were finished.

Dr. John outlined some of the outstanding issues in evaluating the current aviation system performance, citing limitations in analysis tools metrics for assessing capacity, safety, security, and environmental and economic effects. He stated that there was a lack of agreement on the roles, actions, and motivations of pilots, controllers, and airline dispatchers, and on the impact of current weather prediction and forecasting capabilities. There was also lack of agreement on the impact of future restrictions in the environment and in new CNS technology.

Dr. John broadly discussed what he considered to be three priority areas: These were:

1. To strengthen analytical and planning tools that give insight into the capacity, safety, security, environmental, economic, and institutional consequences of alternative traffic management concepts.

2. To develop alternative approaches to overcoming barriers to aviation system transition, including legal considerations, user and provider incentives, and financial alternatives.

3. To support the development of a technical community for aviation system assessment with the wide participation of industry, government, and academia.

Dr. John cited findings of a recent study by the National Research Council that stressed that adequate models were needed to predict the technological and procedural changes in the air transportation system and to meet NASA's goals for system capacity, environmental compatibility, safety, and cost.

Dr. John discussed Free Flight Phase 1 (FFP1) program, stating that it represented a $500 million investment by the FAA, He briefly discussed performance metrics for FFP1 that were presented to the R&D Advisory Committee, stressing that it would be difficult to compare its performance to today's system.

Dr. John briefly mentioned another program (that had been presented by Shelley Meyers) called Safe Flight 21, an $80 million effort that focuses on general aviation. He said that RTCA has spelled out nine enhancements for Safe Flight 21stating that, as with FFP1, that it was important to know whether "we are making the system better or worse and if we don't know that, it would be very hard to convince the users to make changes in what they are doing." He emphasized that his comments were not meant to be demeaning since they only reflected what he saw when the presentations on FFP1 and Safe Flight 21 were made.

Dr. John stated that for the nine enhancements in Safe Flight 21, aside from the intuitive feeling that the experiment results in Alaska and the mid-west will make things better, how will we quantify the performance implications? He said he used this example to set the tone for the two day workshop and to raise the discussions "up a level" to "ask where is it we should be heading and what sort of knowledge we should generate." Dr. John then turned to Dr. Kevin Corker for his opening remarks.

Dr. Kevin Corker of NASA Ames opened his discussion by thanking everyone for coming. He did not have any viewgraphs. He stated that he was enthusiastic about having so many experts who have developed models so that a direction could be charted that would not limit the discussion to only a few models. He said that he was asked by Dr. John to remark on NASA's requirements for modeling, a unique opportunity since he is no longer with NASA. He stated that NASA had at least two major experiments going on, those in capacity and those in safety. He described how NASA are focus on whether a particular direction is the right direction and whether the implementation of the direction yields what it was intended to do.

Dr. Corker stated that the two directions involved a combined $900 million investment over the next five years. The process to arrive at the two experiments is that generally a stakeholder or a group of people representing the industry have identified what they believe is a significant national problem. For example, he showed a well used chart on capacity that showed that if nothing is done the average delay for flights would increase somewhat exponentially. At the point where the delay reaches 4.5 minutes the airlines schedules break down and they can no longer maintain them. The suggestion is that certain technologies, now called Free Flight Phase 1, can do something about that set of delays. He then pointed to another line where the delay line was moved along the capacity abscissa, showing that the 4.5 minute average delay would occur at a higher capacity.

Dr. Corker pointed out that the capacity vs. delay graph was predicated on models which are projected uses and requirements in the airspace. The solution is justified on a similar set of predictions. Then another "to be desired" implementation of all possible improvements are projected. NASA has been working a couple of years to produce an assigned set of future road maps, in this case to triple the thru-put within three years in all weather conditions, while still maintaining safety. As Dick John pointed out, we don't know today's baseline so it will be an interesting process to say that we've tripled the thru-put from a baseline we haven't established.

Given our thru-put goal we got together with the best we can do internally, and with industry, academia, and the FAA and asked what are the technologies that will enable us to meet this goal. So we have identified a set of near and mid term technologies starting with aviation operation and leading to intelligent automation, increasing linkages between air and ground operations, and also a set of technologies associated with improved performance aircraft. All of the projections from 2000 on are based on models.

The safety program has a similar road map and, having been involved early in its planning, I can say that the projections on what will be necessary to enhance safety are also based largely on models of technologies and their impacts. Dr. Corker then showed a Block diagram entitled "Model Use" that showed a temporal progression from Systems Analysis and Investment Modeling; to Prototype and Conceptual Design, to Performance Analysis; and, finally, to Impact Analysis and Effectiveness Measures. The investment modeling predicts whether the technologies and techniques enhance capacity or safety. The Design models provide functional and interface guidance, including those of the human interface. The Performance models determine whether the prototypes are meeting the requirements of the capacity or safety goals. Finally the Impact models compare the changes against the baseline, which, as I have said, is not well known.

Prof. Hansman pointed out that after the Performance model there should be a model that addresses what is going to be bought and installed and how much it will cost. Dr. Corker showed another "cut" viewgraph, entitled "Requirements for Model Integration", that showed different scales of models, ranging from Transportation Systems Models and NAS models to Airspace Specific, Operations and Technology Specific, to Human Performance models. He mentioned that the FAA and Eurocontrol have put out a review of those NAS models that are associated with separation. The Operation and Technology models look at pieces of the full story, while the Human models determine how the technologies are going to be impacted by human performance.

There is feedback of at least one level of feedback, up or down, exists between the five levels, with human models capable of two levels. The identification of human performance is getting better. For example, the implementation in TOPAZ of a cognitive competency model is a significant advance, and we are looking into other advances by the FAA. Dr. Corker postulated that the policy decisions at the higher levels are not being fed back to lower levels, and eventually human performance. He also stated that the issue of the impact of a national safety movement on airline policy, on FAA certification policy, and eventually on operations, is not treated in any models he's aware of.

Dr. Corker then showed a viewgraph entitled "Matrix of Performance Requirements", where in each cell there are dimensions of tradeoffs that can be addressed. And there finer expansions within each of the cells. For example, the rolls and responsibilities in Free Flight operation can vary from autonomy and consultation to cooperation and control distribution. These control actions will vary with the automation level and the types of actions that are taken. He summarized by saying that NASA's needs are for all of those models and their integration.

Dr. Young commented that what was really needed was a methodology, not new models, that would make sure that what was taken away from a model to get from a lower level model to a higher one was adequately represented. And if you have a methodology you can establish a set of requirements for the models.

Steve Bradford of the FAA did not have any formal viewgraphs. He opened his discussion with the question, "What does the FAA need?" He said, "We have two needs. The first is what does air traffic need in order to do its airspace design and its procedures. There we have plenty of models. We have SIMMOD, TAM, RAMS, etc. These models are nicely focused and they fit the bill. Some have strengths and some have weaknesses. But they all lack the ability to capture the future of the NAS because of its complexity.

Mr. Bradford then drew a diagram on a large easel mounted pad of paper. After the workshop was over he submitted more elaborate electronic versions of the themes of his presentation (See pages 55-58 of these proceedings).

Air traffic's goal is to do the most efficient job they can within the constraints of the system. But if you ask them what is their concept of the future, they basically take today's traffic and increase it 200%. That's fine except that the NAS is very complex and very adaptive and it is extremely difficult to predict its future. He said he could give numerous examples of where that's true, e.g., Raleigh-Duram, Nashville, and San Jose.

The problem is that we say, given today's constraints, we do today's traffic world. We should be asking, "What's the problem and what are the potential problems?" For example, everyone is saying that there will be a capacity shortfall in ten years. Maybe yes, and maybe no. We have lots of airports. What are the possibilities for those other airports? NASA has provided two policy goals, first AATT says make all the existing hubs more effective. Then Langley says make all the small airports relieve the traffic at the big ones. So he's worried about the FAA building a NAS against two different goals.

Steve Bradford gave an example of how the problems are not properly defined. It was a case where there is a tool in the field today that is in daily use, where it is not being used for what it was planned for. The tool is the conflict probe and its note being used for that. Its being used as a strip reduction tool. He mentioned a paper given at Orlando that very nicely laid out the focus of the pilot and the focus of the controller at three levels. There was agreement that pilots and controllers have the same objectives at the highest level, but at the next level down they have a completely different view of life. So it appeared to him that the FAA may be building tools from the pilots point of view and then handing them over to the controllers.

Mr. Bradford said that it is important to know the real state of the NAS. For example, do we know how many potential encounters there are out there. What are our right measures? It is pervasive that we build tools to solve perceived problems when we don't know when we don't know what's really out there. He said that there is the question of what's Free Flight Phase 1 all for, particularly since there is no benefits baseline. There is also no NAS performance baseline. No one knows how well the controllers are performing or how many aircraft are being put through the system. There are no measures of efficiency, no knowledge of how good the controller's resolutions are, and no knowledge of whether they're using the right strategy. When one asks are they using conflict resolution, the answer is, "No, they are managing the flow."

Mr. Bradford said that tools should make the pilot's and controller's lives better, but not necessarily easier since they can get bored. We should focus on the real problems, what causes controllers heartburn, and what is their real performance. This led to a discussion of how controllers respond to changes. One participant stated that automated tools that make the controllers more efficient may be rejected if they don't like them, since they can say that the tools may sacrifice safety.

Dr. Corker stated that a higher level would be to get to other constituencies in addition to the air traffic controller, and that is the reason why this first workshop is limited to federal and university parties. Once these parties reach a consensus on what they want to see, a second workshop will be held to determine what everybody else in the aviation industry wants to see. The industry group would include model and system builders.

Steve Bradford said that its easy to model what exists today and to model incremental changes, but radical changes in the future are very difficult to model. There was general agreement on this point. Bradford mentioned that there is an active effort by a Eurocontrol group (Rob Whitiker current chair) to identify what is needed to validate their future concepts. The hope is that we can agree with the Europeans on a single set of requirements. He mentioned that he did not have the slide that showed the future concept of the new architecture as a giant web of decision support systems with an information backbone and, below that, integrated surveillance, communications, and weather. This slide basically says that the NAS is going to stay a human-centered enterprise.

There was general agreement that the major air carriers already have all the navigation capability they need, so they don't need GPS. It was pointed out that smaller aircraft would gain from the low cost of GPS and that air cargo companies, like FedEx would benefit from the capability to land at smaller feeder airports.

Steve Bradford stated that meetings were held with a wide variety of industry people to determine what they wanted from the NAS. Safety was important, particularly for runway incursions, but outside of that issue each constituent group thought everything else was a high priority. When they were asked to come back with the most important high priorities, they couldn't because what's high for airlines, is slightly different for FedEx, and slightly different for general aviation, etc.

One participant stated that it is not the stakeholders that the NAS is funded for. The funds are for the general public. Another said that there was not enough aviation for the general public in rural America.

Steve Bradford asked where NASA should direct its efforts. He suggested that they focus on the biggest hubs where the delays are largest and improvements will have the biggest impact. He said that even the very fine level models like SIMMOD and TAMS treat the scheduled delays, but do not treat the real delays. That is, they don't capture whether the FAA is pushing everyone off the gate or off the queue, and therefore don't capture whether the FAA is being efficient in handling the large queues. This brought back the four minute intolerable (average) delay that Dr. Kevin Corker had presented, since $400 million is being driven by the assumption that the four minutes would bankrupt the airlines. Steve Bradford added…"or that delay is the FAA's responsibility and the FAA should fix that."

A discussion started on whether the airline marketing people get information from their operations people and therefore will schedule a flight at a spare gate even when too many other flights are there. One position was that this was the right decision since it might make the airline more money. A counter argument was that the extra flight was causing delays to other flights and therefore was not productive. One participant stated that schedule integrity is the big item with the airlines, raising the point that the airlines had increased their OAG flight times to show that they were meeting their schedules.

Mr. Charles Heuttner of NASA Headquarters then gave a presentation of high-level efforts to define the coordination of NASA's Advanced Aviation Transportation Technologies program (AATT) with the FAA. (See pages 59-68 of these proceedings). He began by stating that he was the Executive Chair of a NASA/FAA Executive Committee that includes all the FAA Associate Administrators, NASA Center Directors, and is chaired by the NASA Associate Administrator for Aerospace Technology. This Committee is beginning to establish NASA's long-term AATT goals under the premise that NASA will bring research outcomes to the table and the FAA will determine if the outcomes are acceptable to real world. He stated that progress would be better if the Committee had the right models and tools to help them. But they don't.

Mr. Heuttner discussed six independent cultures in a viewgraph entitled "Challenge #2. The Aviation System is Changing." The six cultures were: flight crews; airports; maintenance; aircraft manufacturers; dispatch/flight ops; and air traffic management, and that "free flight" and digital data will be connecting them more. He mentioned safety initiatives for controlled flight into terrain, runway incursions, and synthetic vision; and that safety analysis needs real world operational data.

Dr. John asked, "How can we raise awareness that NASA needs models and simulations in the AATT?'. Mr. Heuttner answered that they're needed but right now there needs to be a better definition of what they're expected to do. This led to an open discussion where the following comments were made by the participants:

--The next war will be economic. Therefore more investment is needed in U.S. aviation and models are needed to evaluate impacts on the national economy.

--There is a White House initiative to raise aviation to a national priority level.

--There is a lot of data to look at and lots of ways to look at it, but we don't know the relationship of the different parts of the aviation system and the feed-backs among these parts.

--A wider view of modeling and simulation is needed when dealing with policy. Better names for this workshop might be "modeling to support national policy" or "a process for aviation system analysis and planning."

--Policy analysis should address the significant changes in the procedures and technologies in the system.

--The Air Force does not go directly into modeling. It is preceded scenarios of the future, then requirements to meet the short-falls; then analysis.

<u>Focus Area 1: Capacity and Delay Analysis and Simulation</u>

Professor Amedeo Odoni of MIT, acting as facilitator, began the focus area by stating that he would identify the current capabilities in **capacity and delay models and simulations** and what the needs are for future development (See pages 69-70 of these proceedings). He said that in the last couple of years there have been significant changes in what we expected these models to do. We used to establish a set of separations, procedures, capacities, and demand and then run the models to see how many aircraft could be processed per unit of time and what the delays were. Recently, with such things like collaborative decision-making, we are doing two important new things. One is that we recognized the system was very complex, having all kinds of real-time interruptions and dynamic behavior which we do not really understand. The second is that the old measures of expected capacity, average capacity, and average delay are not really the measures the airlines and the major users are looking for. The models now have moved from those of capacity and delay to models of traffic efficiency.

To briefly review the state of the art, Prof. Odoni referred to the report, "Existing and Required Modeling Capabilities for Evaluating ATM Systems and Concepts", that MIT did for NASA Ames. MIT concluded in the report that traffic efficiency models were the most advanced of the different types of models, but they still had deficiencies. Other types like conflict detection and resolution, human factors, and even cost/benefit models, that will be talked about later, are less advanced.

Dr. Andres Zellweger raised the issues that an American Airlines study of traffic efficiency predicted grid-lock in the year 2005. Mr. Steve Bradford answered that the study's premise was that if we continue to do business exactly as we do today, grid-lock would occur. Dr. John stated that change would certainly occur and that is a policy question.

Prof. Odoni then gave examples of traffic efficiency model metrics, such as capacity, thruput, number of aircraft landed per hour, and delay. For delay it is important to measure against some normal or optimal time interval, not to measure delay against schedule. The schedule is heavily padded by the airlines, and that we are deceiving ourselves by saying we are sticking to the schedule. Schedule integrity is an important concern to the airlines, that is, its variability and predictability. There are two types of predictability measures that are important. The first is short-term. For example, how does bad weather at San Francisco affect the schedule at Logan that particular morning or day. The second is long-term and addresses how reliable traffic capacity at Logan and how can its variability be reduced.

Steve Bradford referred to Kevin Corker earlier "4.5 minute" delay chart, as an example of not the average, but the variability in that it represented, say, two aircraft that were more than 15 minutes late that could mess up a bank of aircraft.

Prof. Odoni stated that flexibility is another important measure in that it provides the airlines the ability to adjust their schedules in real time during pre-flight. The models do not provide this. He mentioned that the models do capture thruput and delay under regular conditions, but, even though they provide mean and expected values, they do not capture the tails of distributions when the system is extremely stretched. For example, an extreme case where an airplane would have to wait more the 25 minutes. The models are weak in capturing dynamic behavior. For example, how airlines react to ground delay problems, what flights are cancelled and how many. It is also very difficult to predict how delays will spread through the system.

Prof. Odoni pointed out that the deficiencies in the models could be fixed. He mentioned that, with new databases such as ETMS and ASD-B, there is now a golden opportunity to improve the data support for the models. That is, doing case studies and "what if" exercises. We also do not really understand how the system works today. He said that he and Prof. John Hansman are working on a departure planning project for NASA. In their observations at Logan and they are continually surprised by some of the things they see there.

Prof. Odoni said that the models need to be more dynamic by talking to other models that capture some control aspects of the system (e.g., its reaction to events). We need to improve the ways we choose models to the right level of abstraction and how usable they are. He clarified his term "horizontal model integration" by saying that it was coupling models that have the same level of detail. He cautioned against to much dependency on model tool kits (groups of models) since different models have different assumptions. Citing a paper presented in Orlando by Steve Bradford and Dr. Montaloni, he said that there is promise in interprocessing, that is, connecting simulations to organization control groups. Vertical model integration should be looked at, for example distributed simulation and human/machine models.

Prof. Odoni closed by saying the models have strengths but they are static, with no feedback, no agent dynamics, limited capability for integration, and weak in capturing human performance when it is important.

Mr. Richard Wright of the Volpe Center made his presentation on **utility, database, and modeling applications of ETMS, including collaborative decision-making** (See pages 71-74 of these proceedings). He began by saying that the Traffic Management System (TMS) is an operational system that was based, many years ago, on work that was done along the lines of a mesoscale model (in the sense that it doesn't attempt to microscopically model the behaviors of aircraft or air traffic control interactions). It does model aircraft activities rather coarsely to estimate their impact on the system.

Mr. Wright discussed the TMS infrastructure and stated that it showed some potential as a policy-level decision-making model. He said that TMS is process rich, in that it has a lot of independent entities that work within an operating system and where everything can be a peer to peer server or a client to everything else. He showed the major interconnections in TMS and stated that there is a potential for many other. It is highly distributed at a hub site and at remote sites where the operators can call up the information they need. The architecture does not care whether the process is remote or local and the processes can interconnect to other processes in the system in any way they need to.

Mr. Wright said that TMS looks at a space of time that runs from minutes to months (in the case of schedule data). In contrast, CTAS and SMA look at intervals in the half-hour range. The Host looks from “right now” to minutes. TMS has a completely different time horizon, but there is some overlap at the shorter time intervals where, from the point of view of data, the different systems could benefit from interconnection.

TMS divides the air traffic control system into individual pieces: airports, approach, departure, en route, etc. If you look at, say, the tools that fit under Free Flight Phase 1 you’ll have the higher level traffic management User Requested Evaluation Tool for en route; the departure sequencing or flow tool for departures and climbs; for funneling down into the airport the CTAS; and for the surface SMA. TMS addresses this entire spectrum, but not at the microscopic level of detail of the component tools., hence, the mesoscale label.

The TMS hub has strings (circles) of machines with sufficient capacity to do the TMS job. Some are repeated for operational redundancy. There are also development and test strings. This architecture is capable of accepting many more machines or computational hub elements, including a research server, which we are exploring.

TMS has many interconnections, e.g., 50 TRACONS, 22 U.S. ARTCCs, and 12 Canadian ARTCCs. There are some R&D sites and a private network of 35 commercial users for cooperative decision making with the airlines.

Mr. Wright concluded his presentation by discussing two block diagrams. The first was a diagram of the real-time operational TMS itself. It showed the major components, starting from the data sources. it is then normalized by a parser and passed on to from a flight record for each aircraft. The records are then sent to a traffic database where the aggregate impact of all flights in each entity of the ATC system is evaluated in real time.

The main blocks of the TMS are supported by a list server, a flight table manager, and a traffic manager work-bench. The flight table manager allows remote sites to think they are hub sites. The list server are the tools the users have to examine the data. The archiving process, essentially artifact free. gets data from all parts of the system.

The second part of Mr. Wright`s block diagram represented the simulation world that receives archived data that is fed to the parser and the flight database. The list server and the flight table manager are replaced by more elaborate analysis and report generator subsystems. The archived data is useful as a scenario generator because of extensive post-processing before the data is stored. The archives are a history of everything that went on for a number of years.

One participant asked if the simulation parser were the same as the operational parser. Mr. Wright said that it was simpler. Another asked whether the simulation has ever been used to do analysis. The answer was, “Yes, but not as elegantly as it has been depicted since we are still learning how to do this.

In answer to a series of questions by another participant, Mr. Wright stated that, since the TMS has been evolving since 1987, full archive data is only good for the last two years. The data contains all the radar hits that the system gets every 5 minutes for en route, every 30 seconds for TRACONS, and every 30 minutes for oceanic. The data has weather, and the OAG schedule.

He also stated that the archived data is not collected on the operational system; it is on a separate developmental system which does not have back-up and there are therefore some gaps in the data. Volpe would like to develop another separate research system. Dr. Zellweger said that Embry-Riddle has been using the archived data successfully to develop flight data for TAM and other models.

Dr. Duane Small of MITRE gave a brief statement on the kinds of modeling they were doing. He said that, except for specific needs for specific projects for something going on right now, they are not any modeling that addresses future analysis needs. He answered a question that they are using TAM, and they are also providing data support for ATA for airspace redesign.

Dr. Kevin Corker led a general discussion of modeling, beginning with his statement that both the NASA capacity and safety programs have sub-elements to develop models. (See pages 75-77 of these proceedings). The models are intended to justify the investments their effects on the system, in that the models make statements like "the technologies being injected into the system do not have an adverse effect on safety and they have a positive effect on capacity or thruput and their relative contributions are such and such." It is critical, however, that both the safety and capacity models have the same representation of the airspace. The models are not for designing prototypes, but they are intended to evaluate something when it implemented in the future.

The rate of model development and data collection is very slow. For example, a terminal area productivity program had model development at its outset, but it was scrapped because its investment analysis wasn't completed before the program was development was nearing its end. This brings across the point that the tools can be very cumbersome. The delays make it difficult for the policy makers to use the tools.

Prof. John Hansman stated that most models are built to answer a specific set of questions with specific data that needs to be collected. He was skeptical about mixing everything together and having a "grand" model that's supportable. Dr. Bob Simpson echoed this by stating that there is no general purpose model.

Focus Area 2: Safety and Security Analysis

Mr. Charles Heuttner, acting as facilitator began this focus area by repeating his assertion that the policy makers don't have the decision-making tools they need. (See pages 59-68 of these proceedings). He showed his "Goal 1 Safety" viewgraph that he had discussed very briefly in his earlier presentation. He stated that safety modeling and tools are about a decade behind air traffic modernization. With respect to capacity, you know what normal means, but not with safety normal operations haven't been documented.

He said that there are three thrusts that are being looked at for safety. The first is data analysis to determine where the problems are and to fix what we can simply through risk management. To do this, the FAA has a GAIN program, we have the Aviation Safety Reporting System (ASRS) and other reporting systems, and Flight Operational Quality Assurance program where were starting to analyze flight data recording information. The idea is to have a continuous improvement program within the industry. There are certain things that can't be improved this way. For example, controlled flight into terrain, and approach and landing accidents. For these, we have a second effort, an accident prevention program, where we're working on such things as synthetic vision. Lastly, since we might fail to some degree, we have a mitigation process to increase the survivability from accidents that do occur.

Focusing on the Risk Management arrow, since we saw that there was no documentation of normal, we had to somehow shrink down the huge amounts in flight data recorders to get some information out of it. The is one piece of data gathering, but the next piece is that we need a safety model like The Airport Model (TAM) , that is as we are working to define what normal is, we need to look at it over time so we can see if changes occur based on new technology in the cockpit or new air traffic control procedures.

So the safety tools should be able to tell us about the variability around normal. As a pilot, Mr. Huettner stated that he is trained a certain way on operating procedures, but when he gets on the airplane, it does not always operate the way the book says. Nor does he perfectly fly the plane the way he was told to. So what mistakes does he make around normal flying? We don't know. We are hoping to learn through some of the information on flight data recorders and the other operational solutions I've listed on the viewgraphs. When we do learn, our investments in safety technology and advanced training systems will lessen the mistakes we make when we are in the cockpit.

Without trying to unproductively focus on catastrophic accidents which are so rare, we need to improve our cost/benefit analysis and through discussions with the airline and other parties so that we can gather the right kinds of safety information.

Prof. John Hansman asked Mr. Huettner if he was having any luck coming up with safety metrics other than the obvious small number of accident rates? Mr. Heuttner answered that until we get down to a reasonable way of monitoring the actual flight operational data he doesn't know of any useful metrics. The data is out there. For example, crew reaction to windshear can be monitored. Prof. Hansman then stated that accident precursors that are useful in determining the causes of accidents. Dr. Simpson then retorted that there are a chain multiple precursors in an accident that, many times, we pilots get one two or more steps down that chain before we turn around and try to work our way out of them.

Ms. Patricia Ryan of the Volpe Center then gave her presentation on **modeling deployment of explosive detection equipment at airports**. (See pages 78-79 of these proceedings) She stated her group had developed two models for Admiral Flint's organization at FAA Headquarters-- an effectiveness model and a cost model to assess the explosives detection checking of passengers and baggage at airports. The models are used by the Aviation Security Advisory Committee Baseline Working Group to provide analysis and data in their report to the Gore Commission in its study of aviation security.

The effectiveness model is used to calculate the effectiveness of different procedures and screening devices at the airport. The model allows the evaluation of one or more different devices. Examples of screening methods are active or passive profiling. Active profiling occurs when a passenger goes to a ticket counter and is asked, "Did you pack your own bag?" Passive profiling occurs when a passenger is checked against a stored database, and includes passenger-to-bag matching before the bag goes on the plane.

A CTX 5000 is a screening device that uses cat-scan technology that looks for explosives in bags. A Vivid is a dual scan device also used to detect explosives in bags. Trace technologies detect minute particles of explosives on passengers or in bags. An example of the sequencing of screens and bag flows is when profiling first occurs and the bag than goes to a CTX machine. If there is nothing unusual in the bag, it goes to bag match. If profiling fails or the Ctx checks fails, the bag is then hand searched.

The cost model calculates peak bag flow at an airport and is used to estimate the ten-year costs of deploying different screening options. The model user can select the airport or multiple airports, the flight type (domestic or international), the aircraft's passenger capacity, and the day of the week. The model output is on an easily read spreadsheet and provides the costs different screening levels. The costs are broken down for each year by the number of screening machines, their purchase and installation costs, the training involved and other recurring and non-recurring costs.

Dr. Andres Zellweger asked if there were threat profiles in the model. Ms. Flynn said, "Yes, even for combinations of devices, but they are classified." Prof. Hansman then asked, "How do you validate the profiles?" The answer was, "Only on a statistical basis." Dr.Zellweger stated dogs are not effective after a short while.

Dr. John stated that security is a high importance and visibility in Congress, but Congress doesn't originally say what the costs should be. Another participant stated that they are doing a lot more in Europe. Dr. John said that Steve Zaidman told him that Congress allocated 40% of the FAA's R&D budget for security. He added that he was told that the dollars may be more than FAA's security organization could possibly spend. This is an example of why policy people need more information. Steve Bradford said that the high dollars for security were driven by TWA, but when it was determined that it wasn't a bomb, the dollars didn't change. Patricia Ryan stated that, unfortunately, security was driven by catastrophes.

Dr. Odoni said that there was a very good study by NEXTOR on the costs of bag matching. The average delay for 100% bag matching was 1.2 minutes per flight, about a 12% increase in the delay.

Dr. Robert Simpson did not use viewgraphs in his presentation on **conflict detection and resolution models**. He started his talk on conflict detection and resolution models with the statement that one of the problems we have in air traffic management engineering is that we don't know how to measure safety. There is, however, one older model, the North Atlantic collision risk model, that looked at the lateral separation of the aircraft in a non-traffic control situation as they came out of a transoceanic flight and estimated that a crash would occur only once every 150 years.

Dr. Simpson said that if you are addressing radar separations and a situation where you want to pass an aircraft in the front of another, you must know the risk is and be sure that it is not less than one in a million chance of a collision over units of time that are in minutes. In 1950, since we didn't know the risk, we set separations based on "comfort" that haven't changed. For example, two minute separations seemed comfortable for landings. But now, even with more radars, better displays, and other improvements, no one has even raised the issue that we could reduce the separations. For example, if the aircraft are in-trail and going slow, shouldn't we allow them to be only a mile apart?

Dr. Simpson recalled three times in the past five years that he was flying through New York airspace at 500 feet VFR and he heard the usual controller warning. The warning was given to an airline jet and said you have a target, it's a Piper Arrow, and it's at 5,500 (!?) feet at 11 o'clock. Then the controller talks to me and says here comes something like a rocket 1500 feet above me and starts a turn. After this third time, I went to the airman's information manual. The controller's handbook states that minimum radar separation is three miles. But those aircraft were roughly a mile or a mile-and-a-half away from me. To my surprise, the manual said that, for Class B airspace, when one of the aircraft is VFR and is weighing less than 18,500 pounds, then the radar controller can run this airplane (e.g., 727's, 747's) past me with a mile-and-half separation. Where does that reduction in separation come from? The point of my example is that the controllers can reduce separation if they think it's safe. It's legal, and if I'm in Class B airspace, I think it's safe.

Steve Bradford said that there are lots of procedures that can be exercised by the controllers that involve separations below minimums. Dr. Zellweger then asked, "What about the analysis that was done for something like the Final Approach Monitor?" Dr. Simpson answered that there was an analysis done where two aircraft were making an approach at the same time, and it is presumed that one aircraft will make a 30 degree turn and continue it until it gets over the other aircraft. This never happened in the history of civil aviation. But that scenario was the basis for the analysis. It was chosen as an extreme example so that they could get it into the public domain and the controllers and pilots could struggle with it.

Prof. Hansman stated that you always need some hypothetical basis for a scenario. Dr. Simpson answered that it wasn't rational. A better scenario might have been a missed approach on parallel runways by two aircraft in fog where there is very poor guidance. This is a good example of the advantage of GPS, since, after you start the missed approach, with the ILS you don't quite know where you are and the wind could blow you anywhere. Hopefully, you can get the radar controller on the radio and he can tell you that you are drifting together and give you conflict resolution instructions.

Dr. Simpson then began his general discussion of conflict detection and resolution models by saying that he did not know how to do the risk or the safety analysis. He said that the models in the MIT report were really traffic generation models, where criteria are established to get encounter rates. If the rates are too high, the conditions are judged to be unsafe. But they are all inadequate, since they do not address conformance to a path that the airplanes fly. They need to, but don't have, have the flight guidance modes, the wind variability, the navigation and surveillance characteristics, the complexity of the path, and the time-to-go. We do need these additional features in what I call trajectory prediction. And then we must know how rapidly we can intervene and what's the response path.

Another feature that is needed is encounter identification. That is how do pilots and controllers identify that there is a situation that requires some kind of corrective action? Down at Orlando at the Eurocontrol meeting I had a three part view that said there are conflicts, there are hazards, and there are encounters. Encounters are interesting because they are 5 to 15 minutes ahead.

Without the additionally needed features I mentioned, the encounter process will be like: we have an encounter; wait now we don't; oops, now we do. This uncertainty is like a signal that jitters on you. So when you have to resolve the situation, you've got to change your strategy. What we have, conflict alert as a back-up for controllers and TCAS, are escape and evade things, where your down to 30-45 seconds and don't want to argue about the degree of certainty. On the other hand, there will be ten to a hundred times the number of encounters, so you don't want to be constantly resolving things that don't have a high probability of happening.

Dr. Simpson mentioned that criteria for determining intervention rates and separations at passage also need to be established. He said that he would call 500 feet in a circle around the aircraft should be used. He asked what do you do if you really do intervene? One of the things controllers do is just defer encounters and just keep an eye on the situation.

Another technique is to advise and there are several kinds that are given today. For example, messages to two pilots would say, "This is a bad time to go off your altitude because you are going to pass very close to each other. You're a 1000 feet apart. I will tell you what's going on so you're not startled. But I also advise you that that airplane is going to pass 1000 feet under you, so make sure you're at your altitude. Don't start fiddling with maps or other things so you don't wander off. The resolution when intervening is automated needs to be established. This will lead to the definition of separations at passage where the question of how close is safe will arise.

Dr. Simpson said that in safety analysis, if you normalize, you get one measure of the risk. But we've also recognized that in the Atlantic we have another non-normal process called, "The blunder" which is difficult to characterize. For example, pilots doing something wrong with their flight management systems, like the incident with Delta where a passenger told them that they were 60 miles off track. Controller and pilot blunders also exist in the CONUS.

Dr. Simpson resumed his presentation after the lunch hour by saying that, for conflict detection, there are ways to get intention information. TCAS is a primitive separation assurance tool since it assumes that an aircraft is flying in a straight line and will continue to fly in a straight line- a condition that doesn't occur over 99% of the time. For example, under certain circumstances, TCAS can cause a collision by an F-16 coming in behind a 727 in reserved airspace.

The Airborne Separation Assurance System, ASAS, is a method for getting intention information, e.g., tracking over the ground, holding a heading, climbing rate to level off. The question is, even if the TCAS was successful, say between 75 to 95 percent of the time, do you say that it is imperfect technique, particularly since we have not had a mid-air collision between airliners in the last 34 years. There have been very few accidents, but there have been incidents where the pilot is made aware of a potential collision.

There used to be about two dozen mid-air collisions a year in general aviation. That's down to about a dozen now. The problem there is the non-towered airport, where aircraft are flying around and trying to land on the same runway. Mid-air collisions occur around the world, but generally in a non-radar environment. The number of near mid-air collisions in a given area may tell you that you should do something about that area.

Dr. Richard John then thanked Dr. Simpson and said that at lunch a caucus was held to make a little bit of a mid-course correction. The background to this was that the major purpose of the workshop is to get people in the field together to work out ways to create an awareness of analysis, modeling, and simulation. But these are not ends in themselves. For example, Boeing indicated that they were no longer interested in building supersonic transport aircraft in the year 2025. This very soon caused NASA aeronautics budget to get chopped by $500 million. Today, there is a fire wall around the aeronautics and safety budget in NASA. This protection will exist so long as people in the community feel that something will occur that is useful to them.

So Dr. John said that, on a higher level, modeling and simulation is just a way of letting decision makers look at policy alternatives. So we need to look at the kinds of the policy decisions that they will have to make, and then determine what kinds of modeling and simulation is needed to support them. For example, should we go entirely to a space-base communication and navigation system if there is a threat to the system? He then asked for others to express their opinions on this issue.

Prof. Odoni stated that he hoped that what Dr. John suggested would be the outcome of the workshop. But it will be very difficult to determine what specific questions should be asked and what constraints there are on the policies. Dr. Corker said that it was important to identify what issues need to be addressed, do we have the tools to address them, and an assessment of who does what. That is, what are the relative roles of the FAA and NASA?

Charles Heuttner stated that, unofficially, there seems be a lack of awareness of what could be done today. He said that there is great interest in pulling together what we could do in an integrated way. Boeing went to the FAA's Steve Zaidman and Sam Armstrong, who both said, "Why don't we get on with this? We need to get the big picture and find out where there are gaps in the existing tools." We need to do this both for the short and long terms with a plan.
Steve Bradford then said that Congress doesn't fully understand shared decision making, and therefore his budget has been limited over the past three years. Steve Bradford said that, even though this is supposed to be the year of aviation, there is no immediate need from most of the people on the Hill for aviation, except for the small number of 38 Representatives and 19 Senators around the big airports.

Dr. Mike Young, who stated that he doesn't know the business that well but a high level problem statement is needed. For example the tremendous increases in air travel due deregulation is going to severely disrupt the system. The FAA's major investments in the 60's and the 70's will not be able to deal with this growth. So, at the next lower level, its important to talk about the impacts on safety, the environment, etc., of this huge increase. It's also important to evaluate the impacts of the major changes in the European system and their impact on us.

Prof. Bob Simpson, responding to an open discussion on the appropriate ways to express high level problem statements, said that to say "shared responsibility" is at a lower level. He gave an example of a higher level when he said that it takes $18,000 per year or $70 per flight hour for each aircraft just to operate the air traffic system. A high level goal would be to reduce those costs. Charles Heuttner added that it is important for the FAA to prove to OMB that what they want to do will produce a return on investment. Everyone agreed that the proof would have to be said to OMB in simple terms, like a "sound bite", and should not use words like "modeling and simulation."

Dr. John stated that the purpose of the workshop was to find a way to show the importance of analysis, modeling and simulation to all of the constituents in the aviation industry at a subsequent larger workshop. The constituents include airport operators, airlines, and many others who can go to Congress and say, "This is great." Dr. Corker aid that one of the things wrong now is that we don't have the right tools to give us the data to substantiate the importance. So we should pay attention to this lower, but important level.

Mike Young talked about how DOD deals with the future. They first look at several future scenarios of the future world to come up with threats. Then, way before modeling, they do extensive analysis to come up with potential solutions that should be looked at. For example, if we think our forces are vulnerable to aircraft attack, we first examine why we think that's true. Then this analysis goes out to our services and the Air Force will come up with a better air superiority fighter, the Army will come up with some kind of better ground-based missile system, and the Navy will come up with something else. These will all still be paper studies, before modeling begins. These early steps seem to be missing.

<u>Focus Area 3: Environmental Analysis</u>

Prof. Jean-Paul Clarke of MIT began this focus area without the facilitator, Prof. Wes Harris, who could not attend due to illness. Prof. Clark's presentation was on **aircraft noise models**. (See pages 80-91 of these proceedings). He started with the question, "Why do we care about noise models?" At a policy level every knows that, when they try to change an airport's operation, there is a strong negative community response to the aircraft noise. So changes like new arrival and departure patterns or in routings result in lengthy negotiations, to put it mildly. We need enhance our communication with community groups and get data and graphics that the community can understand.

We also have to provide some basis for compensation through Environmental Impact Studies and Part 150 studies to determine who and why one house gets free soundproofing while another across the street doesn't. Prof. Clarke said that design of operational flight procedures with high fidelity noise models can yield big benefits.

Prof. Clarke identified four parameters in noise models, First, aircraft trajectories, where radar data, performance models, or simulation could be used. Second, noise sources, where component models or empirical databases could be used. Third, propagation, where atmospheric conditions and attenuation models (e.g., when an airport is near a body of water), and fourth what is the population distribution and topography near the airport.

Prof. Clarke highlighted two noise models the Integrated Noise Model (INM) and NOISIM. INM is the standard FAA noise model that has been used to predict noise at over 3000 airports. It aggregates noise over an entire year of airport operation. The model is used by the FAA when the airspace around an airport is redesigned. But it is only for the "big picture" over an extended period of time and used a simplified performance model with a limited prediction range and covers a single atmospheric condition. The source noise is obtained from a noise power/distance table look-up, as is the propagation model, which does not have a noise frequency capability.

The model requires additional databases to characterize the population distributions and topographies. It is good for showing people what's going on. We, at MIT, have developed some improvements in the aircraft prediction part of INM. There is also work going on at MIT, Volpe, Airbus, and Boeing to look at: an expanded database of more types of aircraft; spectral classes of noise frequencies; and finer near water and away from water modeling.

NOISIM was developed at MIT. It was developed to do the communication with the public and demonstrations, but also the development of flight procedures. A flight simulator was combined with a noise model and a GIS, all with the highest fidelity possible. It also had the capability to simulate realistic operations, to model the frequency distributions around the aircraft, and to get propagation under actual atmospheric conditions. The model also has detailed single flight trajectories that can be combined for multiple aircraft noise.

Prof. Clarke then presented two examples of design trade-offs that could be done with NOISIM. The first was a departure case study, where at Logan, runway 4 right, with its residential community adjacent to the departure end of the runway. We compared the current departure procedure to another procedure that began with a thrust cut-back, followed by a resumption when the aircraft was over the ocean. The result was that the population impacted by noise greater than 60 dBA was reduced from 67,000 to 57,000.

The second design trade-off was done for a much more highly populated region at JFK airport. Because of Laguardia airport, to land at runway 13 left at JFK, you have to get down really low and intercept the glide-slope at around 2000 feet. Because of this low altitude maneuvering there is a big impact on the population. So we looked at what could be a new procedure that would be useful under all flying conditions.

We first looked at the current visual approach procedure, which was to fly along the coast staying close to Jamaica Bay and turning really close in to the runway, an approach called the Canarsie visual. But this was not good for all weather conditions. So we took a step back and looked at some decelerating approaches we had studied earlier where the glide slope was intercepted at 6000 feet an the aircraft came down at a steady 3 degrees with no change in the descent flight path angle and using a similar ground track as is used now. This was similar to a visual approach. This had a really big impact on the noise, reducing it by 60 percent.

The JFK trade-off was done for one aircraft type. We are now looking a wider range of aircraft types, light, medium, and heavy commercials, to examine the procedures for these aircraft. These can be examined through our automated trajectory database so that aircraft no longer have to be flown in by hand.

Prof. Clarke concluded his presentation by repeating the need for a clearer communication with the public to explain to people why we are doing something and providing a basis for compensation. He mentioned that MIT was doing some work with NASA to examine surface noise emissions. He said, in answer to a question on today's and new engine data that he was treating engines as components, using NASA codes and information from Pratt and Whitney. Dick John then asked what were the major areas at airports where air pollution existed. Prof. Clarke said LAX had a problem and the environmental groups are active there. He also said that the aviation contribution to air pollution was less than two percent, but it is an important issue to people living near airports.

Focus Area 4: Human/Automation Analysis and Modeling Capabilities

Dr. Kevin Corker of NASA Ames, as Facilitator, opened up this area by stating that as a part of their noontime adjustment we discussed an interest in identifying the contribution of a requirement for policy formation. (See pages 75-77 of these proceedings). So in response to this, he was not going to talk about models specifically. The reason why he wants to address the topic of human performance, and be consistent with the subtle change in direction, is that a lot what we anticipate will drive the capacity of the system, including safety, the technologies, policies, and procedures gets translated into something involving performance. So anything that doesn't consider the contribution and impact on human performance is a weak argument, especially in decisions involving policy.

Dr. Corker gave an example of some work he had done while he was on the RTCA Free Flight Task Force, where there was speculation on the need for alert and protected zones. Given the pilot's reaction time, how far in advance should they be warned so that the reaction would not be significantly bothersome to the passengers or expensive in terms of fuel. So he used the model that he would very briefly describe to answer the question, taking into account reaction time, communication time, and flight management procedures. As a result of their analysis, they came up with a communication range for ADS-B of 90 miles or more.

Two years later, working with the Technical Center, he was looking at the range of requirements in a cockpit display of traffic information. He was then told that ADS-B would have an effective range of 90 miles, and perhaps up to 120. When he asked "Why is that?", Someone answered, "We don't know, but some obscure model was used to get this answer and we've been building to that range ever since that time." So you have to be careful about what impact of the tools are.

Dr. Corker then began to briefly describe the Man-Machine Integrated Design and Analysis System (MIDAS). MIDAS is a representation of a set of inputs, which are missions, tasks, crew station designs, operator characteristics. It has some nice graphical interfaces, and at its heart, set of simulation tools that represent human operators both in terms of their physical and cognitive capabilities. It can also determine things that are of interest to decision makers as to whether or not a crew station needs one or two people, or whether a particular task can be handled by a single operator. These are ergonomic, workload analyses, mission and operator operational performance measures, and some visualizations.

The idea is to create an operator in simulation, to change the characteristics of that operator in terms of their intelligence, their effectiveness in a process, and how they carry it out. Having done that, to see what effect of assumptions have on that operator are as you change the operating conditions or change the world in which they work.

Dr. Corker showed an example of the graphics with a body-less helicopter pilot and his/her equipment that has been well described in a functional models. It has an output which are the tasks to be performed over time, with assumptions about such things as resources, scheduling, and task concurrency. It's made up of a set of structures that can represent the domain you are trying to model and a simulation driver. MIDAS has had some validation of its effectiveness of its accuracy and performance.

Dr. Corker asked how human performance models like MIDAS could be integrated with models of larger, scope such as NAS capacity and delay models. He then went on to describe (under theoretical development) three dimensions of models that represent the significant characteristics of the human performance. The first are propositional models that assert that control is basically a computational and logical engine. The second are mathematical models of control theoretic formulation. The body of MIDAS follows this and is built for manual control, extended for decision making, and with the attribute integration. Thirdly, there are models that embody neurological principles, i.e., structures that we understand to be available in the cognitive function of the brain and its memory.

Dr. Corker made the point here that there a range of models and a range of assumptions behind them, so you have to be very careful when using them. He stressed the point raised by Prof. Odoni that the models have been developed for two purposes: first to explain psychological processes and second for guidance in design. But the guidance is only for particular point designs, where the expansion to large scale system issues has not yet been undertaken.

Andres Zellweger then asked if that meant that you couldn't make a policy statement from MIDAS about what the role of the human in the system ought to be. Dr. Corker answered, that it did not and gave an example for the case where one says my policy is to get efficiency. If you said that I'm going to get it by pursuing a development that allows some resectorization of the airspace to reduce the number of controllers, and there will be some automation to produce this, you could use MIDAS. It and other similar models would tell you what is the impact of automation, what kind you would need, and what are the timing parameters. But the next level up, asking if that's the right thing to do, can't be answered by the models.

In closing with two examples, if I made the decision I am going to reduce the number of people in the cockpit by two, there are human factors models that can describe if that's a good idea. But they can't tell you why that decision was made in the first place. We, today, are building a model of air/ground decision-making integration (See Air Ground Integration Loops viewgraph) where two aircraft have the ability with CDTI and alerting logic for traffic to talk to each other, but associated with this are decision-making and communication delays. There continues to be an assertion of ground control and integration, and the ground controller and the cockpit also have these delays with similar decision-making processing tasks. There are also tools--alerting logic in the aircraft and conflict detection on the ground, that aid the operators in performing their tasks. Models can answer if this will work, and if there is sufficient lead time between two aircraft to keep the situation stable, especially if they include decision-making characteristics.

Dr. Hansman commented that with timing models that are bandwidth independent, its not the cognitive or strategy model part, but the missing link from their experience at Logan is that the model works during normal conditions, but when something odd happens, like when a controller says I've got a blocked taxiway; reroute the traffic this way. So you have to include this unusual event. The same problem exists with airline decision models where, say they have extra capacity at Dallas/Fort Worth, what do they do? Dr. Corker agreed that these are additional limitations to the models.

Mike Young of the U. S. Air Force's Research Laboratory gave his presentation **U.S. Air Force long range plans for human/automation modeling and current programs**. (See pages 92-94 of these proceedings). He began by saying that he was going to talk about human/automation modeling, but first had to set the stage by pointing out that in the Department of Defense there is something called QDR or Quadrennial Defense Review. The QDR is a modeling and simulation study held every four years to try to determine DoD investment priorities. In a QDR, some scenarios are set up , like a two regional war conflict, then the Air Force goes in and says we want to buy F-22's and some classified space systems, and the Navy come in and says they want more aircraft carriers, etc.

We participated in the initial QDR and the Air Force "lost" because we only looked as efficient as the Navy and the Army and that got the brass upset because it was clear from recent conflicts we had played a more important role. Part of this problem was that many of our high-tech investments were not showing up as efficient in the QDRs as they were in actual combat. For example, we have assets like the 117 Nighthawk, which conducted 8 percent of the strategic bombing missions, yet destroyed 35 percent of the strategic targets; the value of this stealth technology was not seen in the QDR wargame.

Dr. Young gave an example of Air Force modeling by showing two F15's engaging six incoming bogies, two of which are air-to-air aircraft, like a MIG 29, and four air-to-ground. If you model this stochastically you will have some probability of kill associated with each type of aircraft. So you crunch out the numbers and say that, based on the roll of the dice, we lost this and they lost that.

But that's not what happens. We know that if we pick off and destroy the lead striker (i.e., the flight lead for the air-to-ground aircraft), the other strikers will jettison their munitions and go home. Consequently, we invest in technology that allows us to sort incoming aircraft reactively and have sufficient missile capability to identify the lead striker and shoot them down. That is an example of a non-linear effect that is not seen in stochastic simulation models.

To overcome these limitations, you need to shift to knowledge based modeling techniques, which are high resolution models that include training and tactics and weapons available. One example is where the four air-to-ground bogies will fly a circle in the sky while the two strikers will try to pull off and engage the F15s so the air-to-ground aircraft can get around them. What we will typically do is something called a "grinder", where one of the aircraft will accelerate supersonic and blow through the incoming shooters and send air-to-air missiles into the strikers. To execute a grinder, the pilots need be trained in the execution of the tactic and they also have to have the right weapons. If the aircraft have been on cap (combat air patrol) for a while (and are therefore low on fuel) or the aircraft are not equipped with AARAMS, they will be considerably less effective. This is an example of why you need a high resolution model, where you need model knowledge and a lot of additional detail, to see what the result of your technology investment is going to be.

When we talk about classes of simulations and model we characterize them via a pyramids, where the bottom level are very detailed engineering models of components. The example I just gave corresponds to an engagement or submission model, which is the next level up. When we want to model air superiority we go up to the next higher mission level, where instead of modeling a few aircraft we model many aircraft. The top level, campaign, is much like your National Airspace System model. One key point here is that, if you are looking at a specific technology, like better air to air missiles, you first model there effect at the engagement level where you can se the effect on air to air combat. You then, however, need to take these results up to the campaign level where you can determine the how this technology will impact overall system performance. This is critical because you have limited funds that you can invest, they are several technologies that you can invest in, and you need to see which technology provides the best overall improvement to the whole system (to the overall campaign in military terms).

If you are looking at the overall system performance or the impact of a technology on an organization, you can use a relatively low resolution model, but it is critical that the model provide relevant performance parameters. For the engagement example I gave, the important objective was to keep the air-to-ground strikers from hitting our troops on the ground. This objective can only be measured in a higher level (campaign) model. Further, if the technology you are considering investing in is going to be used by humans, you must also have another class of the human-in-the-loop models, because there are many cases where you insert some automation with the expectation that a certain set of procedures will be followed by the operator, but when they actually get the technology, they use it in an unexpected manner. What this means, is that you can not validate some models, until you see how humans are actually going to employ the new technology.

Dr. Young answered a question about how long it takes to get to the point where the human-in-the-loop simulations are run. He said that it doesn't take too long to establish real-time training and observations of how well the new procedures are being used. But they are still working at measuring the effects at a higher level. If you are looking at how one or two individuals are using technology, you can use MIDAS or a couple of other models that are pretty good. But we see the modeling of teams and organizational behavior as critical areas needing research.

We are beginning to work on information diffusion models, where you combine social belief and communication network models. This will allow us to see how information moves through the system and how it's used. Dr. Young showed a detailed viewgraph on cognitive system engineering and stated that they are also focusing on research in that area, as well as high level architectures and agent-based modeling techniques.

Dr. Young stated that today we would like to defeat an enemy without killing them. We can almost do this since we have reached the point with our electronic systems that we can take over their information management systems. So we are trying to model the cases, or situations, where we defeat an enemy without actually destroying them. This requires very high resolution models. We are also looking at social effects since we go in expecting people to react in one way to a bombing campaign and they often don't behave as expected.

Dr. Young then showed a detailed viewgraph on cognitive system engineering. The viewgraph showed the equivalent of an international airspace; an air support operations center with offensive and defensive operations; a controller reporting center; army support; airport operations center; and forward radars. If you are looking for some impact of automation, say in air support operation which will be co-located with an Army Corps Commander, you have to build a causal model that will include component elements, events, decisions, and acts. You also need a relational model containing functional relations between components, system objectives, and performance criteria. And then, for the actions of the organization you're looking at, you need a means-end hierarchy.

At the bottom level of the means-end hierarchy you would represent the actual equipment that the operators interact with. Next would be the procedures that they use to operate the equipment. At higher levels you would have the local goals, e.g., at an air support operation you would have battlefield air interdiction and close air support gameplans. Higher still would be the Corps Commander's objectives and above that the purposes and constraints of the overall campaign. The idea is that whether you are looking at individuals or organizations you represent information at all of these different levels. So we are doing research to determine how you build models to account for all of these levels. The properties represented side of cognitive system engineering diagram tells us where we need to go to get other information. You also have causal changes that are propagating up through the system.

Dr. Young then discussed modeling languages and how you build models this class of models. The system he described, called the Operator Model Architecture (OMAR), was originally built to do multitasking human performance. It has different languages; a frame language to build up representations of the world such as aircraft and airports. An important class of objects is an agent, which is a process that runs within the simulator. OMAR also provide a forward chaining rule system, and a very advanced language called SCORE that allows control of parallel asynchronous agent.

If you look at how you simulate intelligence, there are basically two different approaches. One is called state space search and it underlies what production systems do. The other is an association mechanism that underlies what neural nets do. We've built control mechanisms which implement both types of control at a symbolic level of abstraction. Many others are doing intelligent agent research, but we differentiate our research from theirs since we're not focusing on mobile agents, but intelligent agents that we call "Mycrofts", who was Sherlock Holmes smarter older brother.

We have also built a distributed computer environment, where you can put OMAR images on different machines, as many as you want, and the agents can communicate back and forth using

Common Object Request Broker Architecture (CORBA) objects or High Level Architecture events. So this is a system that can be scaled up to any level you want.

The Department of Defense is investing around $300 million for the high level architecture and its first implementation in a joint simulation system. The high level architecture (HLA) assumes that you want to put together heterogeneous models and you want to be able to reuse them sporadically. So you might have constructive models, which basically are the type of analytic models we've been talking about today, but you might also might want to include some human-in-the-loop simulations. These models all interact through using something called a run time interface which allows you to build what we call a joint synthetic battlefield. If a particular model does not have an HLA interface, then here is definitely some expense in updating to the HLA.

Dr. Young stated that, in terms of the agent based modeling, we would like to be able to dynamically shift between high and low level resolutions. The idea is that for a series of tasks that have to be performed, the tasks should be mapped to agents. He then showed a viewgraph representing a joint synthetic battle space that had two different types of models hooked up to it. One facet of the SCORE language sets triggering conditions on the agents. This property can be used to create agents which employ different resolution models depending upon properties in the joint synthetic battle space (e.g., aircraft at distance equal to or greater than X, use low resolution model; if aircraft at distance less than X use the high resolution model).

On the topic of non-linear effects, Dr. Young stated that he didn't know if that was the correct term. On the topic of modeling organizational behavior, he said that the best approach appears to be to use agents which have multiple goals and employ multiple inferencing techniques. This enables one to model situated cognition where the agent has multiple goals, engages in proactive and reactive behavior, and shifts back and forth between goals and tasks in a dynamic manner.

Dr. Young summarized his presentation by saying that if you want to accurately predict the impact of your technology investment, you need to conduct simulation studies which use models at multiple resolutions. For example, you need a model of the overall system (i.e., campaign level model), another higher resolution model of the where the technology will actually be inserted, and another with human-in-the-loop data to assure that the technology is being used as expected. We are investing research dollars on non-linear modeling techniques, how to put the models together dynamically, and, on the psychological side, how to build better organizational models.

Dr. John asked Dr. Young what short but succinct message would you give to a four-star general to build your case? Dr. Young answered, "We lost QDR". QDR is the quadrennial defense review which occurs every four years to partially determine where OSD should put our money and why. We, the AF, lost QDR because, two years ago, we couldn't prove the value of Air Force investments using just stochastic models. He then gave another example that discussed how simulation might be used to decide what type of missile defense our country needs. There are a significant number of countries which within the next ten years that will have missile capabilities and weapons of mass destruction. So we are using the models when we go to Congress to say here's where our forces are stationed, and here are the regions the potential rouge countries can hit, with either nuclear, biological, or chemical weapons. And then we add that we need to build some kind of system to prevent this. Then the AF says that a space based system is needed and the Army says we need theater high altitude defense.

Advanced simulation technology, like we have been talking about today, can potentially evaluate these alternatives and provide decision-makers the data they need to prioritize investments. In answer to a last question about using high level architectures, Dr. Young said that there is an extensive effort among all of the armed services to do this and to develop integrated models.

Prof. Cynthia Barnhart, of MIT began her presentation on **airline scheduling office modeling** after Robert Wiseman announced earlier that it was not in the right focus area (User and Provider Economics) because she had a schedule conflict the next day. (See pages 95-97 of these proceedings). She began by saying she wanted to talk briefly about some of the things going on in the airlines. She chose what's happening in the airline schedule planning process because so much has gone on in the last ten years, and this topic will be a good indicator of possibilities over the next decade. She then said that she would address what's involved in modeling the airline's problems, then solving these problems.

Schedule planning involves determining which planes fly, where, when, with what equipment, and with what crew. It is currently being attacked in a sequential manner. The reason for this is that you can't solve it as one large problem. The process starts with the selection of the flight schedule, with the airlines choosing where they want to fly and at what time. The second step is to assign equipment types to the schedule. There follows routing of the equipment through the schedule so that maintenance requirements are met. Finally, crews are assigned to the schedule.

Prof. Barnhart discussed the viewgraphs that represented each of the steps in the process she described and efforts to integrate the steps in them, just to give an idea of the current state of the art. In response to a question about the crew scheduling, she said she would talk mostly about coming up with the daily and monthly work schedules. Issues like where the crews are domiciled and how many extra crews you need are separate. There are a high number of problems that the airlines have solved and sometimes they have tried optimization that hasn't worked out. She stated that she will cover the very large airline operations for the most part, but in the end she would talk about work that's been done in planning that is now being transferred to operations.

Dr. Zellweger asked if the robustness of the schedules was being looked at, for example recovering from a snow storm. Prof. Barnhart answered that traditionally that has not been done since it is a difficult deterministic approach, but one of her areas is to look at robustness. She then stated that, first of all, cost schedule design is justifying flight legs by specifying origin, destination, and departure times in such a way that you maximize your profit. This is done in the face of certain restrictions, such as the kinds of equipment you have available and the rules, such as maintenance, under which you can fly. This is the overall problem and until recently this process was mostly manual. Over the past five years, we have been working with UPS and now with United to try to automate this.

Prof. Barnhart said that we have a long way to go before flight schedule design can be optimized. But with fleet assignment, which is given a flight schedule, assign your different aircraft types, has made a lot of improvements over the last ten years. Ten years ago, the airlines had rudimentary models but were not automating. Now most of the major airlines solve this problem repeatably through the planning horizon and can solve their multi-fleet (e.g., fleets of aircraft) problem on workstation class computers in twenty minutes.

Because of this success, we've been able to start expanding this optimization. For example, in work that a graduate student did with me for United Airlines, we found that the fleet assignment model takes as input a big schedule covering many weeks before the planes are flown. We looked at allowing small re-timings of plus or minus 5 to 10 minutes in departure times while simultaneously selecting departure times and fleet assignment. When we did this, we found that these models, like the fleet assignment models, these models were easy to solve within a short time. The result was that the minor re-timings saved tens of millions of dollars a year, according to United Airlines. So as you begin to step back from the conventional model sets and try to work on something more realistic, you can see that there is a lot of opportunity to improve the output of these models.

In a similar manner, the fleet assignment models make very restrictive assumptions about revenue. For example they have built in legging dependence assumptions. So you can be bumped off one leg of your two-leg itinerary because there are not enough seats on the plane. But you appear on the other leg in these models, which is obviously not accurate. So we're looking at better ways to model passenger support. American Airlines during the last six months reported that they had done similar work on these types of models and they expect revenue increases on the order of $100 million a year. I have given you these numbers so that you can understand the impact of these activities are to the airlines.

Aircraft maintenance routing is that, given that you have assigned a particular type of aircraft to a leg, retrace the routing of the aircraft rotation or routing of that aircraft over the schedule to make sure, as you build the rotations, that there is adequate opportunity for maintenance. This avoids the problem of having to ground aircraft. Most major airlines now use optimization models to solve this, a dramatic change in the last decade.

The last area, crew planning has been the center of attention for the longest time. What's happened in this area is that the scheduling problem has been broken into two pieces. The first piece is called the pairing problem that builds three to five day long schedules for crews. The second stage is to put the three to five day schedules together with training and rest periods and vacations embedded to create monthly trips. There has been four decades of work on the crew planning problem. So for the sizes that the airlines face you can get solutions that typically are within one to two percent of optimal. Even with this, American Airlines has stated that with this increased ability to optimize their expected crew costs have dropped tens of millions of dollars a year.

In answer to a question about crew work weeks, Prof. Barnhart stated that for the U.S., crews fly up to five days before having to come home. Dr. Simpson added that the interval would depend on the FAA, airline and union established number of takeoffs, hours per day, and how much rest. Prof. Barnhart went on to say that this causes non-linear crew costs functions. She stated that we've moved from the late eighties when American Airlines started some research to look at how close the solutions were to optimal. They now know they actually had quite a gap in the past. Although pairing optimization is now widespread, the second problem of putting the shorter work schedules together to cover a month long one is to, a large extent, solved manually. During the last two years, there has been some recent success in solving this problem.

A discussion of what is optimal and whether a baseline on optimal is known. It was agreed that although there is no exact solution one would know that they were close to the optimal. Dr. Barnhart stated that the discussion brought her nicely into her next topic. When you look at any of the problems, they have non-linear objective functions and constraints, intergerality requirements, and especially the issue of size, because you have to deal both with time and space. So there are huge numbers of constraints and variables, and sometimes it hard even to know how to write down the constraints or define the variables.

There has been a lot of work done in the past twenty years on methods to deal with these very large scale problems. The work looks at how you can transform this non-linear formulation into a formulation that has a chance to be solved or near-solved, and with linear objective function and constraints. What is key to this transformation is how you define the variables. A good example is pairing. If you have a full schedule that starts a the crew base and comes back in, say, three days, you can look at what flights are there and check all the rules, and you can come up with an exact cost for that pairing. But if you try to look at pairing on a flight-by-flight basis, you don't know what costs should be assigned to the flight because it's a function of how you put the flight together in advance.

So we step back to where a variable relates to a pairing whose costs we know explicitly, changing our model into one that has linear objective functions and constraints, and integrality requirements. But there is one catch --when you now make decisions about sequences of flights, rather than flights, the number of decision variables explodes. We have a problem that may have thousands to hundreds of thousands of constraints, and easily millions or billions of variables. This full formulation is too much for the computer to handle. So we take a relatively small piece of the problem that may have ten thousand constraints and two hundred thousand variables.

When we solve that little problem, it gives us information about what variables and constraints we ignored, we should not have ignored. So we add in some variables and constraints and the hope is to get to something that is provably optimal before you have to add in all the variables and constraints. This approach has worked extremely well on this very large scale problem and it allows you to get the lower bounds that tell you an optimal solution can't be better than that. That's important to the airlines since it tells them how much room they have for improvement and whether they should be putting resources into the problem.

Prof. Barnhart summarized her presentation by stating that now that many of the sub-problems in a sequential schedule planning process are being solved, you begin to see a shift towards integrating some of these sub-problems. We are in the middle of that, with some successes and some failures. She said that, in the last ten years, she has seen growing enthusiasm by the airlines in applying these methods. The more we can do, the more we find things out there that haven't been done. There are lots of opportunities to close the gap between what is planned and what is actually happening in operations.

Today, if you go to an operations control center you don't see many people pressing the button for the optimization algorithm to solve the problem. What you see is people solving the problem manually. But a lot of the success of the algorithm in planning is slowly beginning to be transferred to operations.

Dr. Simpson said that it is sad that the airlines have something that can be planned to work perfectly but doesn't work as well in the actual air traffic control system. Dr. Corker said the same kind of thing exists with avionics. For example, a flight management system optimizes fuel efficiency, but it can only be used ten percent of the time.

Prof. Odoni then said that, as we know, the airlines have included expected delays into their block times. But suppose that air traffic control managed to reduce the delays by five minutes per flight. We can estimate the resulting savings to the airlines of fuel and so on, but can we also estimate the technology you describe to find out, in the long run, the saving from fewer flights and fewer pilots?

Prof. Barnhart said, "Yes." She stated that the model she talked about on fleet assignment with time delays is directly applicable to answer that question, with a change in the input parameter of block time, and has already been done. Reduce the time by a small percentage and allow minor re-timings in the schedule. The impact is astonishing because, with the extra five minutes, the airlines can change their fleeting to suit the number of passengers. For example, the extra five minutes would allow them to turn a wide body aircraft. So the impacts from both cost and revenue perspectives is great.

We looked at one case where we reduced block times by five percent and there were two things that were interesting. One was the expected savings were in the tens of millions of dollars a year. The second was that they could fly their schedule with fewer aircraft. This would give them opportunities to use their aircraft elsewhere.

Steve Bradford said that we have just seen examples in the last two presentations where models were used to enable decisions to be made. This is because there is a belief in the validity of the models. He stated that he had worked the higher level models while he was in DOD, where it is believed that the models are being used in the correct way and are believable to the point where decisions can be made.

Maybe we have two problems with NAS models. First we don't have all the pieces, for example we don't do the cognitive model for human factors. Second, we don't do component modeling. We do simulations that tell us, say, we can pump six more aircraft through. We don't run it to make a real decision, like a change in procedures, were running it for the gate keepers. He didn't think Steve Zaidman would make a decision with our existing models.

Dr. Simpson asked Steve, "What about the ground delay program?" Steve answered that it was good. They did the modeling right. They did the validity. He said he asked a former Administrator for Acquisition what he thought of the value of the analysis, modeling, and simulation that we do? He said it's like a binary switch. If you come and say to me it's a two-to-one benefit vs. cost advantage, I'll listen to you. Steve added that analysis should give more than just benefit vs. cost information.

Dr. Corker stated that the schedule optimization impacts on capacity are the push rates. Prof. Barnhart said that she had talked to one of the airline users who works on scheduling and he stated that what we really need is more than just a scheduling model. We need a model of what's happening in the NAS. They're trying to make decisions about opening new hubs or closing old ones, but they don't have the historical data to support these decisions. Dr. John stated that we are talking about a knowledge base for decisions that are not just for the Government but also by the rest of the aviation community. But this base can't be established until we know the higher level issues that each of these many constituents have.

Dr. Mike Young stated that one way to get a handle on issues is to look at population shifts from the U. S. Census demographics so that you can look at the changes in the corresponding airport capacity that is needed. Also we are now seeing, from the changing nature of businesses, that there is more transportation by air freight. Dr. John said that it might also be good to come up with a variety of scenarios on a global level to see how each of them affect different parts of the aviation community. Dr. Young added that scenarios don't have to give answers. They just have to raise the potential impacts in the future.

Mr. Bradford stated that it may be more important for NASA to come up with ways that aviation service can be improved, rather than lowering delay. For example improved service to the small communities or to general aviation.

Focus Area 5: User and Provider Economics

Mr. Steve Bradford of the FAA, in the role of both presenter and facilitator, began by showing a simplified diagram (See page 57, #13 of these proceedings). of existing airports and route links. He said that Dr. Simpson and a lot of others say that major city pair parts of this network are full. However, there are other minor city pair parts of the network that are not full. We don't look at this as a total network and ask whether all the links are at capacity. The reason he raised this was if the "sky was falling down" and it is known that there are more flights into Washington than ever before, then I can use Southwest out of Baltimore. He stated that the airlines are having bigger profits. Both of these don't fit the "sky is falling down" position.

But we all know there are pot holes out there. That's the bigger issue—where are the pot holes forming? The FAA's problem, my problem, is to put things in this knapsack (See pages 22 and 23) called NAS to do the best job now and in the future. I have a lot of people coming up with lots of answers, maybe defining the problem, maybe not. They go find user advocates. I get a lot of single purpose items which have benefits in a single thread. My job is to ask do these things fit in my knapsack, does it do any harm, and does it appear to do good? For example, Dallas-Ft. Worth has a thruput problem where all the capacity is not utilized since there is a theoretical maximum capacity that's not being achieved. So with CTAS, you come up with a tool, you find advocates, and you show actual benefits.

A participant stated that does it appear to do good and does it do harm are not mutually exclusive. Mr. Bradford agreed and, by example said does improving American Airline's thruput at Dallas-Ft. Worth harm any of its competitors? He asked is that a problem for me? Or is it a problem that the aviation community has to resolve? So our solution is to make sure everyone has CTAS. An airline will say Delta's doing well with SMA at Atlanta. I'd better get one at my hub airport too. Dr. Corker later stated that CTAS that Dallas-Ft. Worth didn't have the worst thruput problem. CTAS was selected because the controllers were enthusiastic about accepting the new technology. Their enthusiasm was not matched at other airports.

Dr. John asked if WAAS was included. Mr. Bradford said, "Yes. WAAS has an advocate. The FAA likes WAAS because we can reduce our costs if we can get rid of the VORs." There are also other advocates for WAAS and LAAS by people who want greater access. He also stated that even if the VORs and DMEs remain, there will still WAAS and LAAS provide low cost R-nav capabilities on the flight deck, particularly for small aircraft. But he stated that there are a lot of places where the FAA could cut costs that are without advocates, in building repairs for example.

Mr. Bradford stated that, given these things that will go in my knapsack, what are my best set of tools? That's the policy issue. In response to a remark by Dr. John that the benefits for some parts of the aviation community may be drawbacks for other parts, he responded that we can't tilt to any of them.

Mr. Bradford asked how does he, within the analysis environment that he has, do the best job to understand what needs to be done, to make it work, does it fit in, does it do no operational harm, and does it provide an operational improvement? He then switched gears and talked about the Center for Advanced Aviation System Development (CAASD), as another user group. He stated that CAASD tools generally don't have advocates outside of the FAA. For example, conflict probe is not something the airlines would ask for. Conflict probe has a marginal benefit and therefore may only contribute to a marginal policy.

He said that his biggest problem is that there is a paper out there that says there will be gridlock by 2004, but everything else says everything's fine. No one's hurting and everyone here found reasonable flights to Logan. But there are lots of little problems to see if the things in my knapsack fit into the architecture, see if they make sense, and within FAA policy constraints how do I make them work.

Mr. Bradford asked if the NAS could be base-lined and what are the shortfalls and opportunities once the NAS is base-lined? He also asked if its operational effects and benefits could be evaluated, given that the NAS has no performance baseline. But, on the positive side, our intuitions are being refined every day. He thinks that we understand single sectors, but not the Centers since its hard to understand the interconnections. Dr. Zellweger then added that the dynamic behavior and how the system adapts are also important to characterize.

Mr. Bradford agreed and went on to say that we have a lot of data but we only quantify the simplest things. For example, we can tell you about the thruput of a sector and the delays at an airport, but we can't tell you about the controller's workload since it is a touchy area to address.

He stated that we purposely avoid anything that has a political impact. For example, at a policy level, should I help American at Dallas-Ft. Worth or concentrate my effort on New York?

He then showed a traffic density chart with traffic counts at flight levels 150 to 290. The chart showed clumping of traffic through the day, especially in the Northeast where it was very high, while Dallas Ft. Worth also had a lot of clumping, but its airspace was not very dense. The chart pointed out that, in terms of both density and airspace, the real problems were at Chicago and New York. So there are different tools and strategies that have to be used for the different areas. The Northeast triangle is a real problem so, as a first cut, it will take more examination.

Mr. Bradford gave an example of a conflict resolution baseline to characterize the separations being imposed in today's NAS so that we could see how close aircraft came to each other to understand the environment the tools are being dropped into. The most interesting case was one where we tried to find what appeared to be conflicts from 50 hours of data for some Atlanta sectors and only found one conflict per hour. This told us that controllers don't allow the traffic to get into a conflict mode. So I would have to change my conflict paradigm.

We have built a lot of tools and analysis that were based on geographic sectors. We tried to correlate the geographic instantaneous counts with the controller instantaneous counts. They didn't correlate at all because the sectors are constantly changing based on the dynamic agreements between the controllers. We were finding handoffs ten minutes before the aircraft hit the sector boundaries, based on the flow of traffic. We needed to build a tool to understand how the controllers were operating today. That is the existing tools were based on certain assumptions that had to be validated before they could be used.

If controllers are extremely inefficient when it comes to conflict resolution, we have to automate that for them. So it must be known how inefficient they are, before we automate. Conflicts are rare because controllers manage traffic by flow, not by traffic against traffic. Controllers basically keep the airspace "cleaned up" so they don't get into trouble. If you ask a controller what their job is, they will tell you that it is to keep aircraft apart. But their actual job, most of the time, is to keep traffic synchronized for an even flow that is efficient.

We must baseline the NAS before we build tools to improve it because, if we don't, we won't be sure it's the right NAS we will be improving. But, if we assume that there is a short-fall we should do something about it. CTAS is a classic example of this. CTAS fills a need for a strategic planner to balance aircraft onto a runway. Capacity was underutilized because controllers had to handle single flows and they managed them by using separate runways. CTAS realized that the flows are not equal and they are changing over the day. The controllers didn't have the cognitive ability to fit an aircraft in another flow, but CTAS could.

In another example, Mr. Bradford stated that there was a supposition that productivity could be improved with multi-sector planning. The problem today is that we've got flight strips so we have to have an R and a D controller when things get busy. Without flight strips we could have a multi-sector D controller. This is a case where you must have a human/machine real-time simulation. But, even this is probably not good enough to make a giant paradigm shift like this. What is needed is to gather information from the simulation and then build behavior models like MIDAS.

This will allow a larger area of coverage, say an entire Center, where we could look at the overall improvements, and even model several multi-sector controllers interactions.

Today there is a single view of the NAS, the controllers, who adjusts their traffic, provide resolution to the flight decks which adheres to the letter. All of our simulations say there is on focal point for traffic, the tactical controller. But we have heard earlier of models that provide for multiple focal points and multiple decision-making. So you would have, with this integration, the flight deck as a new with a sphere of influence with its own rule base. For this situation we need look at these additional viewpoints at the same time. This is to see how the rules of the road match up flight deck to flight deck, flight deck to multi-sector D, and flight deck to R-side. We don't have this capability now. Once the missing capabilities become available the next question is how are the investment trade-offs evaluated.

In response to a question by Dr. Corker about cost/benefit evaluations in the National Airspace Resource Investment Model (NARIM), Mr. Bradford said that they run the Form 41 data and run it against the delays and with the passenger and aircraft values of time. We also did a prototype of a hierarchical decision tool where a higher level policy can be broken down into its component parts. He stated that passenger values of time are somewhat flaky since there is no policy for them.

He then showed a hand-drawn network viewgraph (like page 8 in his viewgraph package) and stated that we might make the network more efficient providing benefits to both the airlines and passengers. We don't look at encouraging point-to-point for the passengers. In response to a question by Dr. John about the overall benefits of TCAS, Mr. Bradford stated that for each of the airports we should be able to say, with TCAS, we put down one or more aircraft per hour. The airlines would see for Dallas-Ft. Worth that they could get more aircraft down at peak periods. This result would make the FAA's CTAS program under Charlie Keegan a success. But at a higher policy level there's the question of whether a controller needs to pump more aircraft through with TCAS or some other technique.

A discussion about deregulation then took place. Dr. Simpson said that the debate on it lasted from 1973 to 1978. During that time the Government guaranteed that they would do the air traffic control for the free routing that to the airlines under deregulation. He stated that we're living under that high level policy statement made by the Congress unanimously in 1978. A policy decision was made that deregulation would occur even when it was known that there would be problems at the major hub airports. Dr. Corker then stated that NASA is looking at the interaction of capacity and safety with such other issues as the environment and affordability. He added that maybe another system was needed for the smaller aircraft and rotorcraft.

Dr. John raised the point that there is proposed legislation, which may never get through, DOT proposing to spin off air traffic control to a private entity supported by user fees, with the DOT still responsible for safety, security, the environment, and the Airport Trust Fund. That is a big policy question, somewhat like the decision to go with a space-based system where the costs to the airlines, DOD, and general aviation are important. Mr. Bradford stated that the FAA does its budget on the story of a user fee NAS with a non-user fee constituency. In Europe, additional services are proposed and the costs are made known. Then the question is asked, "Do you want this or are you willing to live with the current system?"

Dr. Simpson stated that the airport business has changed tremendously due to deregulation, from a quasi-monopoly to the point where an airline can now state that their five-year lease is up and they are leaving. If you look at the privatization of the air traffic management system you'll find that, at the top level, they are not private. Governments in every case have the ultimate control.

Mr. Bradford then said "If a tool, like CTAS, is to be airport based, should it be a national investment or an airport investment, especially since it would improve the ability of that airport to handle traffic?" He added that it is not the FAA's job to see who will pay for it. We (the FAA) are not like DOD, where they go up to Congress and say our analysis shows that we are going to have a major war and two minor ones with the next ten years and here is our methodology to make this evaluation credible. This establishes the policy for DOD. The FAA doesn't do this. We don't say there's a problem. We may say that there is gridlock, but Congress replies that they don't understand, they have had five opportunities to fly home today.

Mr. Bradford later stated that his work does not involve policy. He is just given something and he has to evaluate it. For example, if a city builds an airport, the FAA has to serve it. Dr. Simpson later added that Mr. Bradford is working within past policy decisions, but now, say 15 years later, no one has revisited those policy decisions, asking, "Is this the right thing to do for the future?" Dr. John also later asked, "What kinds of tools and knowledge bases do we need to enable policy makers and operational people to make better decisions?" He stated that if some states that they want to increase the number of planes at peak periods by two per hour, we need tools to see if that will work.

Prof. Odoni stated that, for two years, NASA was supporting something called ASAC (Aviation System Analysis Capability) and LMI was involved in that. I understand that the progress has been slow. Mr. Hassam answered that that wasn't true because the budget for it was zeroed out recently. He stated that he was leading the ASAC effort and that the biggest problem he had now was adding to the model. When Dr. Simpson asked what was the status of NARIM, Mr. Bradford stated that ASAC was more of a policy tool and NARIM is a tool to evaluate new concepts. He added that many of the tools can be used , but you have to have a coherent strategy for doing analysis top down. Prof. Odoni suggested that there could be value in the airline models for their investments.

As an example of an area where inroads could be made this year, Mr. Bradford mentioned a recent FAA effort to build capability diagrams and information flows based on a service change. So, for their new architecture, they could say if you deliver all this stuff to the field, then you get this capability. This was the system engineering point of view. For example, we said that with data link Build 1, all these organizations have to fly by this time and here's what they have to do. He added that for policy issues we have to show how, in an incremental fashion, we can improve their decision making. We can't go in whole hog. We must say there are the policies we can now help you with, but only these.

The subject of the regional jets and their effect on airports was raised. Dr. Simpson stated that they will have a major impact on Logan airport where 55 or so turboprop or regional aircraft are going in there. We do things in marginal weather with the turboprops. For example there's, a

Canadair regional jet that will do an inner harbor approach where they do an ILS approach to one runway which is 90 degrees to the two runways in operation. Then at 1000 feet ceiling, where I've seen them operate in snow storms, behind the tower they make a 90 degree turn into the harbor area. They then fly directly at the tall buildings in downtown Boston and gets below the level of those buildings. Then they do a turn and put their belly up and comes careening around to one of the parallel runways. I'm waiting for the first regional jet to do that approach. I don't think the FAA will let them.

Focus Area 6: Barriers to Aviation System Transition

Dr. Bob Simpson, acting as facilitator, began this focus area by stating the a barrier to transition is the considerable time it takes to get international agreement on changes to aviation systems. He recognized Charlie Heuttner who stated he worked on investment analysis in aviation and learned that the ICAO process takes a long time. There had been consensus for many years on the new digital communication use of voice TDMA modulation scheme and the desired support for it internationally because it had to be adopted world-wide. What has happened, because it's such a long process, is that new technologies have been developed. So after all this consensus, and after aviation standards has already signed off, and the Swedes are saying, "Why don't you try this more advanced digital communication technology?" So people who have been working for fifteen years get frustrated by having to start all over again.

Dr. Simpson stated that it took eight years for the FANS Committee to tell us what our tools were going to be, e.g., data link, satellites, and Mode-S. It should have been eight weeks. Lock us up and tell us we're not leaving until we make a decision. If you go and do it every three months for a two-day meeting, it will take years. So the problem is that we have a global industry with an alphabet soup of users, 180 Governments that will have to be the providers of air traffic systems, and then all the airports. You have to lead them all to a consensus.

Prof. Hansman stated that the consensus approach doesn't work. That was the problem with Free Flight. ICAO functioned when the U. S. used to dominate and lead it technically. When the Europeans challenged this, things changed. Dr. Simpson stated that the Europeans are spending more money on R&D than we have in the last ten years. So they can say that what they propose for Europe should be a world standard. The FAA then becomes defensive, since they used to say these are our air traffic management problems, we're the first, and we all have to do these things.

Dr. John asked how long has it taken for this reversal to occur. The answer was since 1982 or 1983 and it was given impetus by lots money from the European Common Market, looking at it as a policy of trade. As you know, on the satellite side, they've been struggling with GPS sole control by the U.S., so they are slowly working for GNSS-2 because Siemens and Thompson CFF are looking for huge multi-million dollar contracts.

Mr. Heuttner then asked about the impact of world-wide attempts at the privatization of air traffic control where there would be an emergence of a dynamic flexibility because a privately held company can do things that government organizations can't. That is are we seeing a trend where we are falling behind because we can't adapt quickly? Dr. Simpson answered by stating that in the rest of the world are escaping civil service, raising controller salaries, firing poor performers, and building modern versions of our present air traffic control system. But the organizations are not really different and they're not really privatized. The Dutch, Germans and others have done it and it does make a better management organization. And all the controllers have almost doubled their salaries, but they've laid off three times as many people. In South America and Africa, if you have a college degree, becoming an air traffic controller is an attractive career choice. In Budapest, air traffic controllers are writing papers and are PhDs because it is the only kind of good job they could get.

Dr. Simpson pointed out in answer to a question by Dr. John that, except for the U.S., the rest of the world has user fees. ICAO set this up, saying user fees should be cost recoverable and said that some of the money could be set aside for investments and that the rates should be set by the distance flown and the square root of the weight of the aircraft.

A general discussion of user charges led to some interesting points. First, after the war Vietnam was charging $20, 000 per aircraft to overfly their territory, so airlines would alter their routes to avoid this. Secondly, ICAO collects $2.5 to $3 million per year of these fees. Third, there is an additional terminal area user charge that goes to the airport, and in some cases an air traffic control arrival charge may also occur. Fourth, charges that are based on the time of day are being considered. Fifth, U.S. airlines and general aviation don't pay for our air traffic control system, so until user charges arise here, they won't be interested in ICAO fee structures, or more importantly, lowering the costs of air traffic control. Because it is federally funded, the U. S. air traffic control may be without incentive to cut costs.

Prof. Odoni stated that there is a battle going on in Europe where the airlines are saying that the costs are too high. Dr. Simpson then stated that the Canadians set up an air traffic control corporation where they made the industry the board of directors. He stated that, in our country, we have 250,000 private airplanes, but you won't find any number like that in any country in Europe. So the airlines hold sway there. But here we are influenced by 600,000 private pilots who are active in politics. Congressmen and Senators in such largely rural states as Maine use general aviation aircraft to fly directly to Washington D.C. or to get to hub airports.

Dr. John asked, "Are we at such a high level here that it doesn't pay to generate knowledge bases to bring this discussion to the attention of policy makers?" Dr. Zellweger stated that it is worthwhile to use knowledge bases to assist in policy decisions. We don't do that today. Dr. Simpson added that we need to do studies that will bring things to the attention of those who are influential. If we do something the ATA, the airline CEOs, the airport lobbyists are going to respond and a public discussion could follow. Dr. Zellweger stated that an airline can move to another airport hub quickly, but it takes the FAA much longer to change the infrastructure to support the new hub.

Dr. John asked about the workings of the RTCA. Prof. Hansman stated that they address an issue or a new capability in a Select Committee and then hold open forums to get the views of all of the constituents- so that people can sign up to it. That's how we got free flight. They suffer from the restriction that they can't implement faster than the technology refresh cycle. This results in requirements creep, which doesn't enable them to have large R&D programs.

Dr. John stated that the FAA is doing R&D on security, safety, and some environmental issues. The Hill pushed to move the R&D funding for traffic management to the F&E account. Steve

Zaidman and Jane Garvey have both stated that the FAA is now in partnership with NASA, where NASA is to do the forward thinking. NASA has decision support tools, but the tricky part is, where does the funding come from to deploy these tools if they're beyond what is already in Free Flight Phase 1?

The question was asked, "Have there been a major changes in aviation over the past ten years?" One participant answered, "No, except that air fares have been going down when adjusted for inflation." It was also stated that a lot of air traffic changes come from MITRE, particularly when the FAA operations people request a study. Dr. Simpson stated that the operations people run the air traffic control system. Every once in a while, a few of them take it upon themselves to change the system, and they do it largely without the R&D people. For example, the flow control traffic management was started and continued by operational types.

Dr. Corker stated that with the large investments in free flight, would anyone ask the question how would it affect the desirability of charging user fees? And from who's perspective? Dr. Simpson said it wouldn't make any difference since the airlines could argue that they are paying user fees now. But a counter argument is that the passengers are paying them. Dr. Corker stated that if four of six new technologies were focused on terminal area operations, a significant investment in Free Flight Phase 1. If user fees have to be paid on both terminal and en route operations, do I want two thirds of that investment to be devoted to terminal or more evenly distributed or even biased to en route?

Prof. Hansman asked how well do our models provide us with an understanding of the public benefits of GPS and its impacts on the infrastructure with each of its component benefits? Dr. Zellweger stated that you would get different answers from different stake-holders on that question. One participant said that modeling terminal and en route separately may not be as good as looking at the entire system from end to end. A counter argument was raised when Dr. Corker stated that the technologies associated with moving aircraft when they are closer to the ground are different than those when the aircraft when they are moving much faster at high altitudes.

Dr. Simpson took the position of general aviation that stated they would like it if they could put a $500 box in their aircraft while the FAA was spending $10 billion on the system, rather than a $5,000 box for one billion in FAA costs. But if the Government were to say there will be a user fee for our $10 billion dollar investment, the situation could be quite different. Dr. George Donohue got that far when he said maybe we could persuade Congress to allow us to lease these boxes. This is the top level you will have to go to answer this question.

Dr. John asked the broad question, "Where does the aviation system fit into the nation's economy"? He stated that the next level below that would be the public policy issues, and below that, the operational questions. He said that NASA decision-making tools, although good, were starting below that and a common knowledge base was needed to help the tools make connections to the higher levels. A forum for all the aviation constituents would help define this knowledge base. A participant stressed that this base should concern itself with the long term.

Dr. Simpson stated that, if you said there would be an aviation system planning office at NASA, there would be a lot of people concerned about why those pointy-headed rocket scientists are telling us what we should be doing in the next twenty years. For this reason, he thought that the FAA should have some kind of planning office. Wherever you see Jane Garvey, say at Oskosh or on TV, she is constantly being given policy questions on the future of aviation. Maybe it would be better if you had two planning offices, one in the FAA and one in NASA.

Prof. Hansman stated that it would be better if NASA got the data for the future system, not necessarily doing the planning or telling the FAA how they should run the system. The data could show what the trends are and what the possible implications could be. Dr. John stated that he thought the policy was that NASA was doing long-term research, but the question remains to identify the sort of research that will be done.

Dr. Simpson, in answer to a statement by Dr. Jim Poage, that we may not have to answer now which of the analysis and modeling efforts belong to NASA or the FAA, stated that he was right, but it was important to him that it not be perceived that all the policy development and studies would be done by NASA. It was generally agreed that the knowledge bases were being developed in a very segmented and disorganized way.

Mr. Wright interrupted the proceedings to say that, because of the snow, there was a delay program at Logan and, from ETMS, he has learned that there are about 378 flights delayed inbound, including about 100 of those cancelled. He also stated that he had a list of departure corrections on what the tickets say. The meeting then adjourned for lunch!

Open Session

This session had a much smaller group because a number of the attendees who had made different air travel arrangements at Logan. **Dr. Kevin Corker**, as the facilitator, began the session by recognizing Dr. John who said that, in this year, air transportation had a low level national priority since it was not mentioned in the President's State of the Union address. He added that NASA and the FAA would benefit as they present their budgets if they could increase public awareness.

In response to a statement that the benefits of a well-operating NAS to its many constituents should be calculated, Mr. Robert Wiseman said that, in their past Capital Investment Plans, the FAA has estimated benefits to each part of the entire aviation community. Dr. Corker stated that the benefits must be data driven. Prof. Odoni added that the data should be consistent, and cited the case where there are 20 different versions of what and where the delays are, and what causes them.

Dr. Corker then showed a block diagram on a large easel pad that had a "knowledge base" feeding a higher level block called the "public good." Dr. Corker stated that the lower level of data collection feeding the knowledge base should be institutionalized and that this should be recommended to the NASA/FAA Coordinating Committee. Dr. Zellweger recommended that the "public good" block be expanded to include each of the major constituents in aviation.

A list of the constituents was then added along-side the "public good" block. The list included the airlines, passengers, aircraft and engine manufacturers, and general aviation. Prof. Hansman said that air freight should be added to the list since "just-in-time" delivery was an important issue today. Dr. Poage volunteered to be the recorder of items under discussion. He used the large mounted note pads to summarize issues and stated that there was no immediate need to sort them out since this could be done later by the Volpe Center.

Dr. John asked the group to identify other major policy issues, like the reorganization of the FAA into quasi-public agency. Prof. Hansman answered that he had a list of five. First, how bad will the capacity problem be? Second, a decision on sole means GPS WAAS and LAAS. Third, user fees and the many things associated with them. Fourth, separate infrastructures for air carriers and general aviation. Fifth, managing capacity through a pricing policy. And sixth, the environment.

Dr. Simpson picked up on the environment by stating that there is a Stage IV engine noise issue that is active in Europe. He said that the noise situation is described as one pert of a white paper (See: white_Paper_rev.1.doc) and that anyone could pick it up from the back of the room. He stated that the airlines in this country don't want Stage IV and yet airports can't be expanded because they are already too noisy. We are going to have all Stage III and there is an opportunity to build more runways if we promise the local communities that Stage IV will happen. There is another aspect here where you could have mostly Stage III's, but if one Stage II occurs that seems to get all the negative attention. Dr. Simpson then stated that Stage IV was a major policy issue.

Dr. Corker stated that globalization was a super category involving such issues as different European and U.S. standards for noise and separation and different pricing policies. Dr. Zellweger stated that the impact of security measures in terms of who pays. Ms. Chris Scofield added that security benefits and what security is enough are also important. Prof. Odoni added that an airline study estimated that the cost of security was $2.5 billion per year. But another study estimated $120 million per year, and that this was another example of the discrepancies in information.

Prof. Hansman stated that the equipment compatibility of military aircraft was a big issue in terms of the very large costs to change their cockpit avionics. Dr. John reminded everyone of the previously discussed Dr. George Donohue's position to lease new avionics to general aviation. Dr. Simpson added that equipment was a major international issue. For example, Rowanda wouldn't want special avionics for the middle of Africa. Prof. Hansman then stated that there were significant public benefits for the non-hub airports and the small communities.

Dr. Corker stated that such metrics as preturbability, controlability, relevancy, accuracy, and integrity are important, but these are down a level from the knowledge base block. All agreed that there was a need to understand how the system currently operates. Prof. Hansman stated that there was a level of homogeneity in the NAS. But there was a significant amount of non-homogeneity operating all over the U.S. in procedures, equipment, and tolerances in handling aircraft. For example, there are about 30 to 40 different push-back procedures used at different airports in the U.S. He also stated that an issue that was discussed yesterday was the inability to predict the safety impact of such new things as Free Flight. There is also no basis for defending against the argument that the system isn't safe.

Dr. John said in going to the FAA/NASA Coordinating Committee that, rather than stating that we are a bunch of modelers and want to do some modeling, we could bring up the major generic issues that we think are open, and we have zeroed down on two or three of them. For example, security, user fees, and privatization. Dr. Simpson then asked, "How does one set up a process to direct the long-term aviation research at NASA?"

Dr. Corker then stated that the rate of change of the NAS may be too fast. For example, Free Flight Phase 1 is introducing five or six new technologies at the same time. And NASA future plans may introduce another four or five. All of these changes may occur within the next five years. Dr. Zellweger then stated that the air traffic people say that they can only take so much, but the FAA does, however, do staffing projections to determine how many people are needed to deal with the new system. This tends to limit the speed at which changes are implemented.

Dr. John asked that the group move to operational issues, e.g., shared decision-making. Prof. Hansman stated that the related issue was one of shared responsibility, involving legal ramifications and new roles. Mr. Phillip Snyder stated that, as a start, NASA is looking at local rather than global optimization. Dr. Eugene Gilbo stated that optimizations were very sensitive to scheduling priorities.

Dr. John then asked the group to focus on the four areas of safety, security, environment, and efficiency. Maybe the issues could be identified in one or two of these areas. Prof. Hansman stated that he was afraid that most of the issues would be in the efficiency area. Dr. Poage stated that some of the issues would cut across all of the areas. Ms. Scofield said that Congress would want to hear that we have looked at the problem, selected solutions, these are the constituencies that have net benefits, and these are the costs to the government.

Dr. John asked how do we make statements of the problem and solutions in ways that are simple enough for Congress and the public to understand? Prof. Hansman stated that it might be best if the wording used in the NRC study was used. He also said that there are two separate ways to address the problem. The first is at an operational level, for example, in flow control what are the temporal conditions that make sense for shared decision aids? The second is at a higher level and would determine how dependent the U.S. economy is on such things as "just-in-time" delivery of air traffic and what would be the impact on, say, the semiconductor industry?

Dr. John mentioned that there could be a worldwide future increase in disposable income with a consequent increase in tourist trade. This could lead to the question of whether we, as a nation, are well equipped to attract these tourist dollars and to handle the increased traffic. Dr. Poage stated that the Internet is now a big business with one or two day deliveries as an important capability. This will also increase the involvement of small communities.

Prof. Odoni asked the question: How does the air transportation system, and especially its infrastructure, affect the national economy and the public good? He stated that this was the question that had to be answered for the FAA/NASA Coordinating Committee and for Congress.

After a short break, the Open Session resumed with attention to the knowledge base. Dr. Poage stated that decisions had to be made on the subsets of data that would be used in the knowledge base, given that it could be very large and that even $10 million couldn't entirely cover it. Mr. Wright stated that some of the data and information was being prepared in a detailed and systematic manner. For example, in CTAS, Sterling has a contract for $100 million to provide detailed procedure adaptations for five airports. This data could be easily tapped, providing a base that could be used for generalizations.

Dr. Simpson stated that it would be important to convince the decision maker's staff . They will have time to examine things closely. Mr. Wright said that the knowledge base would also be available to constituents who may inform the policy maker as adversaries. So the existence of the base would strengthen the policy and raise it above the level of conjecture.

Dr. Corker asked Mr. Hassam about the Aviation System Analysis Capability (ASAC) tool. He stated that it was his understanding that the tool had been under development for five years, but has anyone used it? Mr. Hassam answered that it had and cited MOAS (Mother of All Systems) to look at each of NASA ten major goals. The intent was to see how far NASA had progress toward these goals and, therefore, what were the gaps. ASAC is not over-used because it isn't finished yet. Today's version is only used by the LMI analysts. However other NASA people have used it just to get data by downloading it to their own computers. Dr. Corker then gave the ASAC Internet address to the participants.

Dr. John and Dr. Corker then closed the workshop by thanking everyone for their participation.

Current Aviation System Performance Outstanding Issues (Illustrative)

→Limitations of current aviation system analysis tools due to lack of defined metrics for:

- Capacity
- Safety
- Security
- Environment
- Economics

→Lack of agreement on the impact of:

- Roles, actions, and motivations of pilots, controllers, dispatchers
- Restrictions of CNS technology
- Environmental restrictions
- Current weather prediction and forecasting capabilities

Breakthrough Technologies: Priority Areas

→Strengthen analytical and planning tools that give insight into the capacity, safety, security, environmental, economic, and institutional consequences of alternative air traffic management concepts and architectures.

→Develop alternative approaches to overcoming barriers to aviation system transition, including legal considerations, user/provider incentives, and financial alternatives.

→Support the development of a vigorous technical community (industry, government, academia) for aviation system assessment.

Models to Predict the Impact of New Technologies and Procedures

- Many of the information-based technologies that could enable major changes to the air transportation system, such as the Global Positioning System (GPS), etc. have already been developed. However, because of the complex interactions between economic, political, sociological, and technological forces in the air transportation system, it has been extremely difficult to predict the impact of new technologies or changes in operational procedures on operations and safety.

Reference: National Council, "Breakthrough Technologies to Meet Future Air and Space Transportation Needs and Goals," 1998

Free Flight Phase I Presented to RE&D Advisory Committee

Performance Metrics

- Metrics based on expected operational impacts of FFP1 tools.
- FFP1 and RTCA developing consensus on "core" metrics.
- Collection of baseline data has begun-including conditions influencing metrics.
- User groups will participate fully in the evaluation of metrics.
- FFP1 potential benefits based on experience at prototype sites.
- No "benefits baseline" for FFP1-focus on actual tool performance.

What is Safe Flight 21?

- An Operational Evaluation focused on...

RTCA Nine Operational Enhancements

- Provide weather and other information to the cockpit.
- Affordable means to reduce controlled flight into terrain.
- Improved capability for approaches in low visibility conditions.
- Enhanced capability to see and avoid adjacent traffic.
- Enhanced capability to delegate aircraft separation authority to the pilot.
- Improved capability for pilots to navigate airport taxiways.
- Enhances capability for controllers to manage aircraft and vehicular traffic on airport surface.
- Provides surveillance coverage in non-radar airspace.
- Provide improved separation standards.

...And a Link Evaluation

AVIATION MODELING AND SIMULATION NEEDS AND REQUIREMENTS WORKSHOP

Volpe National Transportation Systems Center
Cambridge, Ma

January 27-28, 1999

The development of models to predict the impact of technological and procedural changes on the air transportation system will be critical to the long-term future of aeronautics and to meeting NASA's goals relevant to system capacity, environmental compatibility, safety, and cost. November, 1998

Reference: National Research Council. "Breakthrough Technologies to Meet Future Air and Space Transportation Needs and Goals." 1998

National Research Council

Breakthrough Technologies to Meet Future Air and Space Transportation Needs and Goals

Expanded notes from the Volpe Meeting

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Policy

- We have a policy based on an incomplete understanding of the NAS as a system due to our continuing reliance on the business "health" of the users as the indicator.
- Within that potentially flawed policy we make sub-optimal decisions based on inaccurate estimates of point performance
- Our decisions are based on point estimates not a system evaluation.

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A question raised by Monte Belger.

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Enroute Versus Terminal

- Question: Why focus on the enroute improvements if terminals are the problem?
- Answer: We don't know if terminals are a problem from a national perspective or a local perspective.
  - A partially used network is not a over subscribed network.
  - A queue is an inefficiency not by its existence, but in its management.

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Performance in the current and future NAS

- The FAA's policy is to meet the needs of its users
  - The daily performance is based on Air Traffic's goal to provide the most efficient service within today's constraints.
  - We measure the "health" of the NAS based on the differences in the outcome for our users day-to-day.

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Performance in the current and future NAS (2)

- Future NAS Performance is estimated on the same basis.
  - It uses the daily performance and the current objectives of the users as a given.
  - It places the full burden for future performance on the FAA.
  - It predicts dire straits for the NAS - But!

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Performance in the current and future NAS (3)

- Where are the potholes to show that the NAS is falling down?
  - Are we confusing individual user performance with NAS health?
  - Are we identifying "problems" that the market is solving as we take direct action?
  - If the NAS is failing in 2005, shouldn't we already be seeing constraints on growth and change?

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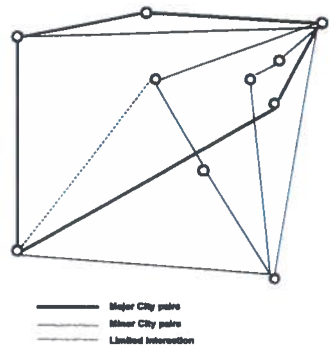

The NAS is viewed as a network of airports with the packets moving across the network = the scheduled flights. Evaluations of the capacity of the network are based on the delays associated with individual flights.

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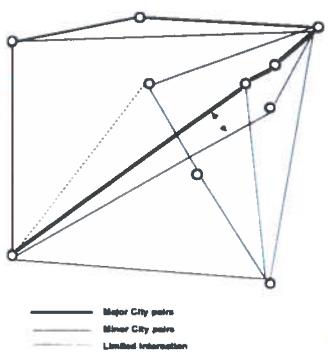

Analysis of future growth is based on the current flow within the network - without any potential change. But, the network is constantly changing based on the business case of the users. This volatility is noted but always ignored in our analysis.

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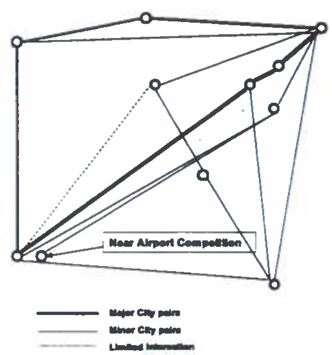

The view of a static network limits our vision of other potential changes in the NAS. Looking at moving passengers from O to D we see packet switching - e.g. Southwest, et al, filling in at the airport or nearby airports.

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Big Question Number 1 -

- What is the carrying power of the NAS?
  - The continuing entry of flight alternatives runs counter to the argument of demand near capacity in the network.
  - We have this disconnect because we continue to only view the paths currently selected.
  - We do not say the NAS is at a capacity impasse by proving that the business case can not be sustained without action to overtly improve capacity utilization.

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Big Question Number 1 - (cont.)

- We need to know when the full network will be unable to sustain the growth in traffic
- We need to understand what the policy of following the day-to-day business case of the users means for NAS modernization
- We need to state clearly what our objectives are for the future.
- For instance ...

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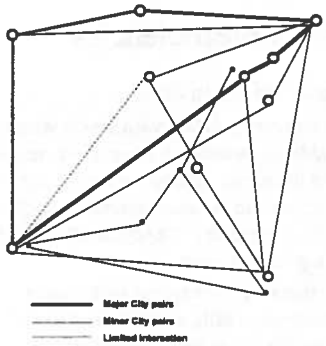

The SATS effort by NASA is a look at alternative policies for meeting the growth in demand and the economic benefit of a local, scheduled aviation presence in "smaller" communities. FAA efforts are not "mission need", it is ***policy*** examination.

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Big Question Number 2 -

- How inefficient are terminals?

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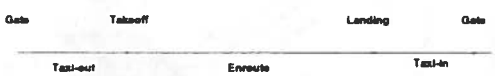
Let's turn now to individual terminals

- To have a queue is not an inefficiency!



Consider a nominal path - "delays" can occur anywhere along the path - but are they inefficiencies?

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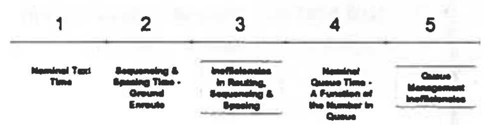
Consider just one component - taxi-out. We could split the taxi-out time line in five components - only 2 of which are system inefficiencies 3 & 5. We currently report 2 to 5 as "delay" and, given pushback practices of the user, 4 can easily be the predominate value.

The same phenomena occurs on the arrival side - where aircraft queue either virtually and/or in a trombone or holding stack for a runway. Just switch approach for taxi in the legend.



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Terminal Inefficiencies

- So we have a number which at best reflects both the business case/practices of the user and the quality of the service delivered.
- 100% efficiency on the part of the FAA will not eliminate parts 2 & 4.
- It may well be that we are as efficient as we can be - but the raw numbers will still call for improvement.

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Terminal Inefficiencies

- The reality:
  - We do not have (except for the CTAS analysis for approach in DFW) any times belonging to demand on capacity and those that are inefficiencies.
  - The FAA is only responsible for the inefficiencies. (CTAS is clearly a queue management tool to remove queue inefficiencies.)

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Terminal Inefficiencies

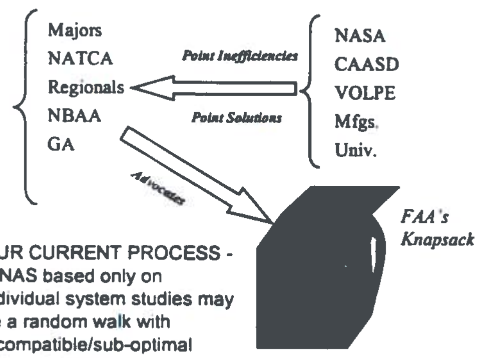
- The large, raw "delay" numbers are not indicators of what the FAA can do to improve the NAS. We need to identify the actual inefficiencies - not the queue effects.
- The real question should be - **Where are the queues (sector, approach, runway) most inefficiently managed? and Where can the FAA best make its investment to improve those queue's management?**

NAS Inefficiencies

- This is easier said than done -
  - we have a number, delay, with which we are comfortable and which we consistently use as our major decisions variable - even though it may be wrong! So we must overcome tradition and inertia. Remember in a regulated industry delay is a good indicator.
  - Splitting that number requires us to gather information not readily available and to do analysis which is not easily tractable.

Finally -

- One of the key steps required to becoming part of the NAS is to find someone who will advocate your program. We ask - who is the program champion.
- We also gear our analyses not to system effects but to acquisition potential ...



OUR CURRENT PROCESS - A NAS based only on individual system studies may be a random walk with incompatible/sub-optimal point solutions.

Result

- A knapsack:
  - full of consensus items,
  - in which everything is of equal weight
  - a knapsack in which the whole can end up being much smaller than the sum of the parts

FAA/NASA EXECUTIVE COMMITTEE

Committee Membership

Cochairmen:

FAA	AA for Research and Acquisition	Steve Zaidman
NASA	AA for Aero-Space Technology	Sam Armstrong

Members:

FAA	AA for Air Traffic Services	Steve Brown
	AA for Regulation and Certification	Tom McSweeny
	AA for Airports	Susan Kurland
	AA for Commercial Space Transportation	Patti Smith
	AA for Policy, Planning and International	David Traynham
	AA for System Safety	Chris Hart
	Director for Aviation Medicine	Jon Jordan
	Director for Aviation Research	Herm Rediess
	Director, Wm. J. Hughes Technical Ctr	Anne Harlan
NASA	Director, Langley Research Center	Jerry Creedon
	Director, Ames Research Center	Harry McDonald
	Director, Lewis Research Center	Don Campbell
	Director, Dryden Flight Research Center	Kevin Pet
	Director, Marshall Space Flight Center	Art Stephenson
	Director, Goals Division	Mike Mann
	Director, Programs Division	Rich Christiansen
	Director, Commercial Technology Div	Bob Norwood
Executive Secretariate		Charlie Huettner

FAA/NASA
Executive Committee Charter

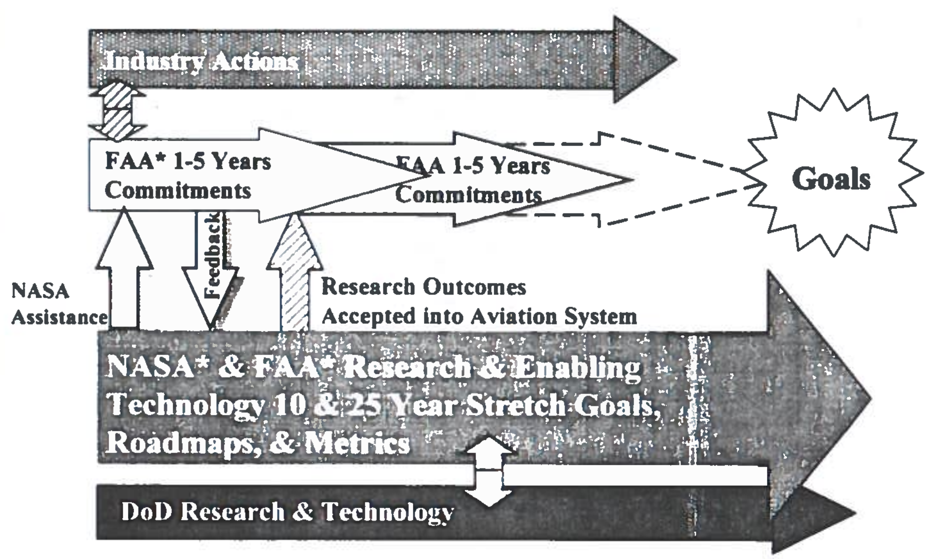
A. Foster an effective FAA/NASA partnership in research and development.

B. Ensure that complementary aviation and future space transportation goals for FAA and NASA are defined that reflect each agency's mission, and which both agencies acknowledge and support

C. Ensure that FAA and NASA planning and resources to achieve the goals are coordinated, when appropriate.

D. Monitor progress toward the goals and propose adjustments in agency roadmaps, plans, and resources as necessary.

E. Propose changes to goals and plans based on changing stakeholder and customer requirements.



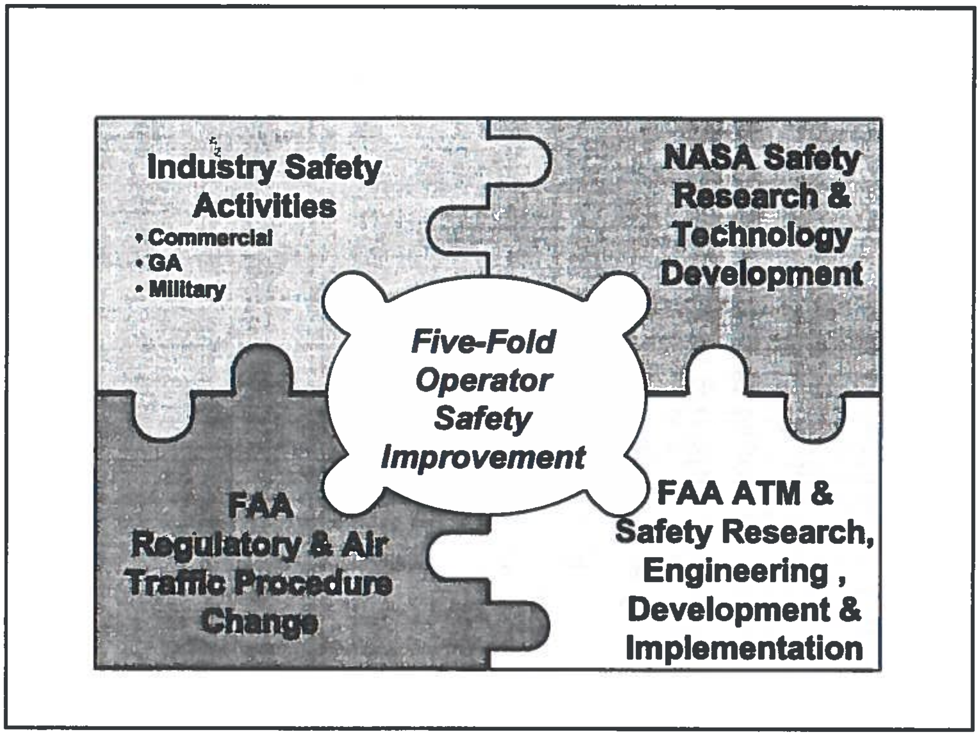
*Includes collaboration with DoD & Industry

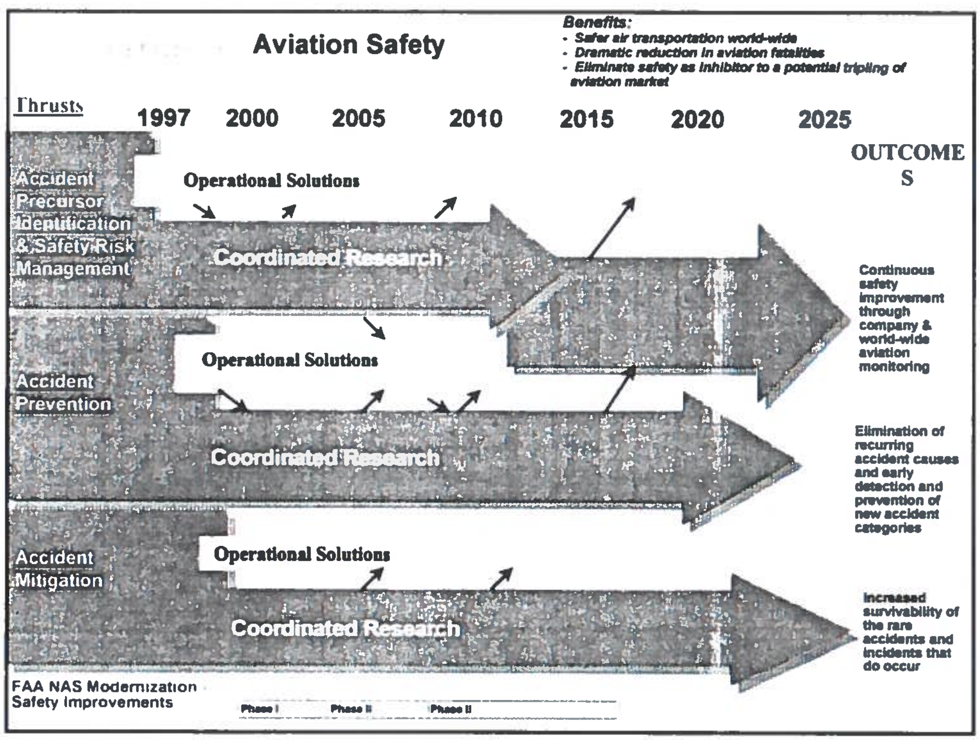
Four Levels of Effort to Improve Safety, Security and Efficiency

- **White House Initiative - National Aviation Priorities - OSTP**
- **National R&D Plan - NSTC - FAA, NASA, DOD, Volpe**
  - Primary Audience - OMB & Congress
- **FAA/NASA Executive Committee**
  - Harmonizing Goals - First FAA meeting 12/18
    - Safety - Common Goal - Need Common Metrics & Review Process
    - Efficiency - Herm will begin discussion with FAA Associates
    - Environment - Howard Wesoky (FAA) forming work group
    - Space Transportation - Preliminary discussion meeting
  - Advisory Committee Harmonization
  - Committee Operating Principles - Approved Jan 13
- **Joint IPT & Work Groups - Goal, MOU, Metrics & Plans**

NSTC National R&D Plan for Aviation Safety, Security and Efficiency

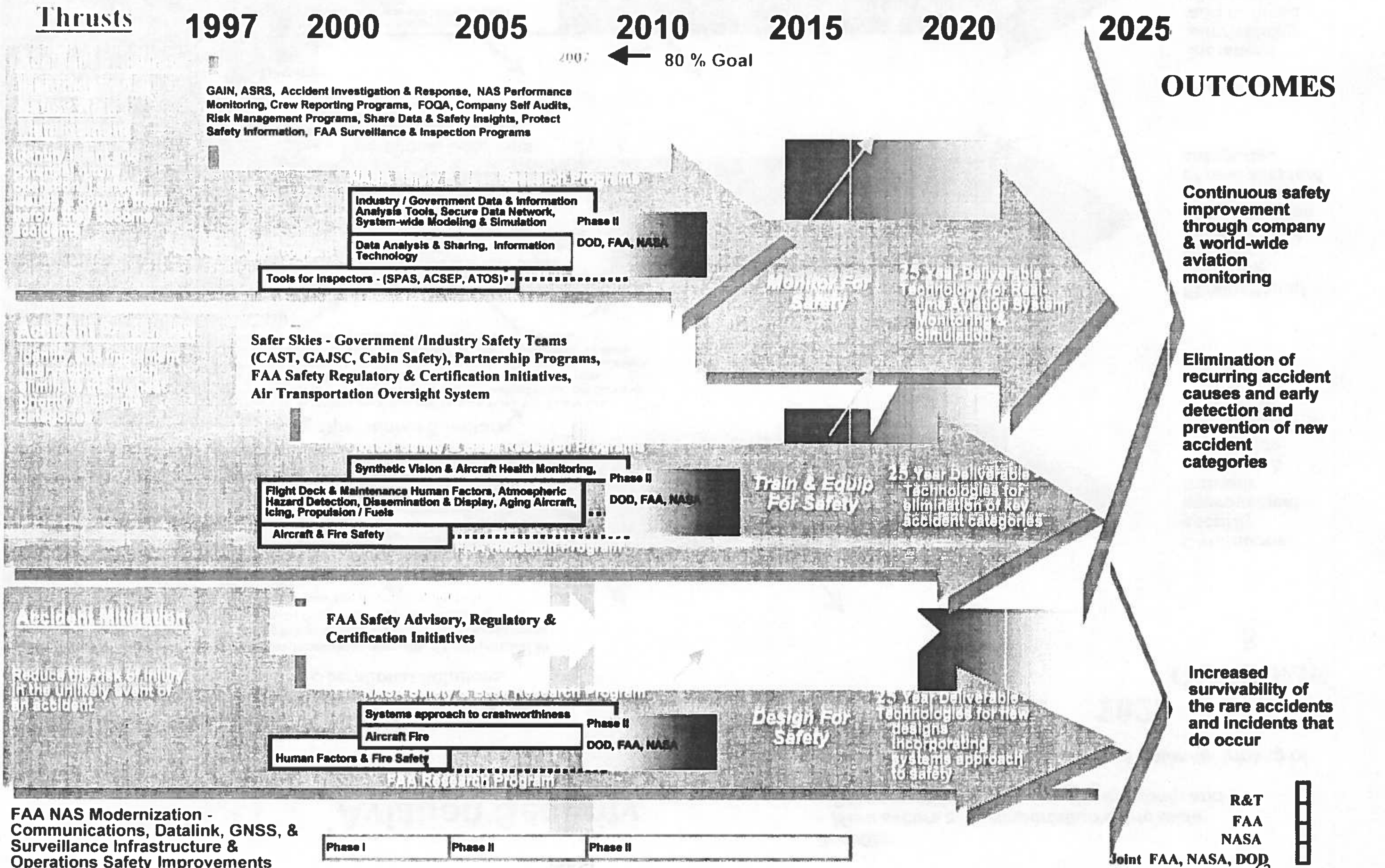
- **Objectives**
  - Relationship FAA, NASA, DOD to achieve Civil Aviation Goals
  - Research & technology development is both linked and critical to achieving real world outcomes
  - Show highest level roadmap for each goal showing major agency programs in operations & technology development and their relationship to each other
- **Outline**
  - Background - Link to Gore Commission
  - Relationship model & description
  - Roadmaps
    - Overview
    - Description of each element
    - Examples of ongoing interagency efforts


Industry Safety Activities
• Commercial
• GA
• Military
NASA Safety Research & Technology Development
Five-Fold Operator Safety Improvement
FAA Regulatory & Air Traffic Procedure Change
FAA ATM & Safety Research, Engineering , Development & Implementation


Aviation Safety
Benefits:
- Safer air transportation world-wide
- Dramatic reduction in aviation fatalities
- Eliminate safety as inhibitor to a potential tripling of aviation market
Thrusts
1997 2000 2005 2010 2015 2020 2025
OUTCOMES
Accident Precursor Identification & Safety Risk Management
Operational Solutions
Coordinated Research
Continuous safety improvement through company & world-wide aviation monitoring
Accident Prevention
Operational Solutions
Coordinated Research
Elimination of recurring accident causes and early detection and prevention of new accident categories
Accident Mitigation
Operational Solutions
Coordinated Research
Increased survivability of the rare accidents and incidents that do occur
FAA NAS Modernization Safety Improvements
Phase I
Phase II
Phase II

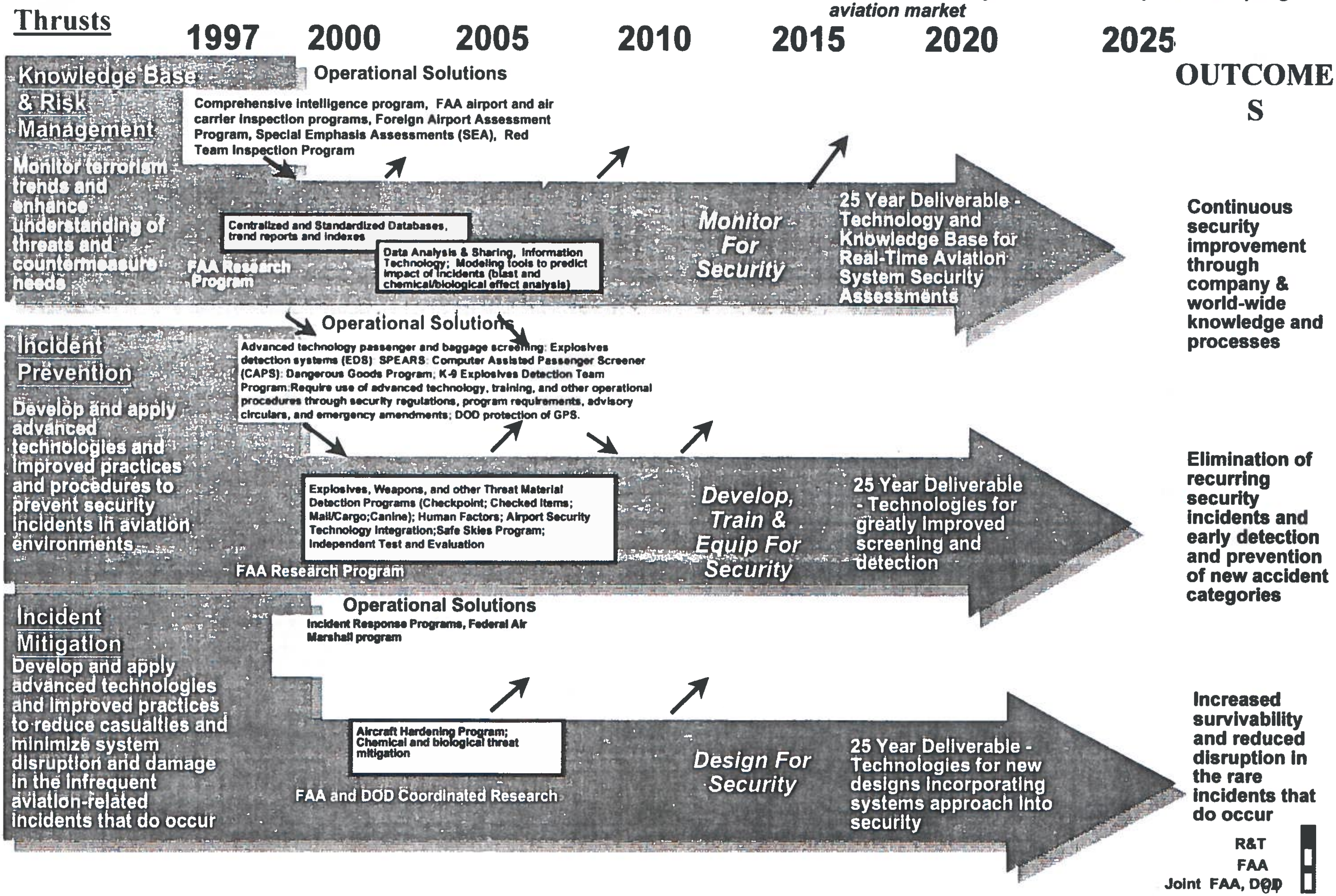
Aviation Safety

Benefits:
- *Safer air transportation world-wide*
- *Dramatic reduction in aviation fatalities*
- *Eliminate safety as inhibitor to a potential tripling of aviation market*



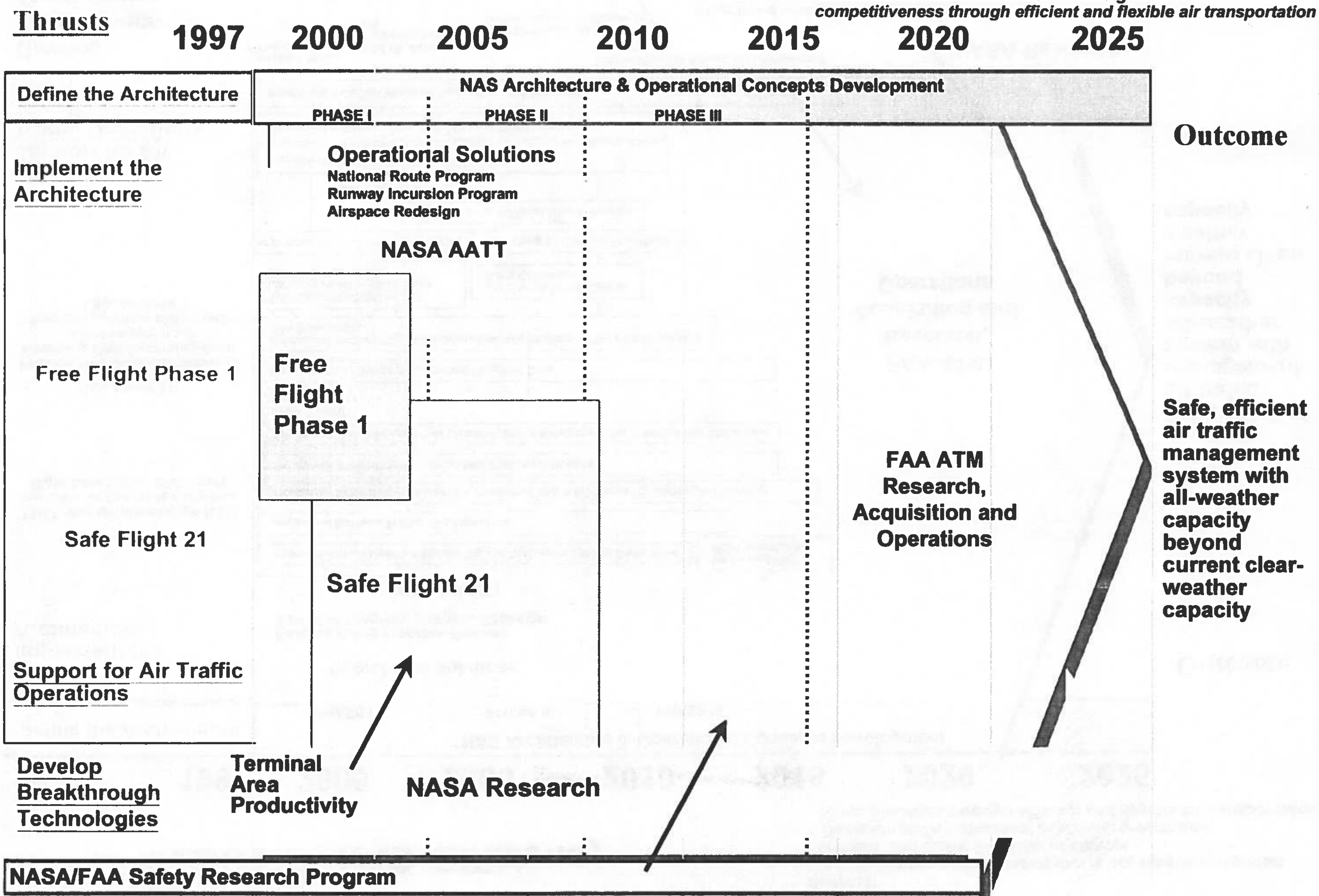
Goal 2 Aviation Security

Benefits:
- *More secure air transportation world-wide*
- *Dramatic reduction in security incidents and consequences*
- *Eliminate security as inhibitor to a potential tripling of aviation market*



Goal 3 NAS Efficiency

Benefits:
- *An air transportation system that is accessible, integrated, efficient, and offers flexibility of choices*
- *Domestic and international economic growth and competitiveness through efficient and flexible air transportation*



Goal 3 NAS Efficiency

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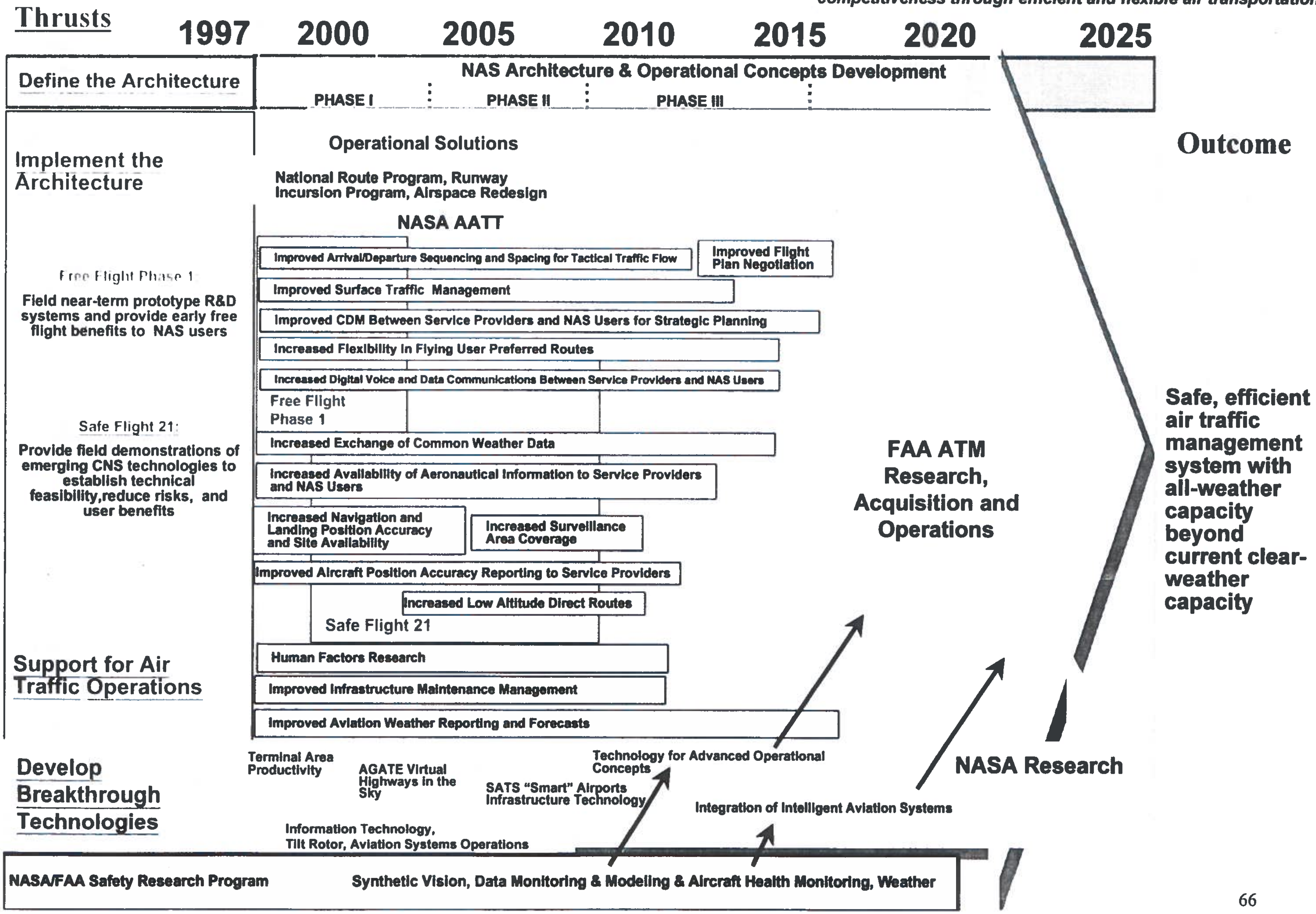
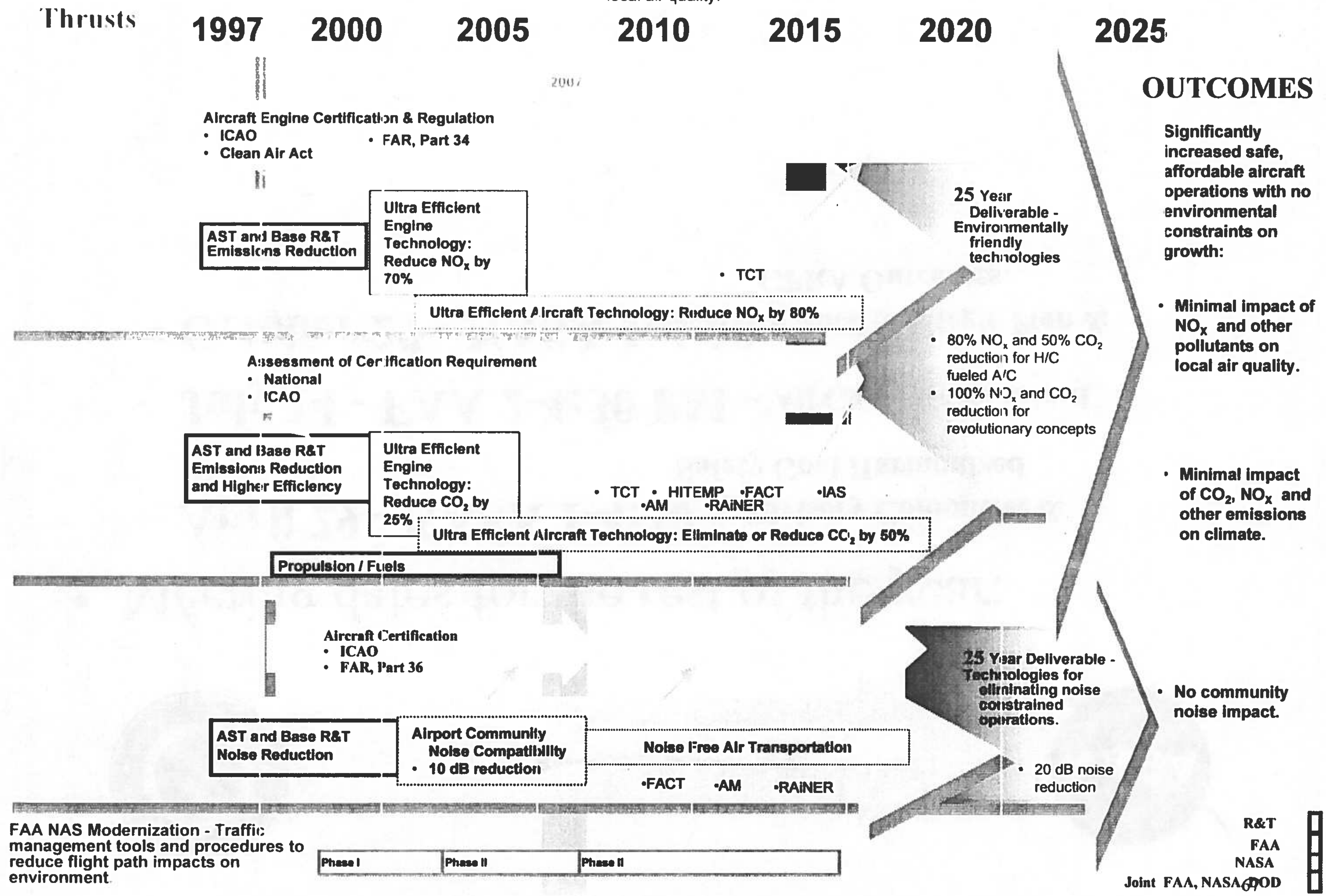


Environmental Compatibility

Benefits:
- Understand effects and reduce emissions and community noise.
- Potential for curfew free, unconstrained flight operations and growth.
- Significant reduction of aircraft emissions as a source of climate change and degradation of local air quality.



- Meeting dates for the rest of the year:
  - **April 29 - NASA 1-4:30 - Advisory Committee & Safety Goal Harmonized**
  - **July 14 - FAA 2-4:30 PM - All Goals Harmonized**
  - **October 27 - NASA 1-4:30 - 2000 Strategic Plan & GPRA Outcomes**

Capacity and Delay Analysis and Simulation

Amedeo R. Odoni
MIT
January 27,1999

State of the Art: Modeling (Fast-time)

- Traffic efficiency models are most advanced, but..
- Conflict models have scattered capabilities
- Human factors modeling is weak
- Some progress in economic impact assessment
- Safety modeling/relationships are extremely difficult (system complexity, high safety levels, automation/software validation)
- Weak model compatibility, integration, HMI

MIT, "Existing models and future requirements"
http://web.mit.edu/aeroastro/www/labs/AATT/aatt.html (3/97)

Increased Expectations

- The stakes for capacity and delay models have been raised:
  - growing emphasis on partial decentralization of ATM decision-making
  - estimating expected values alone (especially, in the case of delay) is not sufficient to gauge performance
  - need to better understand the dynamic behavior of a highly interactive system
- Models need to capture this increasingly complex environment

Indicators of Traffic-Handling Efficiency

- Capacity / Throughput
  - "no. of aircraft that can land per hour"
- Delay
  - "difference between optimal and actual en route time"
- Predictability (long- and short-term)
  - "airport capacity variability due to weather"
  - "delay prediction and propagation during GDPs"
- Flexibility
  - "increase no. of granted user preferred routes"
- Access
  - "no. of airports with precision approaches"

Observations re. Existing Models

- Existing models focus, almost exclusively, on capacity/throughput and delay
- Reasonably accurate predictions of mean throughput rates and of "regular" delays
- Stochastic capabilities are often limited or difficult-to-use or absent –>> weak in estimating long-term (statistical) variability/predictability
- Weak in modeling dynamic user behavior
- Usually cannot deal with dynamic predictability
- Little available on system flexibility

Areas for Model Improvement

- Stochastic capabilities (random variate generation, measures of variability, "tails" of distributions, statistical analysis)
- Data support: current major area of opportunity
- Modeling of dynamic behavior of "agents"
- Incorporating dynamic control and optimization actions
- Metrics other than those directly related to capacity/throughput and delays

Improving the Usability of Models

- Selecting the right model or the right "level" of modeling
- "Horizontal" model integration
  - Toolkits (many pitfalls)
  - Interprocessing with optimization and control tools
- Vertical model integration (across levels of detail)
- Distributed simulation
- HMI

Examples from ATM-98 Meeting

- Model integration: Bradford et al.; Brunetta et al.
- Landside ops: Brunetta et al.
- Agent behavior and dynamic control: DP project
- Impacts of ATM improvements:
  - On carriers: Sinnott + MacReynolds, Gaier + Kostiuk
  - On terminal area costs: Weidner
  - On environment: Liang et al.

Conclusions

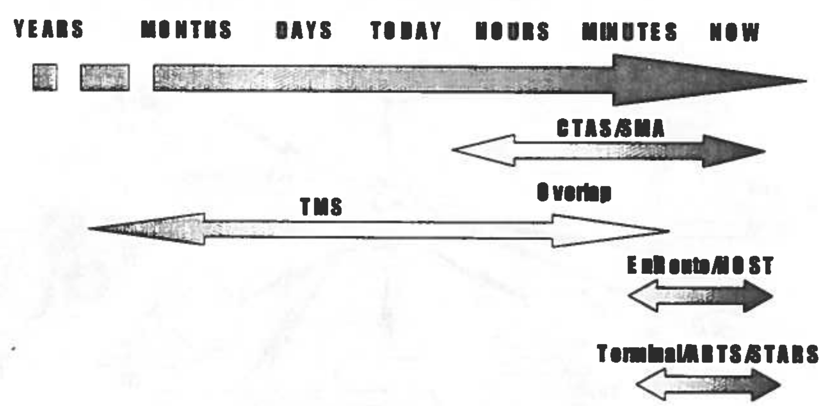
- Capacity (throughput) and "regular" delays are best bets
- Models are static (no feedback effects, no agent dynamics)
- Limited compatibility and integration
- Weak in dealing with uncertainty
- Weak in predicting performance when user behavior is important (e.g., CDM, irregular ops)
- Much work to be done!

TMS

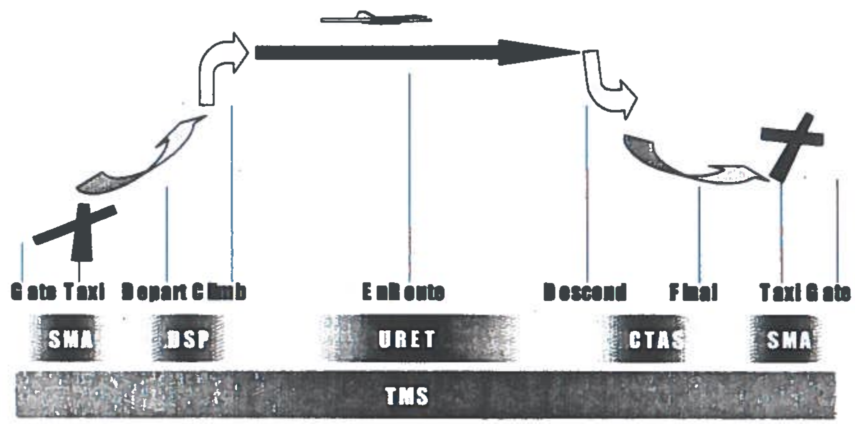
Volpe Workshop on
Simulation & Modeling
January 27, 1999

Time Sensitivity

Planning Horizon

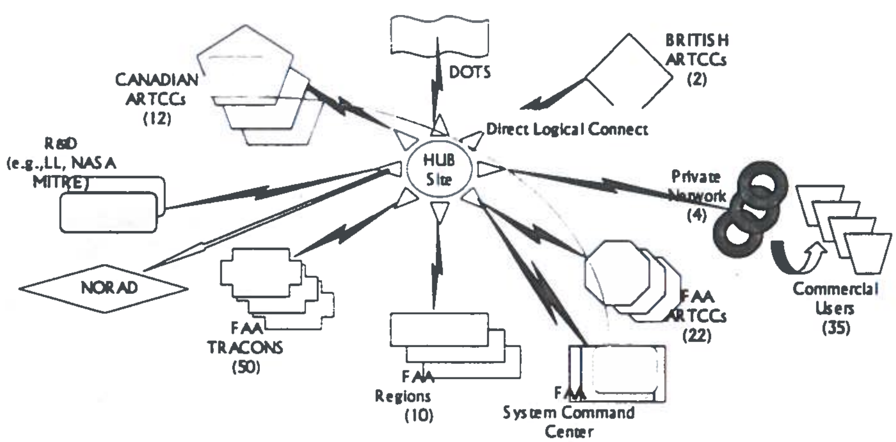


ATM Flight Regimes



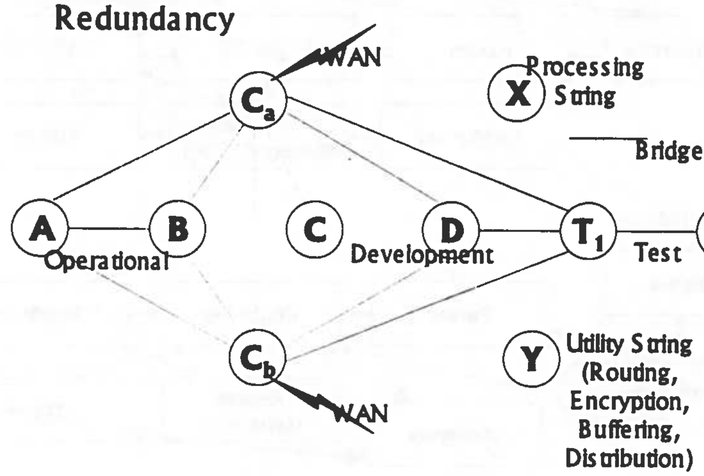
TMS Architecture

- TMS WAN Topology
  - Communications Topology: Star over MCI Network
  - System (Logical) Topology: Point-to-Point by Process

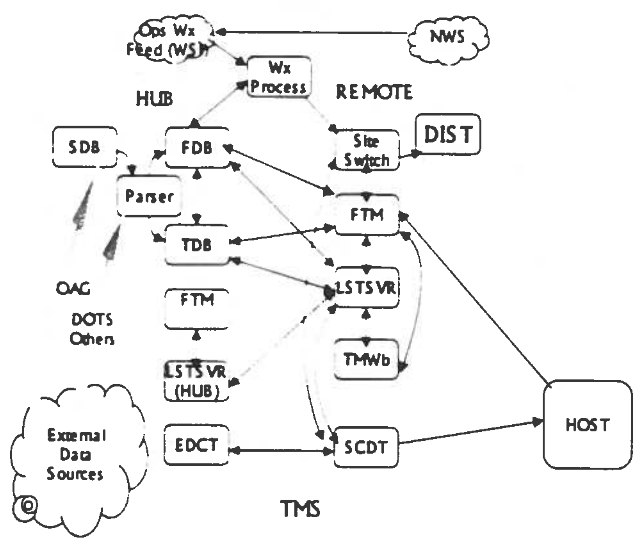


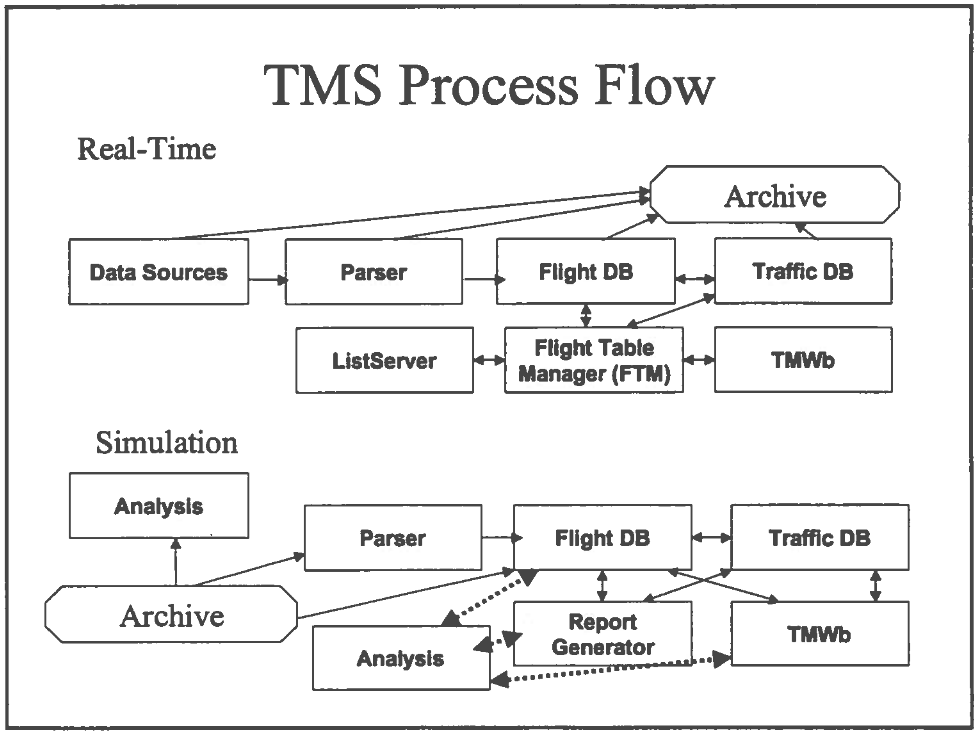
TMS Architecture

- TMS Hub Site Topology
  - Multiple Strings to Reduce LAN Traffic &Provide Redundancy



TMS





TMS Process Flow
Real-Time
Archive
Data Sources
Parser
Flight DB
Traffic DB
ListServer
Flight Table Manager (FTM)
TMWb
Simulation
Analysis
Parser
Flight DB
Traffic DB
Archive
Report Generator
TMWb
Analysis

Flight Management & Human Factors

Aviation Modeling & Simulation Workshop

NASA Model Development Requirements

Kevin Corker
San Jose State University

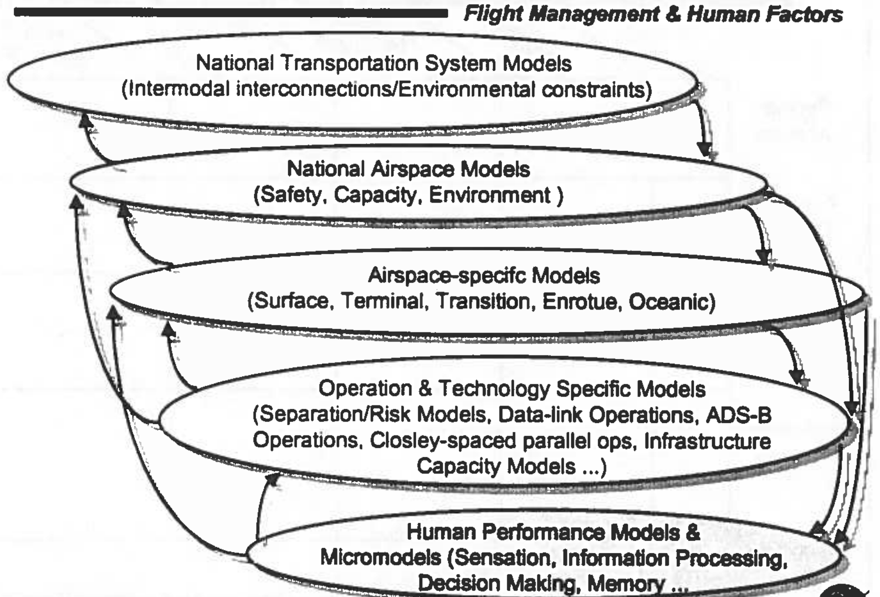
Volpe National Transportation Systems Center

January 27-28, 1999

K. M. Corker

Requirements for Model Integration

Flight Management & Human Factors



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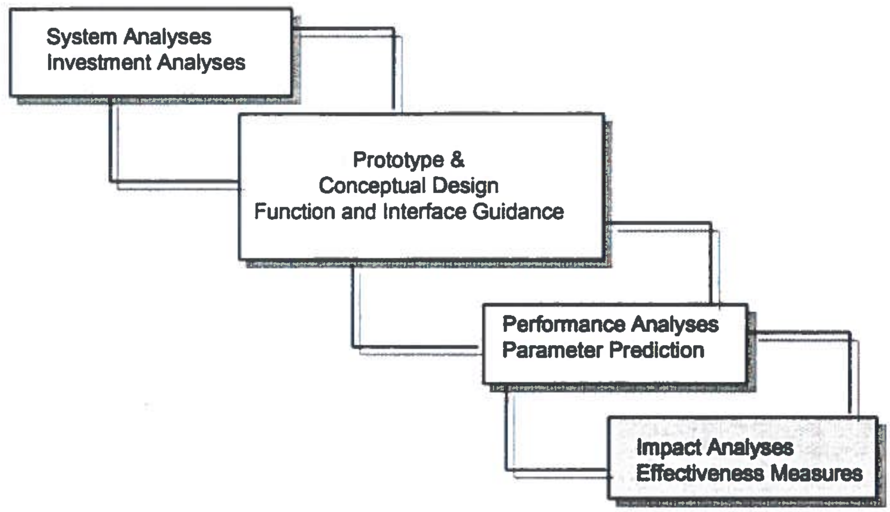
Model Use

Flight Management & Human Factors



K. M. Corker

Matrix Model Performance Reqs.

Flight Management & Human Factors

	Transport	Airspace	Airspace Segment	Tech Specific	Human Performance
System Analysis					
Prototype Concept					
Performance Analyses					
Effectiveness Analyses					

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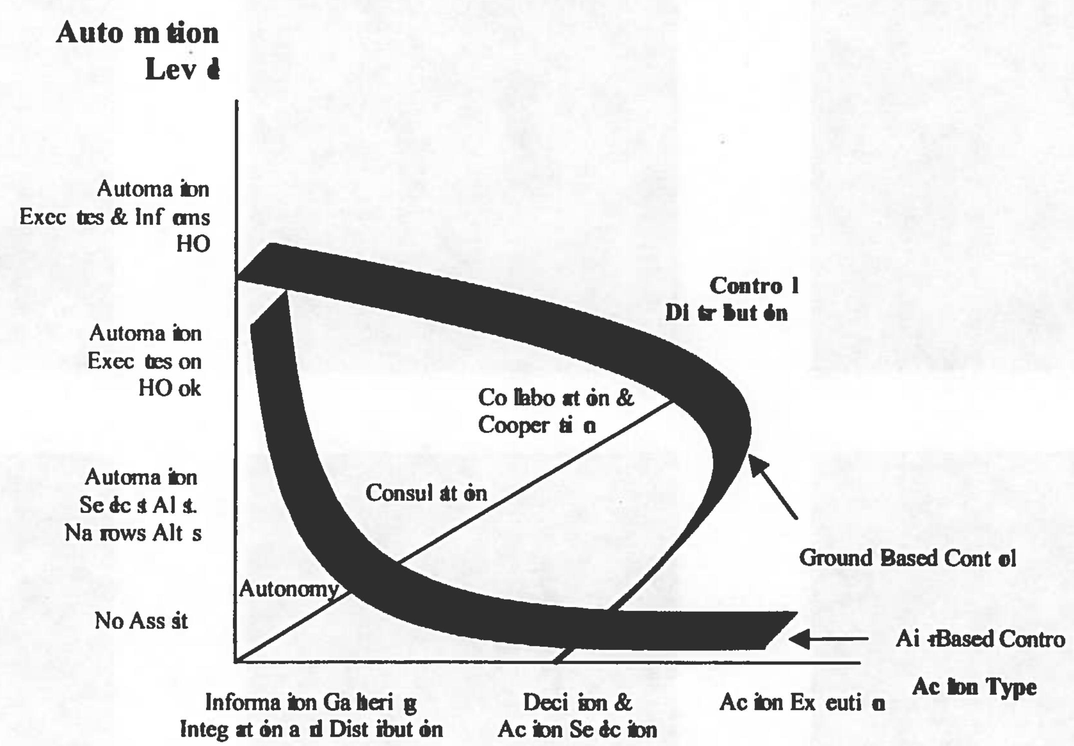
Expansion of Intersection Cell

Flight Management & Human Factors

Dimensions of the Human Automation Interaction:



The relation between air-borne separation and ground-based automation and the use of automation, the type of action undertaken and the distribution of control are illustrated in this graph. The challenge for research is to come up with an effective way in which the system and the operators can transition between fundamentally different profiles and maintain a stable state.

K. M. Corker

Analyses Using Effectiveness and Cost Models

Infrastructure Protection and Operations Division

Volpe Center

Patricia H. Ryan

Effectiveness and Cost Models

- Analytical Tools
- Used by the Aviation Security Advisory Committees Domestic Security Baseline Working Group
- Data to Gore Commission

Effectiveness and Cost Models

- Models Provide Way to Quantitatively Compare
  - Technologies
  - Threats
  - Bag Flows
- Strategies at Various Airports

Effectiveness Model

SCREENING METHODS

- Profiling (Active and/or Passive)
- Bag Match
- CTX5000 (automated or manual)
- Vivid
- Trace Technologies
- Hand Search
- K-9
- Other Screening Methods

Effectiveness Model

Define Sequencing of Screens and Bag Flow

Cost Model

WHAT IT IS

- Calculate 10 Year Costs for Deploying Screening Options (ex. Profiling, CTX5000, K9, and Hand Search)
- User Selects Airports (Individual Airport or many)
- User select Flight Type, Aircraft Capacity, Day of Week

Cost Model

WHAT IT DOES

- Output Easy to Read Excel Spreadsheet

Cost Model

Economic, View the Ruling

box 0 100 All Level 10/27/98

File Edit

Year	1997	1998	1999	2000	2001
Deliveries	326	2	19	16	64
Cum. Deliv.	326	328	347	363	427
Cost	65	0	3	3	12
Installation	0	0	0	0	0
Training	32	0	1	1	6
Tot. Acquis.	97	0	5	4	19
Construction	601	32	0	0	41
Refurbish	359	2	20	17	70
Tot. NonRecur.	958	35	26	22	130
Lease	359	361	382	400	470
Maint.	0	0	0	0	0
Labor	27962	29530	30007	30485	37919
Annual Train.	0	0	0	0	0
Tot. Recur.	28321	29892	30390	30885	38389
Tot Recur/NonRecur	29279	29927	30417	30907	38520
Discount	29279	29927	30417	30907	38520

Click on the Select to view the Ruling. There is a Print option under the File Menu which sends a copy of the ruling to your printer. Under the Edit Menu there is an option to Copy Grid to Clipboard. Use that option to paste the ruling directly into the spreadsheet of your choice, thereby permitting additional analysis of the reported costs.

MIT ICAT

AIRCRAFT NOISE MODELS

Prof. John-Paul Clarke
Department of Aeronautics and Astronautics
Massachusetts Institute of Technology
Cambridge, MA

Aviation Modeling and Simulation Workshop
Volpe Transportation Systems Center
Cambridge, MA

January 27-28, 1999

Why Noise Models?

- Noise is a constraint on airport operations and expansion
  - Negative response of communities to aircraft noise
  - Changes require lengthy negotiations
- Enhance communication with community groups
  - Data and graphics for community forums and discussions
- Provide basis for compensation
  - Environmental Impact Studies
  - Part 150 studies
- Enable design of flight procedures to reduce noise impact
  - Designers can compare alternatives
  - Requires high fidelity models

Parameters

- Aircraft Trajectory
  - Radar
  - Performance models
  - Simulation
- Source Noise
  - Component models
  - Empirical databases
- Propagation
  - Atmospheric conditions
  - Attenuation models
- Receiver Characteristics
  - Population distribution
  - Topography

INM

- FAA standard
- Aircraft Trajectory
  - Simplified performance model
  - Limited prediction range
- Source Noise & Propagation
  - Empirical Noise Power Distance (NPD) database developed from certification data
  - Single atmospheric condition
  - Simplified attenuation model
- Receiver Characteristics
  - Population distribution and topography may be included but are not a part of the core model
- Not applicable to flight procedure design

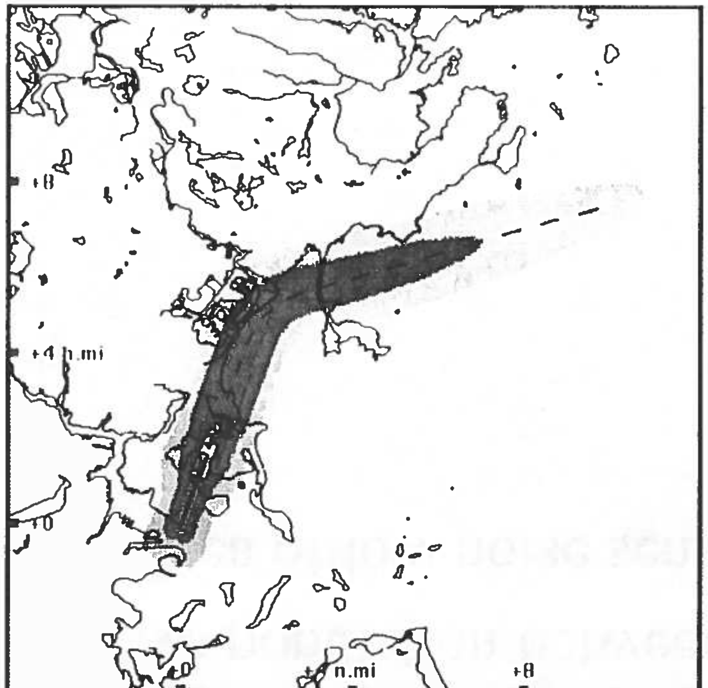
On-Going INM Improvements

- Aircraft Trajectory
  - Improved aircraft performance model that predicts aircraft trajectory over wider range of flight conditions (MIT)
- Source Noise & Propagation
  - Expansion and validation of NPD database (Boeing, Airbus, MIT)
  - Introduction of spectral classes to enable propagation prediction for different types of aircraft under different atmospheric conditions (Volpe)
  - Improved lateral attenuation model that enables prediction over different types of terrain (Volpe, MIT)

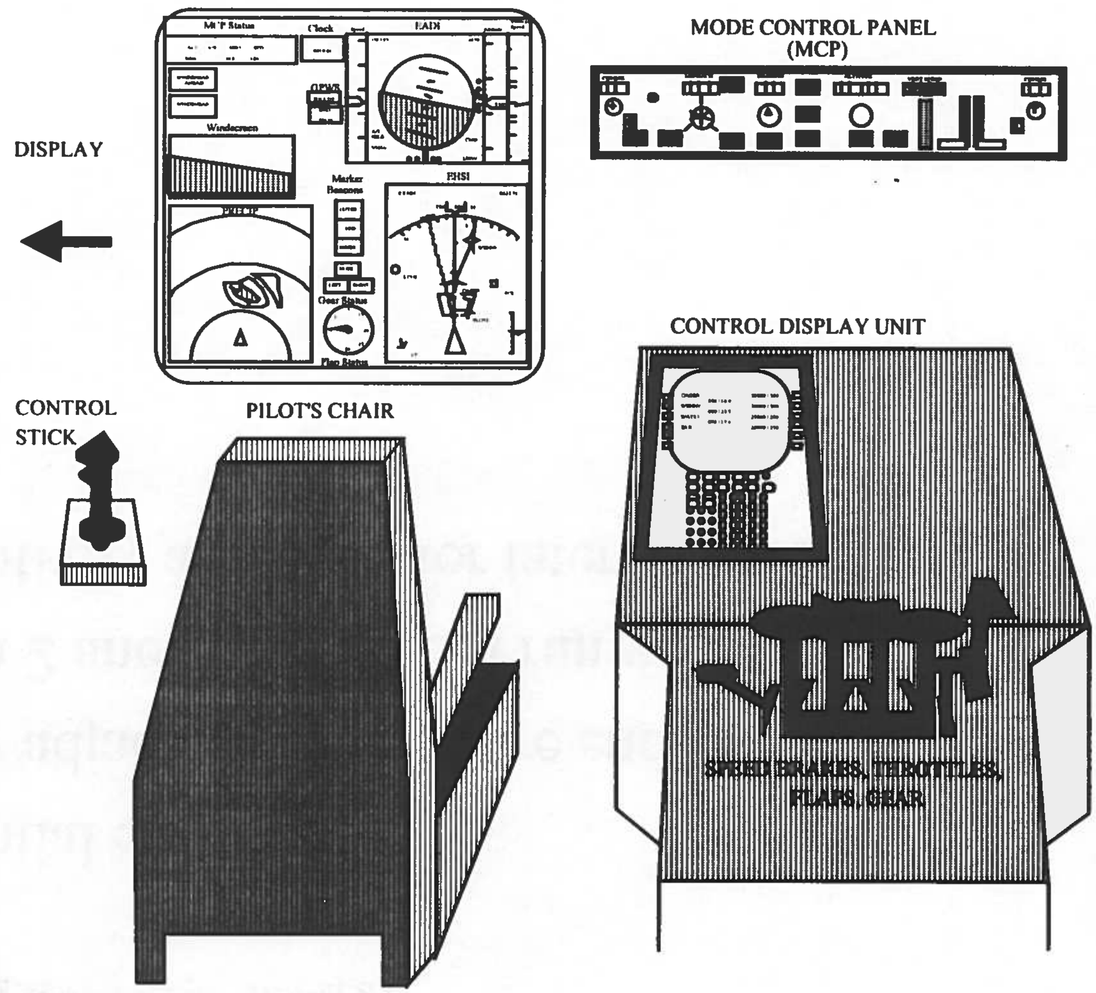
NOISIM

- Combines Flight Simulator, Noise Model, and Geographic Information System (GIS)
- High fidelity
- Simulates
  - Realistic aircraft operation
  - Frequency and spatial noise characteristics
  - Propagation under actual flight conditions
  - Actual population distribution
- Allows rapid prototyping and evaluation of noise abatement procedures

NOISIM



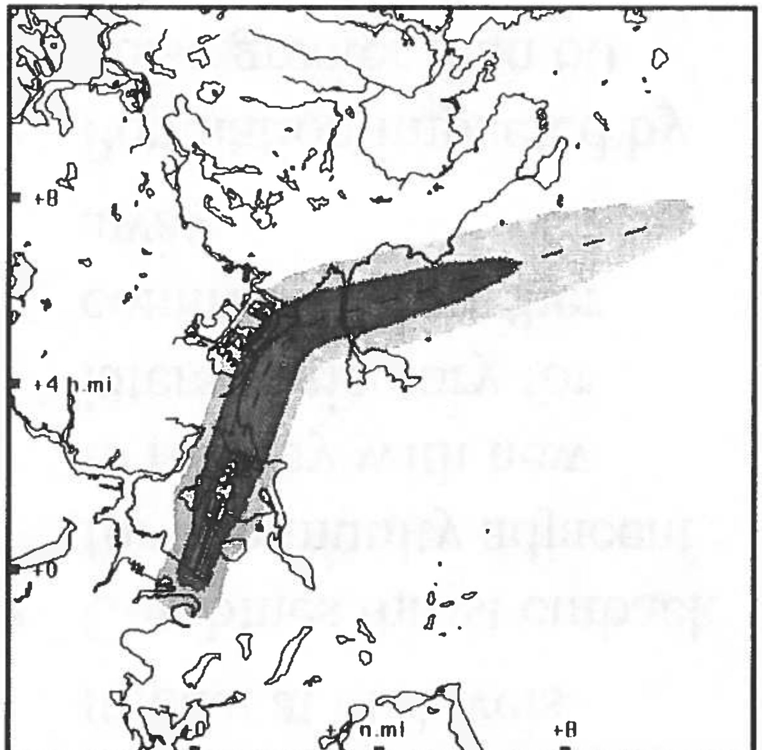
60 70 dBA 4.409 sq.mi. 35322 people	70 80 dBA 2.143 sq.mi 21429 people	80 90 dBA 0.915 sq.mi 9378 people	90 100 dBA 0.093 sq.mi. 950 people
100 110 dBA 0.000 sq.mi. 0 people	110 120 dBA 0.000 sq.mi 0 people	120 130 dBA 0.000 sq.mi 0 people	130 140 dBA 0.000 sq.mi. 0 people



Departure Case Study: KBOS 4R

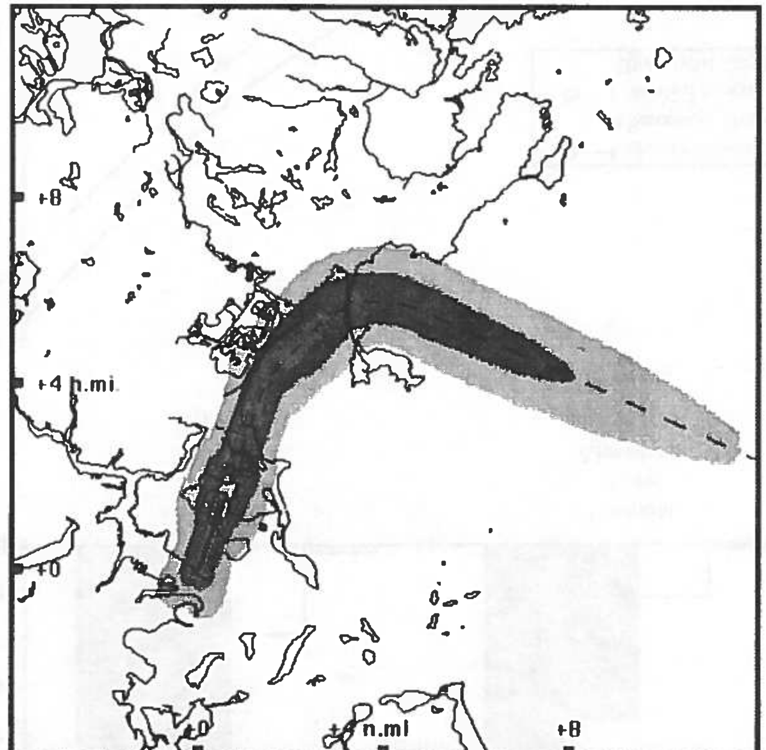
- Airport close to residential communities
- Residential community adjacent to departure end of runway
- No population between 2 and 4 n.mi. from runway threshold
- Area of low noise sensitivity available for lateral deviation

Departure Case Study: KBOS 4R



60 70 dBA 4.409 sq.mi 35322 people	70 80 dBA 2.143 sq.mi 21429 people	80 90 dBA 0.915 sq.mi. 9378 people	90 100 dBA 0.093 sq.mi. 950 people
100-110 dBA 0.000 sq.mi 0 people	110-120 dBA 0.000 sq.mi 0 people	120-130 dBA 0.000 sq.mi 0 people	130-140 dBA 0.000 sq.mi 0 people

Existing Noise Abatement Departure
(Full Thrust Takeoff & Heading Guidance)

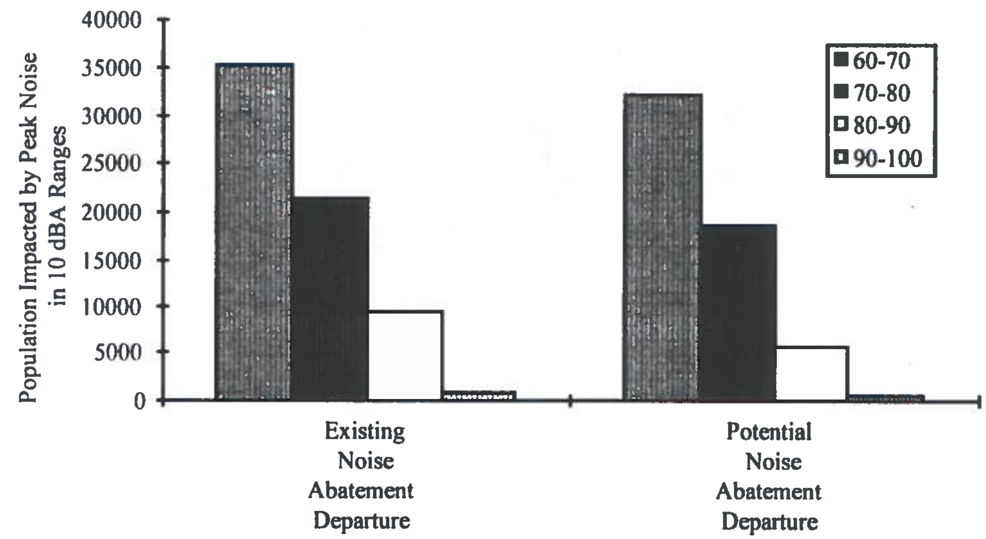


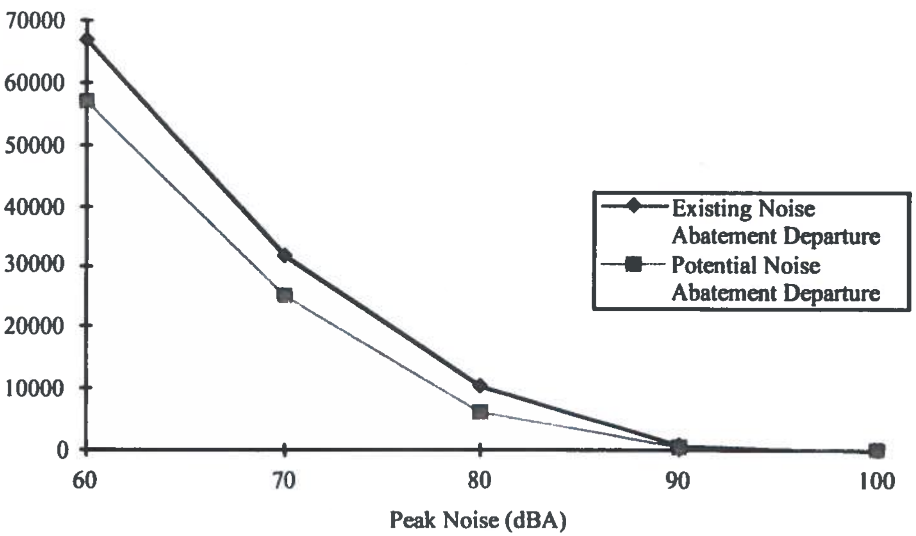
60 70 dBA 3.792 sq.mi. 32231 people	70 80 dBA 1.838 sq.mi. 18608 people	80- 90 dBA 0.556 sq.mi 5698 people	90- 100 dBA 0.054 sq.mi. 554 people
100-110 dBA 0.000 sq.mi. 0 people	110-120 dBA 0.000 sq.mi. 0 people	120-130 dBA 0.000 sq.mi. 0 people	130-140 dBA 0.000 sq.mi. 0 people

Potential Noise Abatement Departure
(Thrust Cutback & LNAV Guidance)

Departure Case Study: KBOS 4R

- Potential noise abatement departure reduces noise impact at all levels
- Combines thrust cutback for community adjacent to runway with new lateral trajectory for communities further away
- Population impacted by noise greater than 60 dBA reduced from 67,079 to 57,091





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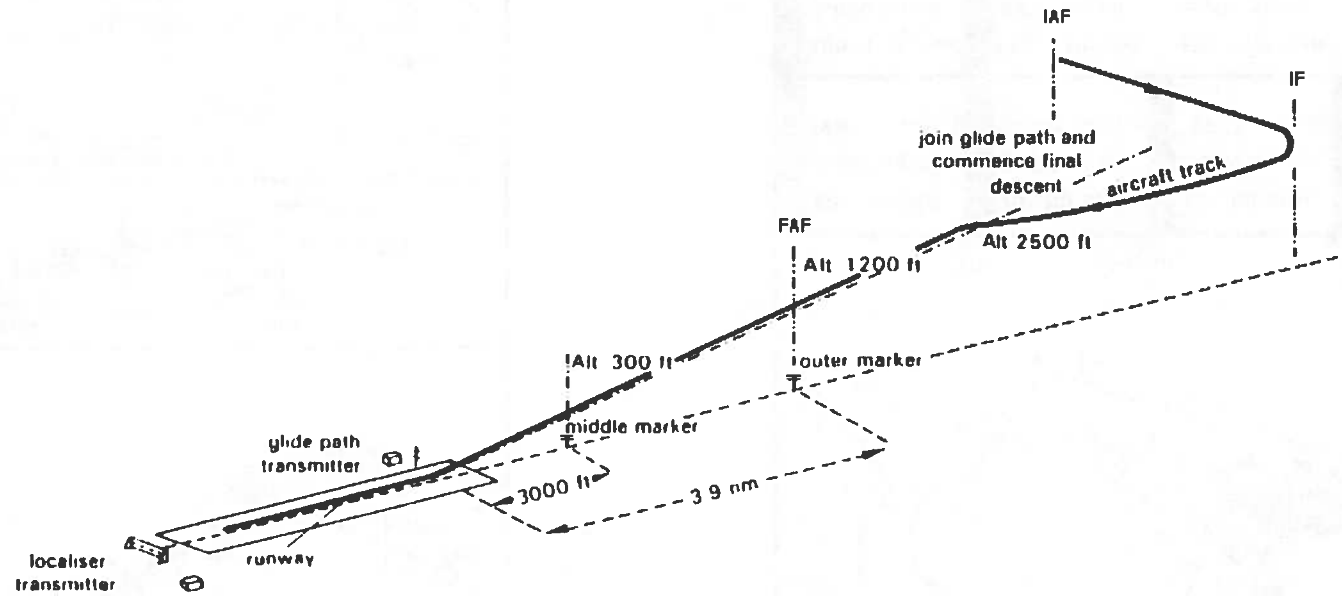
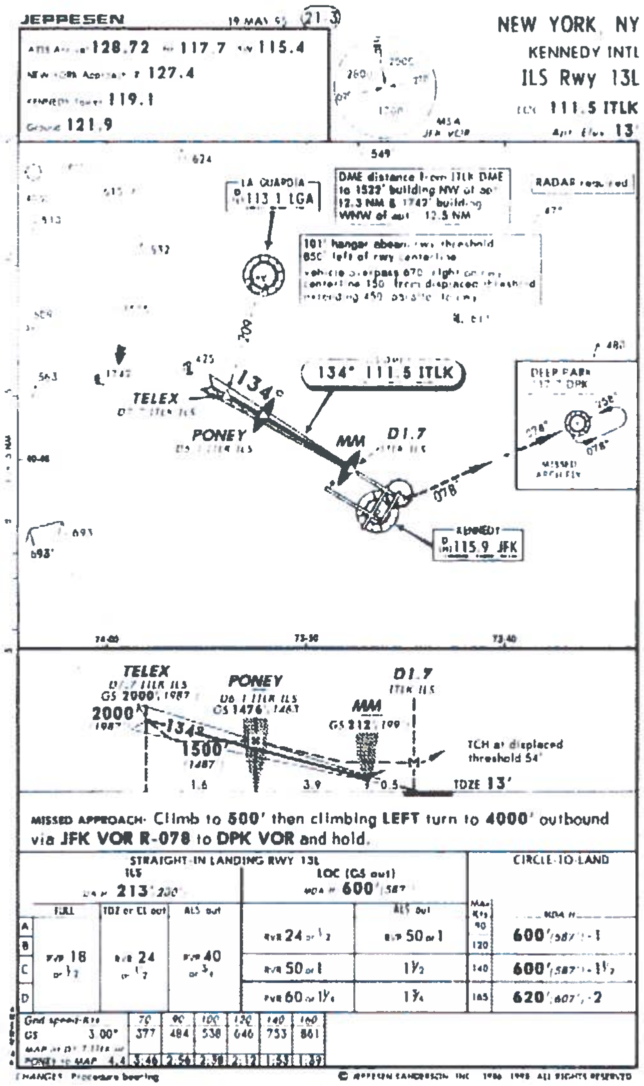
ILS Approach (Baseline)

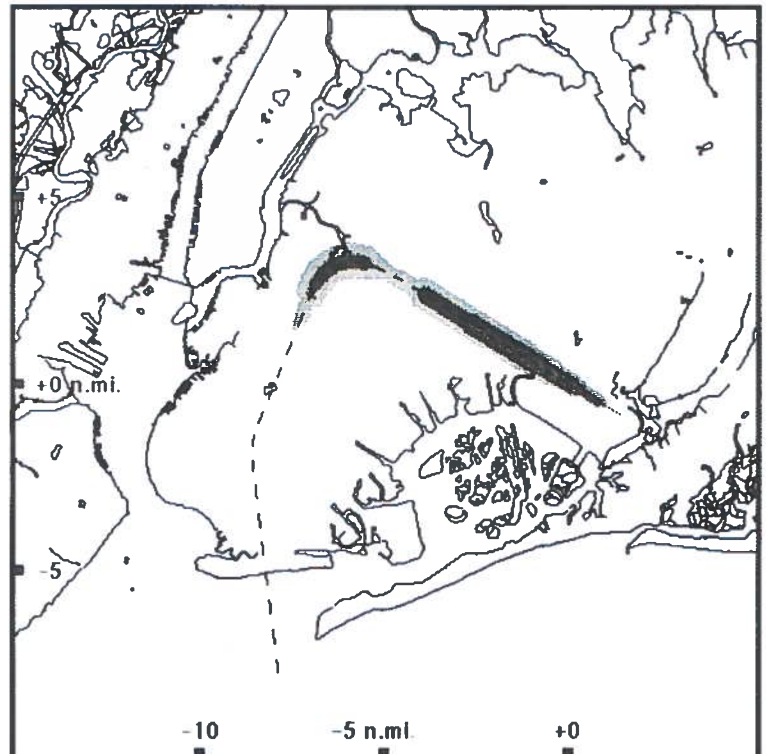


- Glide Slope intercepted from below
- Aircraft flies along extended centerline for much of approach (final and intermediate segments)
- Low altitude maneuvering

KJFK 13L: ILS Approach (Baseline)



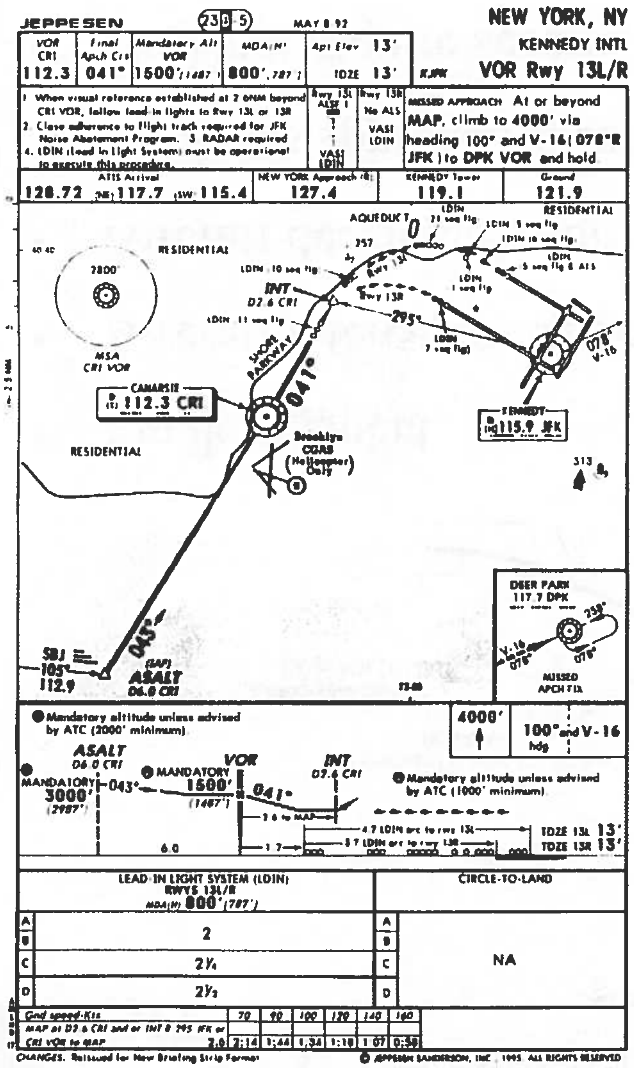
Approach Chart



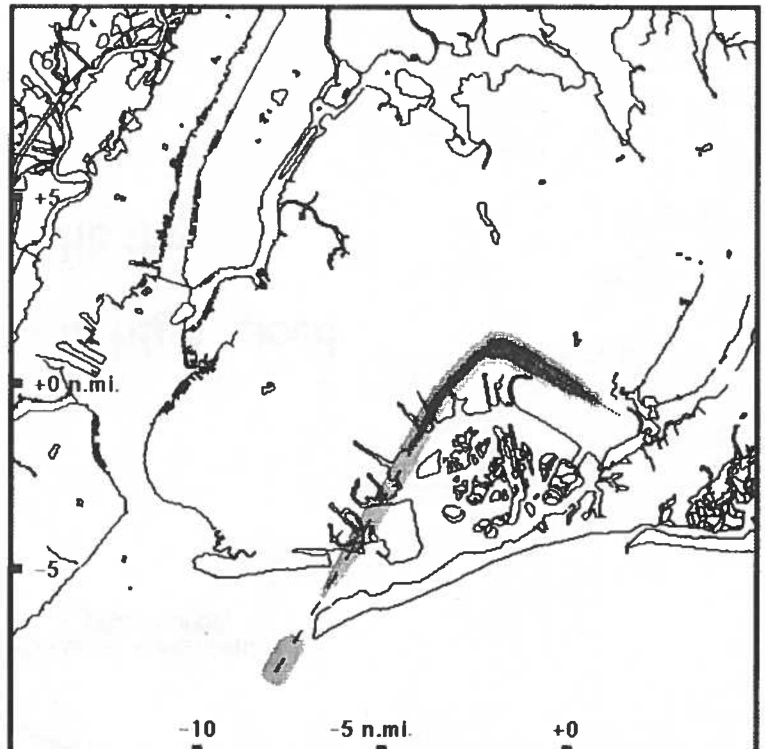
60–70 dBA 8.432 sq.mi. 178430 people	70–80 dBA 3.309 sq.mi. 64201 people	80–90 dBA 0.610 sq.mi. 9977 people	90–100 dBA 0.008 sq.mi. 126 people
100–110 dBA 0.000 sq.mi. 0 people	110–120 dBA 0.000 sq.mi. 0 people	120–130 dBA 0.000 sq.mi. 0 people	130–140 dBA 0.000 sq.mi. 0 people

Noise Impact

KJFK 13L: Canarsie VOR Approach (VMC)



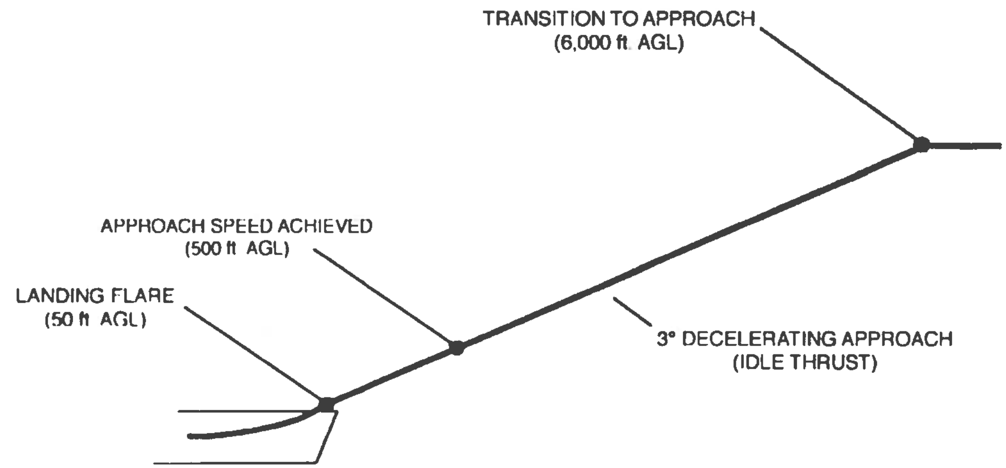
Approach Chart



60–70 dBA 3.467 sq.mi. 75503 people	70–80 dBA 1.320 sq.mi. 22252 people	80–90 dBA 0.425 sq.mi. 6946 people	90–100 dBA 0.027 sq.mi. 442 people
100–110 dBA 0.000 sq.mi. 0 people	110–120 dBA 0.000 sq.mi 0 people	120–130 dBA 0.000 sq.mi 0 people	130–140 dBA 0.000 sq.mi 0 people

Noise Impact

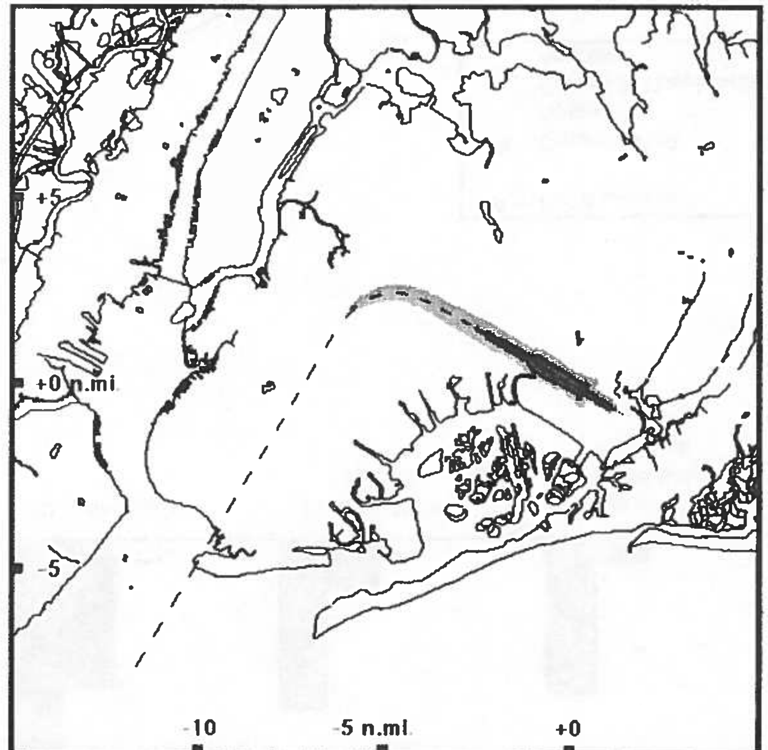
3° Decelerating Approach



- Single segment
- Aircraft intercepts segment at 6,000 ft. at high speed
- Aircraft decelerates during descent at idle thrust
- Achieves approach speed at ~ 500 ft.
- Does not require second glide slope

KJFK 13L: 3° Decelerating Approach

- 3° decelerating approach implemented to reduce noise associated with low altitude vectoring
- Lateral trajectory of decelerating approach similar to ILS approach to avoid traffic of other airports



60–70 dBA 3.826 sq.mi. 68485 people	70–80 dBA 0.645 sq.mi. 10545 people	80–90 dBA 0.050 sq.mi. 821 people	90–100 dBA 0.000 sq.mi. 0 people
100–110 dBA 0.000 sq.mi. 0 people	110–120 dBA 0.000 sq.mi 0 people	120–130 dBA 0.000 sq.mi. 0 people	130–140 dBA 0.000 sq.mi 0 people

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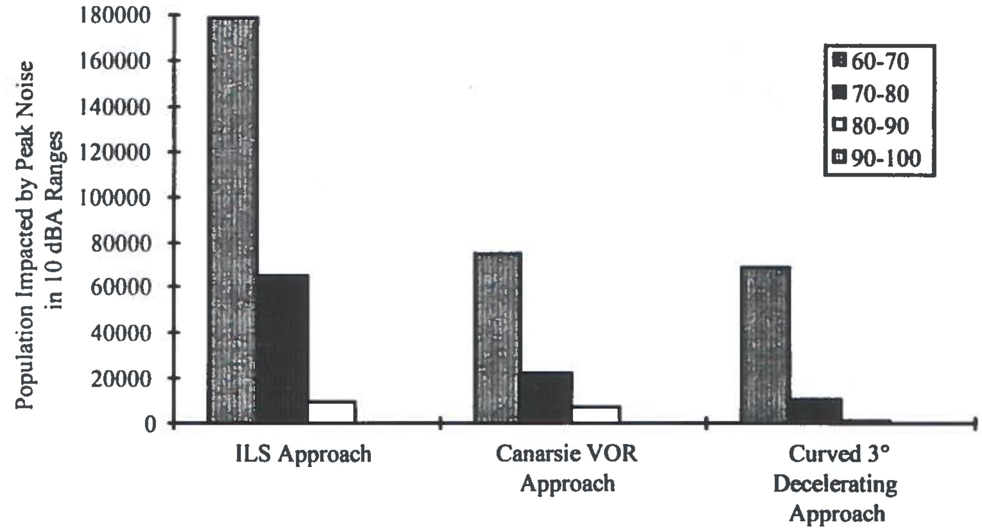
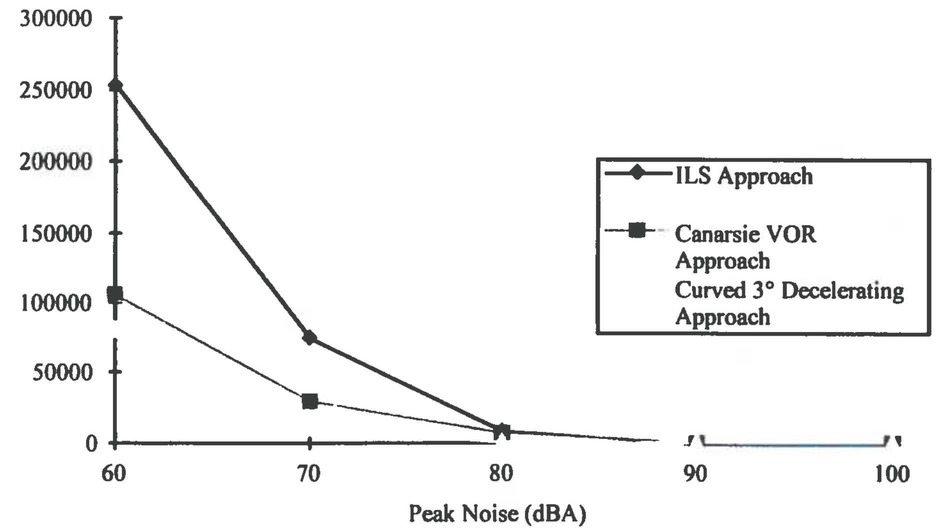
KJFK 13L: Comparison & Summary

- 3° decelerating approach has equivalent noise impact to Canarsie approach
- Population impacted by noise greater than 60 dBA reduced from 252,734 (ILS) to 79,851
- 3° decelerating approach can be used in Instrument Meteorological Conditions (IMC)





MIT ICAT On-Going NOISIM Improvements

- Performance for 3 Commercial Aircraft
  - Small, Medium, Large Aircraft
  - Aircraft Performance may be determined in all conditions
  - Effect on new technology may be determined over representative fleet
- Trajectory based input
  - Complement to cockpit input
  - Retains detailed aircraft performance prediction of flight simulator

MIT ICAT Conclusions

- Noise models are of critical importance for enhancing communication with community groups, providing a basis for compensation, and enabling the design of flight procedures that reduce noise impact.
- INM is the FAA standard but was not designed as a tool for developing noise abatement procedures.
- NOISIM provides a unique rapid prototyping and simulation environment to develop and evaluate noise abatement procedures, and compare engine technologies.

Human/Automation Modeling: Some Current Issues

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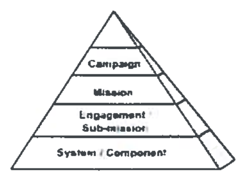
The Critical Question

- How can you use modeling and simulation to understand the effects of various technology investments?

An Example: 2 V 6

- Stochastic (Linear) versus Non-Linear Modeling
- Modeling of Non-Linear Effects:
  - Requires high resolution model
  - Requires the modeling of "knowledge"
    - Training in tactics
    - Weapons available

Local versus Aggregate Effects



- Engagement level - 2 V 6 outcome
- Campaign level - effect of "technology" on overall system performance
- Accurate prediction of campaign level effects requires non-linear engagement level effects to be propagated upwards

Predicting Automation Effects

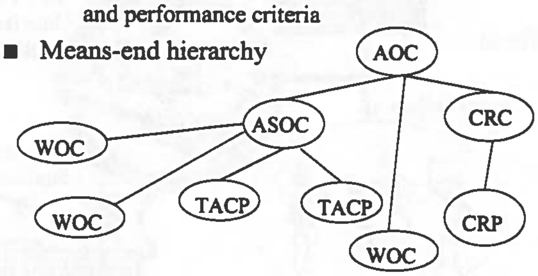
- Must have "campaign" or "mission" model
  - Model all entities
  - Low resolution
  - Relevant performance parameters
- Where technology is to be inserted:
  - High resolution, non-linear, models
  - Mechanism to propagate effects to other models
- But you must also have human in loop studies to identify unanticipated impacts of automation on operations

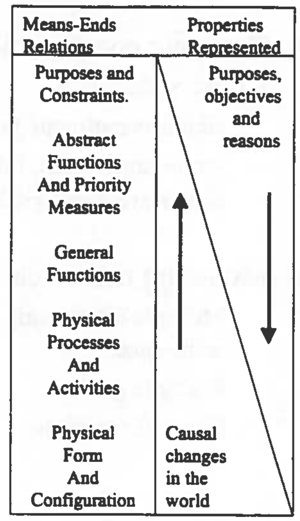
Critical Research Areas

- Better models of team and organizational behavior
  - Information diffusion models
  - Cognitive System Engineering
- Advanced simulation languages and environments
  - High level architecture
  - Agent-based modeling

Cognitive System Engineering

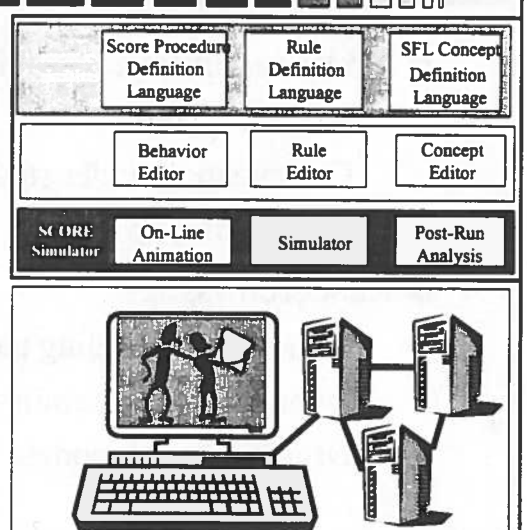
- Casual Model
  - Component elements
  - Events, decisions, and acts
- Relational Model
  - Functional relations between components
  - System objectives, functional constraints, and performance criteria
- Means-end hierarchy





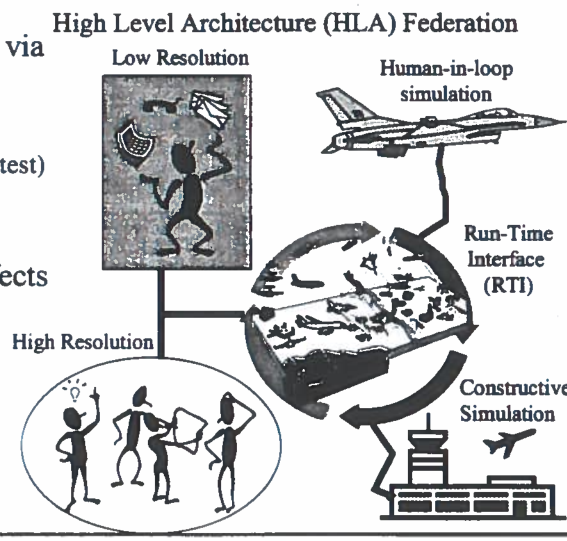
Operator Model Architecture (OMAR)

- Seamless integration of artificial intelligence and intelligent agents
  - Three knowledge representation languages
  - Two mechanisms for control
- Heavy weight agents - Mycrofts
  - Very high intelligence
  - Very high agency
  - Very low mobility
- Distributed models
  - CORBA interface
  - HLA interface



Agent-based Modeling

- Dynamic composability via signal semantics
  - signal-event(name,body)
  - with-signal(name, body, test)
  - signal-event-external
- Modeling non-linear effects
  - Multiple inferencing techniques
  - Multiple goals
  - Situated cognition



Summary

- Multi-resolution models
  - Overall system
  - Organization under study
  - Human in loop
- Research Issues
  - Non-linear modeling techniques
  - Dynamic composability
  - Organizational models

RECENT DEVELOPMENTS IN AIRLINE OPERATIONS RESEARCH

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Outline

- Airline Schedule Planning Process
- Modeling Airline Problems
- Solving Airline Problems
- Summary

Airline Schedule Planning

Flight Schedule Design

Fleet Assignment

Aircraft Maintenance Routing

Crew Planning

Flight Schedule Design

- Find the set of **scheduled flight legs** (origin, destination, departure time) that **maximize profit** given restrictions imposed by fleets, crews, regulatory agencies, ...
- Mainly only recent activity to try to solve this problem using optimization techniques
- Airlines solve this problem primarily manually, with some assistance from automated *profitability* tools

Fleet Assignment

- Find the **profit maximizing assignment of aircraft types to flights** given restrictions imposed by flight coverage, fleet balance, fleet count and maintenance
- In the last 10 years, sophisticated optimization models and algorithms have been built to solve this problem
- Most major U.S. airlines use these fleet assignment optimizers to plan

Fleet Assignment: Integration

- Fleet assignment with time windows (with B. Rexing and United)
  - Allows flights to be re-timed slightly to allow for improved fleet assignment
- Fleet assignment with passenger flows (with T. Kniker and United)
  - Models more precisely the revenue associated with any fleet assignment by considering the passenger flows

Aircraft Maintenance Routing

- Find the set of **aircraft rotations** that **maximize through revenues** given maintenance requirements
- Most major U.S. airlines use optimization models and algorithms to solve this problem

Crew Schedule Planning

Crew Pairing Problem

Crew Scheduling Problem

Some definitions

- A ***crew pairing*** is a sequence of ***flights*** beginning and ending at a crew base satisfying numerous restrictions from regulatory agencies and collective bargaining agreements
- A ***crew schedule*** is a sequence of ***pairings*** satisfying numerous restrictions from regulatory agencies and collective bargaining agreements

Crew Pairing Problem

- Find the **cost minimizing** set of crew pairings given restrictions imposed by flight coverage, work restrictions and crew availability
- This problem has been studied by operations researchers for at least 4 decades
- Most major U.S. airlines use crew pairing optimizers for the cockpit crews

Crew Scheduling Problem

- Find the **cost minimizing** set of crew schedules given restrictions imposed by pairing coverage, work restrictions and crew availability
- This problem has received only relatively recent attention from operations researchers
- Most major U.S. airlines solve this problem manually

Modeling Airline Problems

- Nonlinear objective functions
- Nonlinear constraints
- Integrality requirements
- Two dimensional decisions: ***time and space***
- Huge numbers of variables, constraints

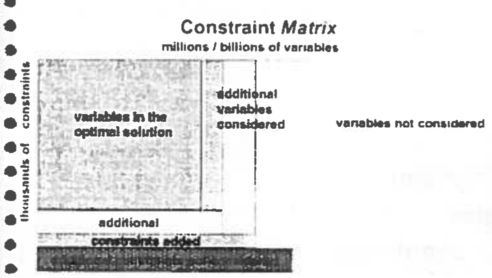
Transformed Airline Planning Models

- Linear objective function and constraints
  - Variable definition is key
  - Result is an *explosion* in the number of variables
- Integrality requirements on decision variables

Solving Airline Problems

- Too many variables: ***column generation*** is essential
- Often too many constraints: ***row generation*** might be needed
- Conventional branch-and-bound doesn't work, must use ***branch-and-price-and-cut*** approaches
  - Generate columns and/ or rows as needed
  - Specialized branching strategies needed

Column and Cut Generation Methods



Summary

- Many *subproblems* in the sequential schedule planning process are routinely solved using optimization
- Integration of the subproblems has begun to occur, with some limited success
  - Column and row generation necessary
  - Not close to a single, unified model and algorithm

Future Work

- Research is necessary to develop improved models and/or algorithms so that LP solution fractionality is not so debilitating
- Many problems remain unsolved
  - The use of optimization at airlines is increasing rapidly
- Gap between planning and operations
- Robustness has not been addressed

Draft White Paper

Current Situation for Global Air Traffic Management

January, 1998

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Contents

The Current Situation in Global ATM

Today's ATM systems for USA and Europe have the following problems which threaten the future growth and efficiency of the global Air Transport System;

1) inadequate traffic handling capacity
2) expensive and rising costs for providing ATM services
3) inefficient and costly procedures for aircraft operations.

Problem 1) - Lack of ATM Traffic Handling Capacity

The primary lack of capacity in the USA is arrival capacity at major airports in marginal/bad weather. As the visibility lowers, the controllers transition from higher capacity visual approach procedures (where the pilot is responsible for spacing on final approach and there are simultaneous visual approaches to multiple runways) to lower capacity instrument approach procedures (where the radar controller becomes responsible for applying larger IFR separations on final approach, and where the number of approaches simultaneously available is reduced).

AS A RESULT, THERE ARE TIMES AT BUSY US AIRPORTS DURING NON-VISUAL WEATHER CONDITIONS WHERE THE SCHEDULED TRAFFIC ARRIVAL RATES SIGNIFICANTLY EXCEED THE CURRENT APPROACH CAPACITY RATES.

This is not a new problem. In the 1960's and 1970's, with a regulated air transport industry, there was an explicit industry goal to provide reliable, on time service independent of weather. In the face of lack of instrument approach capacity in the late 60's, five congested US airports received hourly quotas for scheduled operations (takeoffs and landings combined in any clock hour, with some discrimination for the use of secondary runways by smaller aircraft operated by commuter airlines and general aviation, but no limits on operations in any arbitrary hour-long period, nor lesser periods of time (such as a half or quarter hour), nor on just arrivals to match the approach capacity. With government approval these quotas were managed by airline committees to ensure schedules which did not exceed hourly capacity at the airport. Since airline economic deregulation, this goal of "all weather reliability" has been abandoned by US airlines, and they, through the Airline Transport Association of America, have petitioned the US government to prevent the application of similar slot quotas at other airports, or the introduction of slot auctioning systems to allocate the slot capacity.

THE US AIRLINE INDUSTRY HAS DELIBERATELY ABANDONED THE GOAL OF PROVIDING RELIABLE, ALL WEATHER AIR TRANSPORT SERVICE

The US Air Transport System consists of three major elements which are owned and operated by three different groups of managers: the airlines which own and operate transport aircraft; the airports which are owned and operated by agencies of local government which usually have a monopoly on providing airport services in an area; and the ATM system which is operated by the federal government which has a monopoly on providing ATM services in the nation's airspace. In a deregulated environment, it is difficult to organize the actions of each of these elements to reach an optimum situation for the system as a whole. The capacity constraints of the current form of ATM capabilities have been reached for individual airports, and it is naively accepted that the federal government should invest its money to improve the ATM capacity. But the airline and airport managers could solve the problem with investments in the form of newer airports around the major cities, or the use of aircraft of larger capacity, or could work harder at introducing quieter aircraft operations during takeoff and landing since construction of new airports has not kept up with the growth of air transport due to the noise from jet transport aircraft.

Despite an international program to quieten all jet transport aircraft introduced 20 years ago by the US federal government, the world's airlines have resisted its adoption, and its early implementation, and now are resisting any extension to even quieter aircraft available through new technologies. Because of the potential impacts of this noise on local communities, and their power over local airport agencies through local politicians, it has not been possible for airport managers to build new airports where they are needed, or even to enlist the support of airline managers (their customers) that another airport is desirable. Airports are very expensive, are financed with airline support, and will serve for perhaps 50 years, well beyond the tenure of any airline manager.

THE ROOT CAUSE OF THE AIRPORT CAPACITY PROBLEM IS THE NOISE PRODUCED BY AIRLINE TRANSPORT AIRCRAFT.

After airline deregulation in the US, the major airlines purchased large fleets of relatively smaller transport aircraft (150 seats) so that they could compete on a national scale in serving many more smaller cities by building "Connecting Hubs" at major US airports. As a result, a situation has been created where flights into many major US Hub airports now suffer "normal" delays even when the weather is good, and when the weather is marginal or bad over periods of more than a few hours, airline service suffers severe delays and large scale cancellations of service, events which were unheard of in pre-deregulation days.

THE CREATION OF HUB AIRPORTS AND THE CONSEQUENT INVESTMENT OF THE LARGE US AIRLINES IN SMALLER CAPACITY AIRCRAFT FOLLOWING US AIRLINE DEREGULATION HAS CREATED "GOOD WEATHER" CAPACITY PROBLEMS AT THESE HUB AIRPORTS AND A DEGRADATION OF SERVICE QUALITY IN TERMS OF FLIGHT TIMES. THIS DEGRADATION DOES NOT SHOW UP IN CURRENT DELAY MEASURES

The small "normal" delays even in good weather at US hub airports, in the form of flight times into these hubs by the same airline and aircraft type which are now 15-20 minutes longer on average, and suffer a much wider dispersion around that average than in the 1970's. These smaller delays are "hidden" delays since the schedule times have been increased to keep "on-time" statistics acceptable to the government. Even though they avoid being reported as delays, they represent a degradation of air transport service to the passengers, and since they are now "scheduled delays", they cause a proportional increase in the direct operating costs (fuel and time) for airline aircraft. This is a severe cost penalty since the average flight is only 90 minutes, and since 95% or more of flights by larger US airlines are either into or out of a hub airport.

SCHEDULED FLIGHT TIMES INTO MAJOR US HUB AIRPORTS ARE NOW 15-20 MINUTES LONGER THAN NECESSARY, REPRESENTING A COST TO BOTH PASSENGERS AND AIRCRAFT OPERATORS.

These longer average flight times in good weather are caused by the lack of approach capacity to handle the peak time surges in demand caused by "arrival banks" of 30-40 aircraft from one airline trying to arrive in a 15-30 minute period along with aircraft scheduled by other airlines. To eliminate vertical holding patterns (stacks) which consume valuable airspace around the busy airports, and which would exist most of the day at these hub airports, en route controllers in the USA have been asked by the Terminal Area controllers to use an inefficient technique called "miles-in-trail." Aircraft from a given direction (e.g., from the east, or northeast) destined for a congested airport are segregated from other traffic to form a long stream of arriving traffic along a published "ATC-Preferred Arrival Route." The "miles-in-trail" technique reduces airspeeds and altitudes of arriving aircraft in order to space them as they are merged into this arrival stream. At times the slowly moving, lower altitude, arrival queue can be 300-400 miles long consisting of 60-80 aircraft being handled by several en route controllers in different ATC Centers. These "normal" delays occur en route rather than at the terminal area, but the cause of the delay is the lack of approach capacity, not any lack of en route capacity.

THE CURRENT US TECHNIQUES FOR HANDLING "NORMAL" CONGESTION AT A HUB AIRPORT IN GOOD WEATHER ARE INEFFICIENT.

In low visibility and low cloud weather, the approach capacity of any airport can be well below the scheduled traffic level by a wide margin, and if the bad weather persists, it causes severe delays of several hours or more, and large cancellations of daily service. While this situation may occur only at one airport, it causes poor service throughout the country, not just at the bad weather airports, and not just during the bad weather since aircraft and crews are disrupted from their planned daily itineraries which involve all airports and extend over the next few days. These disruptions are very expensive to both the airlines, but also to the flying public as their planned travel and business activities are disrupted. It is caused by deliberate scheduling of traffic which cannot be handled at the airport in bad weather. During such severe congestion events in the USA, airport slot quotas, abandoned by economic regulators in DOT at the request of the ATA, are now declared by ATC Flow Managers in the FAA based on their forecasted times for the onset and clearing of poor weather and their forecast for airport acceptance rates. To prevent congestion in the air, a national Ground Delay Program can now be instituted to control the departure times at all airports for aircraft destined to the congested airport. This keeps aircraft on the ground for lengthy periods at these "good weather" airports, and may cause congestion at the airline's gates, or on the surface of the airport. The uncertainty in the timing and severity of the weather requires that conservative margins be used in reducing traffic at the beginning of the bad weather, and in increasing traffic at the ending of the bad weather. These margins cause inefficient use of the approach capacity which is actually available at the airport, causing unnecessary delays beyond that actually due to the weather.

THE OVERSCHEDULING OF US AIRLINE TRAFFIC ABOVE BAD WEATHER CAPACITIES AT HUB AIRPORTS CAUSES SEVERE DELAYS AND FLIGHT CANCELLATIONS WHEN NON-VISUAL WEATHER OCCURS AT AN AIRPORT, RESULTING IN VERY EXPENSIVE DISRUPTIONS OF SERVICE THROUGHOUT THE COUNTRY. THE CURRENT US TECHNIQUES FOR HANDLING SEVERE CONGESTION ON A NATIONAL SCALE HAS BEEN VERY INEFFICIENT, CAUSING UNNECESSARY

DELAYS AND CANCELLATIONS BEYOND THOSE WHICH CAN BE ATTRIBUTED TO THE WEATHER-REDUCED CAPACITY.

In Europe, the goal of all-weather reliability is still being pursued by its airlines and airports. Most airports have placed slot quotas (sometimes over 5 minute periods) on scheduled arrival operations which are designed to allow them to continue to operate reliably in very bad visibility weather. So the Europeans currently enjoy much more reliable air service in bad weather than offered in the USA, and some airports continue on-time service in very poor visibility conditions which continue for a week or more throughout the winter. Unlike the US airlines most European airlines have fully equipped fleets and pilots capable of automatic, blind landing down to Cat. 3a, 3b. So the capacity problem in Europe is different than in the USA - it is not an airport capacity problem.

IN EUROPE, THE GOAL OF ALL WEATHER RELIABILITY HAS BEEN ACHIEVED, BUT THERE ARE SLOT LIMITATIONS ON SCHEDULED ARRIVALS AT MOST AIRPORTS. HOWEVER, THERE ARE ARTIFICIAL CONSTRAINTS ON ROUTINGS IN THE ENROUTE AIRSPACE DUE TO POOR COORDINATION ACROSS THE BOUNDARIES OF NATIONAL ATM SYSTEMS.

The current ATM capacity problem in Europe is an en route airspace problem involving predetermined limits on the rate of scheduled flight plans through en route waypoints in various countries. Flights between European cities are short haul, and jet aircraft spend a higher proportion of the time in climb and descent, but it is similar to the northeast portion of the USA where no such limitations have been enforced. These limits have been arbitrarily and rigidly pre-determined by ATM managers to protect the workload levels of en route controllers in their country. The problem is caused by to poor communication and a resulting lack of tactical coordination between ATM organizations in adjacent countries. The slow communication does not allow rapid, real time adjustments in routing and altitude to ease the peaking of short term workload of certain en route controllers near national borders, and poor coordination prevents the flexible, in-flight re-routing and altitude changes for incoming flights over the next 30 minutes as practiced in the USA using FDP (Flight Data Processing) capabilities of the NAS. In Europe, ad hoc, in-flight deviations from the filed flight plan are very rare compared to the routing/altitude changes which occur on almost every US flight. The new Traffic Flow Management techniques introduced by Eurocontrol still rigidly control routings of aircraft in the months and days before departure to meet these inflexible limits so that European airlines cannot vary the flight path to get the best routings and altitudes for their relatively short haul flights on a day to day basis.

IN EUROPE, THE ATM CAPACITY PROBLEM IS A SHORTAGE OF AIRSPACE CAUSED BY POOR INTERFACILITY COMMUNICATION AND A RESULTING LACK OF TACTICAL COORDINATION BETWEEN ATM AGENCIES IN DIFFERENT COUNTRIES

2) ATM User Costs

While traditionally small, the fastest rising component of cost for the world's airlines is now ATM charges. The method used by most of the world's ATM agencies in recovering the cost of providing ATM services is direct user charges which follow international guidelines published by ICAO, and are proportional to hours flown, size of aircraft, number of landings, etc. The predominant customers for ATM services are the world's airlines. Since ATM agencies are government controlled monopolies, the principal of equitable cost recovery is applied in determining the level of charges, so that most airlines are directly interested in the cost of providing ATM services. In the USA, the current costs for operation and maintenance of the NAS are more than 6000$/year/active pilot, more than 100$/aircraft handled, and more than 60$/flight hour. Current ATM systems are labor intensive (there is almost one controller/manager on duty for every airborne IFR aircraft in the US system).

The US airlines, and US general aviation have not evinced much interest in reducing ATM costs because they do not pay direct user fees - instead there is a 10% tax on airline tickets paid by their customers, the airline passenger. However, there has been a continuing effort by recent US administrations towards introducing a direct user charge for ATM services. US airlines would then have a very strong interest in finding a cost-effective way to provide ATM services, and would then be vitally involved in directing the future development of the ATM system such as to reduce ATM operating costs. Today they claim to be interested only in reducing their costs for operating aircraft - and while there certainly is room for achieving that goal also as discussed in the next section, they don't seem to understand that they are vitally interested in the longer term in the total costs of operating the ATM system, both here and abroad.. Imposition of direct user fees in the USA would cure that problem.

The key to reducing ATM operating costs is the introduction of new automation techniques which radically increases the productivity of controllers. There are very few automated Decision Support Tools (DST) to help ATC controllers to perform their functions more accurately, or to handle more aircraft simultaneously. Those that do exist are unreliable, backup alerting systems to warn of imminent collision with other aircraft or terrain. They are not designed to make controllers more productive and allow them to handle more aircraft simultaneously - thereby reducing the major component of current ATM operating costs - i.e., labor costs. A complete paradigm shift is needed for ATM operating procedures and practices, and that radical change is now possible using much better CNS technologies. That is the essence of the "Free Flight" thrust, but it has not yet been translated into any activities likely to achieve that goal.

But the questions are "How do we transition to a radically new and different ATM operating environment? How do we get agreement on the form of that new ATM environment? Who pays for the costs of transition? How do we safely maintain simultaneous operations by old and new aircraft and systems during a long transition period? How do we get unimaginative controllers to understand how a new system might operate, and be receptive to new training, to operating the old and new system simultaneously?" A very careful and long term plan for transitioning to the new system needs to be established and promoted to the international aviation industry to achieve acceptance. We need to know where we are going in ATM, and the speed at which we will be transitioning to a more efficient environment. It will take over 20 years to achieve a new form of ATC operations, which destroys favorable Cost-Benefit ratios.

3) ATM Inefficient Procedures

The current global ATM system uses radio/radar technologies dating from World War 2. The limitations of these old CNS technologies provide poor performance in critical ATM processes of Communication, Navigation (and Guidance), and Surveillance. Consequently, to ensure safety, a very loose degree of control must be tolerated in current ATM in order to overcome long control response times, uncertain and unreliable communication, poor conformance of aircraft to assigned paths, and non-precise data on aircraft positions, speeds, and directions from radar surveillance. These deficiencies cause conservative criteria for separating aircraft and inefficient ATM procedures, especially to cover the possible occurrence of unexpected or abnormal events. The deficiencies also require larger volumes of airspace to segregate arriving and departing aircraft in high density, multi-airport traffic areas resulting in round-about, irregular, and complex routings. These segregation practices translate to longer flight times and paths, inefficient use of altitude, inefficient climb and descent procedures, and higher fuel consumptions for each trip. These particularly affect shorter haul trips where arrival and departure represent a higher proportion of the trip time. These are the higher costs of operating aircraft in today's system which should be reduced by a new ATM system through the introduction of efficient and innovative ATM operating procedures.

Engineering a Completely New ATM System

The current CNS technologies have greatly influenced the development and standardization of ATC operational procedures and practices around the world as the current ATM system developed over the last 50 years. These procedures and practices were developed during a time when capacity of ATM was not a factor - instead, the primary goal was safe all-weather operation. Leadership in developing the current ATM system came from the FAA and US industry who had considerably more influence with other nations and ICAO in the period from 1950 to 1970 than they now enjoy. The aviation industry is now at a point where it is time to change technologies, and to make a major change in ATM operating procedures and practices with emphasis on a goal of ridding ATM systems from congestion and delay. An excess of new technologies is available - although in different states of validation.

However, it is not easy to <u>transition</u> to a new operating paradigm since it requires a global understanding and acceptance of the long term TRANSITION PLAN by the <u>operators</u> (pilots and controllers who must be retrained), the <u>providers</u> (aviation regulatory authorities who must acquire new facilities and services), and all <u>users</u> in the form of aircraft owners (national and international airlines, military services, business and commercial aviation operators, private aircraft owners).

The current problem is an "engineering" problem in the fullest professional sense involving the design, development, and implementation of a cost effective, large scale, global public system involving new technology while considering operating costs, financing, operational safety, etc., and at the same time handling aero-technical politics across many countries. How do we design, promote, and implement a plan for a reliable and cost-effective new ATM operational environment; and then create a global consensus within the global aviation industry about a longer term development and transition plan? FAA and Eurocontrol do not exhibit this broader understanding of the ATM "engineering" problem - they cannot see the ATM forest because the trees of ATM component development are in the way!

1) Current Communication Technologies

1) air-to-ground by VHF voice radio which (to provide coverage to overcome it's line of sight limitations) requires an extensive network of remote ground transmit/receive sites and ground communication relays into ATM centers over distances of up to 300 miles. Voice communication limits the speed, accuracy, and reliability of information exchanges between pilot and controller, and is a fundamental weakness of the current ATM system (although not always recognized as such). It prevents "tightening" the ATC control loop.

2) ground to ground exchanges between ATM facilities by various dedicated media such as telephone, telex, and data link to allow coordination such as the re-routing of aircraft and "Flow Control" over traffic arrival rates. This is expensive.

3) use of High Frequency radio for oceanic air-to-ground with poor quality and unreliable coverage, and often requires forwarding the message by intermediate ground HF stations. Reliable long range communication by itself would solve most of today's oceanic ATM problems

2) Current Navigation and Guidance Technologies

1) for overland flying, a network of VOR ground stations (VHF Omni Range) spaced roughly every 80 miles is used to create an airways network. There are 1200 in the USA at an investment of 600 million, and an annual maintenance cost of 180 million $, and requiring frequent flight monitoring (80 million $ annually. This system provides a precision measured in a few degrees or a few miles. This poor precision results in sloppy guidance from manual steering or pilot-monitored" heading-hold" guidance. Inertial guidance, and advanced guidance such as the FMS has been available for many years but ATM system procedures and safety margins are still based on the poorest guidance performance of aircraft in the traffic mix. Tracks over the ground are irregular, as pilots monitor VOR deviations and make heading corrections. Airways are 8 nautical miles wide, but there has been no adoption of closer spaced multiple lanes within the airway for overland flight (this is a current initiative in Europe).

2) ILS is used to provide a single accurate glide path to selected runways which can be used for manual or automatic approach and landing. But it has a major impact on approach and landing procedures since it requires aircraft to join the runway centerline about 10 miles away from touchdown and acquire the glide slope from below. This requirement has a very significant impact on current design of terminal airspace and procedures for arrival and departures since it results in excess terminal area airspace volumes, extended arrival and departure routings, especially in busy multi-airport terminal areas. The long approach path degrades the approach capacity since longitudinal separations are maintained along the complete length for aircraft of different arrival/approach speeds.

3) Current Surveillance Technologies

1) the prime source for surveillance information is the secondary radar from ground stations which are networked into ATC facilities by yet another ground communications system. The secondary radar is actually a primitive data link consisting of beacon transponders on each aircraft to give onboard identity and altitude, as well as recent positions (every 12 seconds, or 5 seconds in the terminal area) and a unreliable rough estimate of ground speed (± 10 knots if path is unaccelerated). An overlap of radar returns or "garbling" means that ATM procedures and practices generally keep aircraft 1.65 miles apart regardless of altitude, thereby reducing airspace capacity and affecting airspace procedures.

2) the secondary source is primary radar data from co-located stations provides the controller with backup information on the recent speed and direction of each aircraft in the event of failure of the secondary radar or an aircraft's transponder. It does not provide identity or altitude, but it can also provide information on location and extent of severe precipitation.

The Need for a Systems Engineering Approach

After a decade of committee work, there is a worldwide agreement through ICAO (FANS - Future Air Navigation System) to introduce satellite-based and other CNS technologies for the future global ATM system, but there is no clear idea anywhere in the aviation community on innovative future operational concepts/requirements which achieve: 1) operational benefits for users; and 2) a reduction in operating costs for providers (and consequently, for users since they pay these costs). If we are to "engineer" the new system, a detailed description of these innovative future operational procedures is a necessary pre-requisite to specify the technical requirements of CNS performance for components of the new system. Instead we seem to be adding expensive, technical capability to ATM components to see later if pilot and controllers will be able to make innovative use of it, and hoping that they will discover ways to operate which brings user and provider benefits. This is not professional practice for systems engineering.

Currently, we are not designing a completely new ATM system but rather trying to find new, improved CNS components for the old system and its operating procedures. This fragmented, component-based approach occurs because no one agency is charge of the systems design problem; because it has not been the practice to do complete ATM systems engineering over the last 50 years; because managers and engineers in the firms which are suppliers of ATM equipment are narrowly focused on small components of the system; and because there are very few persons who truly understand operational problems of air traffic control. Even the controllers or their managers do not "understand" their problems and have difficulty describing what they do, or envisaging new ways to operate.

It was the same situation with the pilots when digital avionics arrived and automation began to enter the cockpit of jet transport aircraft. The aircraft manufacturers had experience for engineering in this environment, and used experienced transport pilots (both employees and customers) who also had the engineering skills to work on automation in the digital cockpit. It still wasn't easy, and mistakes were made in automating the cockpit even though a very gradual approach was sometimes used. But around the world, we simply don't have experienced controllers with an education in science or engineering to help us in automating the ATM console. But whatever happens with the introduction of automation to ground consoles is going to affect cockpit design in future aircraft and cause retrofits to current aircraft - it will be an extension of the digital cockpit to the ground. We badly need to create an experienced global systems engineering team with real controllers and real pilots as associated members.

The current non-engineering, component-based approach for ATM development is going to be expensive and slow. It will lead to multiple, expensive, unsuccessful ATM development projects, under and over-specified performance of CNS equipment, false starts, and redundant ground and airborne equipment installations which will need constant upgrading as we grope our way to a new ATM operating environment. Someone has to change the aviation industry approach to our ATM efforts, and change it on a global scale. We need a lead organization which can do "ATM Systems Engineering" to create the ATM conceptual design and to detail the innovative operational procedures, including reduced separation criteria. No such organization exists today - the technical/operational leadership which used to exist at ICAO, IATA, major airlines, and FAA in the 1950's and 60's has been allowed to atrophy, and is sadly lacking today.

Currently, there is a divergence in proposed CNS innovations by research and development agencies in Europe (Eurocontrol) and in the USA (FAA). The lack of an agreement on a **new operating concept** for the longer term (e.g., 20 years) will delay the **transition** to new systems around the world, and increase the cost of development as these two groups muddle their way towards new possibilities. The world of aviation needs to find a consensus on a long term plan for the development, implementation, and a timetable for transition to a new form of ATM operations.

The Implementation Plan and Transition Problem

The transition to new operational procedures in an ATM system that runs 24 hours a day and 365 days a year must ensure that the old and new operational procedures are compatible since they will be safely operated simultaneously at the same locations for several or more years, and the transitions to the new system will not occur everywhere around the world in the same year. The need for simultaneous operation means that transition problems becomes a critical and essential part of the design and engineering of the new ATM system. It is so critical that it may actually determine the endpoint of the new system concept since we may not be able to transition to certain desirable operating concepts.

There are political issues in forcing the transition on ATM providers and users, and it is desirable to allow them to retrofit at their own pace, and to give them incentives to do so in the form of provider and user benefits. A generalized transition schedule of ATM operations in smaller airspace volumes around the world should be agreed upon to guide manufacturers of ATM ground and airborne equipment, airline managers, aircraft owners, ATM system managers, etc.

The transitions will not occur everywhere at the same time. Each stage of the transition at each location should bring benefits to the local aircraft owners and operators to encourage retrofit. Some parts of the world (such as China, Russia, Africa, and South America) do not have the current modern ATM system, and may want to jump into newer system operations earlier than USA and Europe). The planning of a transition schedule is not a trivial task, involving safety, politics, economics, and financial capability of all the airlines, military, general aviation aircraft owners, airports, and ATM providers around the world, and cannot be decided by one body in rigorous detail to be imposed on the community with an expectation that the timing of the schedule will be achieved. But it is necessary for everyone to know where we are going - (we must have new ATM system operating concept) - for everyone to see that it is in their interest to go there also, - and for everyone to be able to go there at their own pace.

THESE CONSTRAINTS WHICH DETERMINE THE FORM OF AN NEW ATM OPERATIONAL SYSTEM CONCEPT WHICH IS ACCEPTABLE TO THE WORLD OF AVIATION MUST BE KNOWN TO ANYONE INTERESTED IN DIRECTING THE RESEARCH, AND DEVELOPMENT, AND IMPLEMENTATION ACTIVITIES WHICH ARE NEEDED TO DO A COMPLETE AND THOROUGH JOB OF ATM SYSTEMS ENGINEERING.

BUT THE SYSTEMS OPERATING CONCEPT IS ONLY THE INITIAL STEP AND WHILE IT NEEDS MUCH MORE DETAILED WORK THAN THE PRESENT EFFORTS IN EUROPE AND NORTH AMERICA HAVE PROVIDED, THERE IS A NEED TO INVEST IN A MAJOR PRELIMINARY SYSTEMS ENGINEERING DESIGN STUDY TO DETERMINE THE FORM OF A GLOBAL ATM SYSTEM BASED ON THE NEW CONCEPTS WHICH QUANTIFIES ALL THE TRADEOFFS. THE BENEFIT SIDE OF THE TRADEOFFS ONLY COME WHEN DETAILLED NEW OPERATING CONCEPTS CAN BE SHOWN TO BE TECHOLOGICALLY AND OPERATIONALLY FEASIBLE, AND WHEN THE FULL IMPACT OF NEW CONCEPTS ON THE FORM OF FUTURE ATM ORGANIZATIONS IS UNDERSTOOD.

(some description of the process of preliminary ATM systems design should be added here for non-engineers) (examples of some new operational concepts which are now possible and their impact on controller productivity, airspace structures, and ATM procedures are also needed)

WORKSHOP ATTENDEES

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Mr. Stephen Bradford, Manager, NAS Concept Development, FAA
Prof. John-Paul Clarke, MIT
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