TRANSPORTATION RESEARCH
CIRCULAR

Number 478 November 1997

Toward an Intelligent Air Transportation System:

The Role of Technology Transfer

TRANSPORTATION RESEARCH BOARD / NATIONAL RESEARCH COUNCIL

TRANSPORTATION
RESEARCH
CIRCULAR

Number 478, November 1997
ISSN 0097-8515

TOWARD AN INTELLIGENT AIR TRANSPORTATION SYSTEM: THE ROLE OF TECHNOLOGY TRANSFER

COMMITTEE ON INTERGOVERNMENTAL RELATIONS IN AVIATION

A.H. Childs, Chair
Roger P. Moog, Secretary

John H. Acock, Jr.
Winfield S. Beyea
David Braslau
Margaret Broten
Robert J. Czerniak
Sharon Glasgow
Geoffrey David Gosling
Linda Howard
Keith F. McCrea
Susan J. Mertes
Bruce F. Mundie
Ralph Nicosia-Rusin
Adiele G. Nwankwo
Emmett N. O'Hare
Geraldine Poor
Stephen M. Quilty
Bryon H. Rakoff
Paula J. Raney
Raymond J. Rought
Hubert C. Smith
H. Alan Speak
Chase C. Stockon
Francis F. Strouse

Joseph A. Breen, TRB Staff Representative

Subscriber category
V aviation

Transportation Research Board
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

ACKNOWLEDGMENT

I would like to acknowledge the input and cooperation of a multitude of friends and colleagues. First and foremost, the Intergovernmental Committee on Aviation, under the leadership of A. H. (Rick) Childs, gave us the opportunity to conduct this panel discussion using a large chunk of "prime time" at the Transportation Research Board's (TRB) annual meeting. Our TRB staff contact, Joseph Breen, assisted us all the way—from the beginning through the publication of this Circular. It goes without saying that the Panel and the audience made this formidable task possible. They are the body and soul of this undertaking and particularly this document. Aside from sharing their thoughts and ideas, some of them even took the time to assist the editor in the refinement of this final document, for which I am most grateful.

The views expressed in this report are those of the individuals and in no way represent the positions of their affiliations, either past or present.

Yupo Chan, Presiding Chair, Report Editor

CONTENTS

TOWARD AN INTELLIGENT AIR TRANSPORTATION SYSTEM: THE ROLE OF TECHNOLOGY TRANSFER

INTRODUCTION

Historically, progress in aviation has been advanced by both the military and commercial sectors. Since the Wright brothers ground-breaking experiments near Dayton, Ohio, and Kitty Hawk, North Carolina, aviation has advanced by leaps and bounds. Progress in air transportation has been nothing short of dramatic, particularly considering the many institutional impediments. In recent years we have heard about outsourcing military aviation research and education to civilian institutions to save money. It is but one of many efforts at improving efficiency—and it reflects pressures within the Department of Defense (DOD) to do more with considerably less. Many other "outsourcing" examples can be cited: we witnessed the heavy reliance upon commercial carriers during Operation Desert Storm; and it is also clear that the Global Reach mission of the armed forces will depend increasingly on the Civil Reserve Air Fleet's (CRAF) commercial aircraft as well as its own transport aircraft.

The intent of this guided panel discussion was to consider increased cross fertilization of aviation technology between the military and commercial communities, including industries and government agencies. In the past, significant yet independent advances have been achieved in both communities. Economic and political reality demands that these advances be more effectively shared than they have been. Such synergism is particularly important during this era of fiscal austerity in public-sector spending and increased domestic and international competition in aviation technologies. To continue the progress in aviation and to remain competitive, cooperation between all sectors of the economy—governments, business, and the research community—is critical.

OVERVIEW

There are many ways technology can be transferred. For example, the Defense Department is actively looking for ways to disseminate cutting-edge aerospace know-how to maximize the benefits of defense spending. Likewise, the Federal Aviation Administration (FAA) is proposing "Free Flight" as a cost-effective alternative to implement the new National Airspace System (NAS) plan. Meanwhile, air carriers have evolved highly efficient methods to operate in the face of increasing competition. Universities and the research communities often have basic research breakthroughs that can be implemented much more quickly if active communication can be increased with the user community. Technology can be transferred not only between aviation communities, but also between other transportation modes. In short, all can benefit from increased dialogue for a win-win outcome.

Toward this end, the TRB Intergovernmental Relations in Aviation Committee (A1J01) sponsored a panel discussion entitled "Toward an Intelligent Air Transportation System: The Role of Technology Transfer" during the 76th Annual Transportation Research Board meeting. Key figures from industry, government, and academia were invited to offer their views and work toward a common understanding on this important issue. The panelists involved and the net result of their discussions are outlined in the remainder of this paper.

THE PANELISTS

Yupo Chan, Panel Chair, Professor, Department of Operational Sciences, Air Force Institute of Technology, Wright Patterson AFB, Ohio.

George Blomme, President, Airport Planning Technology Systems.

Norman Fujisaki, Director for Investment Analysis and Operations Research, Federal Aviation Administration.

Neal D. Glassman, Program Manager for Optimization and Discrete Mathematics at the Air Force Office of Scientific Research.

Rose Hsu, Principal Researcher, Sabre Decision Technologies, and Manager for American Airlines' Operations Analysis Group.

Adib Kanafani, Professor of Civil Engineering and Director of the Institute of Transportation Studies at the University of California at Berkeley.

James W. Kelsey, Director of Advanced Aircraft Programs, Advance Transport Aircraft Systems, McDonnell Douglas Military Aircraft (now Boeing).

David Merrill, Senior Analyst, Analysis Group, U.S. Air Force Air Mobility Command.

John D. Morrison, Technology and Safety Assessment Division, Los Alamos National Laboratory.

FIVE MAIN POINTS

By posing a series of questions to our panel of experts we developed a roadmap for implementing technology transfer. The questions are organized around five main points.

Main Point 1: Inter- and Intragovernmental Communication (Including FAA and Airspace Users)

The first step in technology transfer is an open channel of communication. Increasing use of aviation facilities among passenger, cargo and military uses, however, leads toward possible conflicts of interest and necessitates even better communication among the diverse users. Communication takes several forms. Technological advances allow better sharing of information, but they will not overcome institutional barriers. Such barriers include fundamental conflicts of interest and competition among service providers. For example, noise abatement can stand in the way of operational efficiency and even safety. In such a situation, all stakeholders should have access to accurate information, which can often dispell any misunderstanding. In the long run, this will be more effective in fostering effective cooperation among diverse interest groups.

The most appropriate means toward improved communication will depend on the audience and the nature of the information to be communicated. The Internet can provide an effective way to share information, particularly statistical or other factual information. Further, much as we now have web masters for Internet sites, we could have technology transfer masters who tend to sites that could give citizens groups, such as those concerned about aircraft noise, access to the same information as professionals—but reprogrammed, if desired, into a more useful layman's format.

Meanwhile, commercial and military aviation users may each have common requirements. For example, both military and commercial air carriers might compete for choice landing slots at major airports: the former for a larger throughput and the latter for increased market share (see J. Morrison's individual comments on page 11 for elaboration on this point). In view of these divergent and common interests, can you think of ways and means for effective communication among these diverse groups as a first step in technology transfer?

Questions and Responses

What is the first step in implementing aviation-technology transfer?

- Better communication among the diverse users.
- Better sharing of information.

What are the major barriers to communication among diverse groups?

- Fundamental conflicts of interest.
- Competition among service providers.

Can you cite examples of fundamental conflicts of interest?

- Noise abatement can stand in the way of operational efficiency and even safety.
- Civilian aviation users have different requirements than the military.
- Air carriers compete for landing slots at major airports.
- The "not invented here" mentality prevents sharing.

What are the desirable results from research activities?

- Increased use of information technology such as the Internet.
- A fundamental change in the natural habits to guard company secrets and to offer information for sharing.
- Identify win-win situations as incentives for cooperation.
- Form working groups, working committees with a broker, and integrated process teams.

From the discussions, we arrived at some general guidelines for effective communication among diverse groups. Inter- and intra-governmental communication (including FAA and airspace users) is absolutely necessary to start the process of technology transfer. Now that we have identified a general way to communicate effectively among diverse groups, we need to focus on specific examples to fully appreciate how this would lead toward technology transfer. We will offer some specific examples.

Main Point 2: Cooperative Decisionmaking to Allocate Scarce Resources in a Competitive Environment

Take a common problem at many of our major airports as an example of conflicts of interests. Slots are at a premium at busy airports, particularly during bad weather. Resource assignment of this type could possibly be modeled by a technique called game theory—a body of knowledge well known to operations researchers and economists. Game-theoretic analysis can point toward win-win situations for potential adversaries. The premise is that such basic research in game theory can be initiated at a university and the technology can be transferred directly to the conflicting parties for implementation. Are there suggestions to researchers as to how to proceed with their endeavors? Specifically, what factors should they consider in their work and what are the desirable results from such research activities? (See N. Glassman's comments starting on page 14 for elaboration.)

Questions and Responses

What is a good example of cooperative decisionmaking in the civilian airline industry?

▪ Slots are at a premium at our busy airports, particularly during bad weather. Under some conditions, competing airlines' mutual interests may be best served by one airline freeing up slots for a competitor's use, instead of wasting these slots. The objective is to have them work together toward creative solutions.

Resource assignment structure of this type can possibly be modeled by game theory. Define the term game theory.

▪ Game theory is nothing more than a formal way to quantify a competitive situation between two parties who wish to outwit one another—a body of knowledge well known to operations researchers and economists.

Are there any suggestions to researchers as to how they can proceed with their endeavors? Specifically, what factors should they consider?

▪ A broker such as the FAA must be involved. This will complicate conventional game theory, which assumes that actions come only from the "opponents."

What are the desirable results from such research activities?

▪ The technique must be robust enough to adapt to changing practices such as airport privatization, whereby each airport aims for maximum revenue among other objectives such as safety, security, customer service, and congestion relief.

▪ The desirable goal is to identify win-win situations leading toward the best use of limited airport capacity.

Delay allocation and traffic-flow management appear to be promising areas for collaborative decisionmaking (CDM). The FAA has already begun to work with the airline industry to develop procedures to implement CDM strategies. Typical factors to be considered are, for example, safety and security and customer service. The desirable result would be to maximize these three factors as deliverables but at minimum cost. For the record it should be noted that there are only four slot-controlled airports in the United States, and the FAA has no power to reallocate those slots if a flight is late.

Now that we have discussed a commercial example, let us discuss possible cooperation between the military and commercial sectors.

Main Point 3: Airspace Design and Control Strategies for Nonground-Based Navigation

The FAA recently proposed the concept of "Free Flight" to replace the existing Air Traffic Control System. We anticipate increased use of the Global Positioning System (GPS) in communication, navigation, and surveillance. For years, such technologies have been used extensively by the military. Here is an opportunity for the Defense Department to transfer its experience to the FAA. (See J.W. Kelsey's remarks on page 17 for elaboration.)

Assuming such transfer does take place, the use of way-point structure is still required to communicate flight intent and enable flight control and conflict detection and resolution. At the same time, the resulting airspace configurations must be capable of adapting to local topology, physical obstacles, environmentally sensitive areas, or airport location. One example of such complexity is the New York Class B Airspace. [Class B Airspace is defined generally as that airspace surrounding the nation's busiest airports in terms of Instrument Flight Rules (IFR) operation or passenger enplanements.] Local authorities therefore need to share their knowledge with the rest of the system's users. (For more details, see G.W. Bloomme's remarks on page 15.)

Do you have any additional visions regarding this future scenario of Free Flight? What are the challenges and opportunities that you see from your vantage point? Where there are challenges, can these challenges be met?

Questions and Responses

The FAA recently proposed the concept of Free Flight to replace the existing Air Traffic Control System. Would you define the concept of Free Flight?

▪ Free Flight means different things to different people; basically, it shifts responsibility from centralized control by the FAA to a more decentralized control by the users of the system.

The Free Flight concept shifts a lot of responsibilities from ground-based control to individual pilots and local authorities. What type of technology is needed to make this happen?

■ For one, we anticipate increased use of GPS in communication, navigation, and surveillance.

If GPS is what is needed, how can DOD help?

■ DOD developed and has been advancing GPS technology for many years. Recent acquisition programs include Future Air Navigation System (FANS) (see D. Merrill's comments on page 16). Sharing between DOD and the FAA may be a very cost-effective way to do business.

What are the challenges and opportunities that you see from your vantage point?

■ What is needed is a smooth transition from the current centralized system to the decentralized system. The key is to maintain safety and traffic flow as we introduce Free Flight.

Overall, the hope is that Free Flight will provide increased capacity and significant fuel savings, while reducing the costs of operating the National Airspace System (NAS). The extent to which it can do this will depend on the details of the implementation, which thus far have only been defined in very broad terms. Expert opinion suggests that Free Flight can work as an advanced outgrowth of GPS and newer, related technologies. Safety and security remain paramount. The challenge is to develop a Free Flight system that is significantly safer than current approaches. With national commitment and carefully coordinated testing, this can be accomplished—just as precision linking of American and Russian spacecraft, which was first designed, tested, and simulated in a laboratory environment, is now routinely done in space.

Main Point 4: Software Certification and Reliability

As the Air Traffic Control System becomes decentralized, many of the decisions made by the FAA are delegated to pilots and local authorities. Computer software often provides the key information on which sound decisions can be made. Given the critical nature of this information, how do we ensure the transferability and quality of air-traffic-control software? Recent efforts by the DOD in software verification, validation, and accreditation (VV&A) can be relevant to the civilian aviation community. Of equal interest is the development of a High Level Architecture for interoperability and database sharing. Here is another vivid example of technology transfer. Can the panel comment on the issues associated with model and software accreditation in civilian aviation? Specifically, how do we prevent misuse of analytic tools by incompetent users?

Questions and Responses

Let us begin by a definition of VV&A; any volunteers?

■ It is a software standardization effort spearheaded by DOD—perhaps motivated by its huge acquisition programs, which needs careful analysis by "accepted" models. Note that the VV&A definition used in this context diverges from that adopted by the Institute of Electrical and Electronic Engineers.

How can the civilian sector benefit from the VV&A process?

■ The DOD has had heated debates regarding VV&A. It is not sure whether the analyst or the models are the most important part of the process. Neither is the implementation step clear. Such experience is of great value to the commercial sector.

What are the scientific tools for VV&A?

■ To determine the properties of a model, statistical analysis can be performed on the ouput of the model, for example. An interesting question arises when only sparse data are available for validation.

What is High Level Architecture?

■ In view of fiscal austerity and the joint-services operating environment, DOD has encouraged the services to share their models and databases as much as possible. One possible way to do this is to construct a common platform to host these models and data for transfer across defense agencies.

For quality-control purposes and for security reasons, signature/password verification may have to be used for access to a central pool of verified, validated, and accredited software. This screening process will have to be developed beyond what is now available for E-mail and what will soon be available for electronic commerce on the Web. User IDs and passwords should only be given to certified, qualified users. Misuse by incompetent users could be prevented by adapting a "three-strikes-and-you're-out" approach, or, for example, an even more demanding approach—three consecutive or sequential errors (or fewer, depending on standards set) followed by denial of further access to use of the software until the user successfully completes appropriate retraining. All-encompassing procedures are needed to make sure that analyses are not only performed by competent people, but that analytical results are subject to independent verification and not simply taken at face value.

Main Point 5: Technology Transfer

The bottom line for any innovative idea is its eventual dissemination and implementation. Timely and responsive dissemination of information takes multiple forms. Many state universities, by virtue of their land-grant mission, already have technical assistance programs in place. The recently formed National Center of Excellence in Aviation Operations Research (NEXTOR) launches a potentially excellent model for rapid implementation of basic university research by industrial partners. Can you think of other effective means for information exchange? Specifically, are there more innovative means beyond traditional seminars and discussion forums?

Questions and Responses

Any other examples similar to NEXTOR?

- Many other consortiums exist; working groups are less formal analogues of FAA's Centers of Excellence.

As convenient as the Internet is for sharing information, what are some of the drawbacks?

- Search among Web sites often leads to superfluous information; perhaps a better linkage among sites, including a "smart" search engine, is in order.

What do you think of the three examples of technology transfer mentioned earlier under Main Point 2 through Main Point 4?

- They all prove to be excellent models for technology transfer. Main Point 2 illustrates how basic research can play a part in cooperative decisionmaking. Main Point 3 illustrates the synergy possible among the military, civilian and local aviation entities. Main Point 4 again shows the usefulness of information technology from DOD.

It remains to be seen how successful Centers of Excellence will be at rapid implementation of research findings. The Internet is already the fastest and probably the most readily available forum for information dissemination in the near future. Use of E-mail notification of newly posted information (which already exists on sites equipped with "push" technology), password-protected Web sites, scheduled Internet Rewrite Chat (IRC) rooms (with prearranged schedules), and 24-hour bulletin boards (monitored daily) can all be used to achieve the desired results. It should be remembered that information exchange is only one part of technology transfer. The more difficult part is developing the research result (or prototype technology) into an implementable product. This requires a further and substantial commitment of resources. For a number of years, the Federal Highway Administration has supported a large technology transfer program that might provide some useful ideas.

PERSPECTIVES ON TECHNOLOGY TRANSFER

Aside from questions and responses, selected panelists have provided individual statements on technology transfer. Following are the statements directly supplied by the identified contributor, with minimal editing.

Technology Transfer Between Transportation Modes (J. Morrison)

The purpose of my remarks is to highlight differences between modeling and analysis requirements for different modes of transportation as well as significant differences between commercial and military air transport systems. Transportation system throughput estimates such as travel time and ton-miles-per-day are influenced by a range of phenomena. Some of these phenomena are mode-specific, some are influenced by the network control system, and some are associated with specific classes of transportation activities. It is important that transportation models accurately reflect the effects of these unique interactions in order to produce realistic predictions.

Characteristics of Route (Link) Travel Times

Consider the four basic modes of military and commercial transportation: surface (roadway), rail, maritime, and air. Each of these network systems has unique characteristics that affect the rate of travel and predictions associated with travel planning. To a large extent, these differences reflect the relationship between the transportation performance of a particular platform (vehicle type) and the activity of other platforms. More specifically, some transportation phenomena are relatively independent, and some are not. Examples of relatively independent phenomena are air and sea, port-to-port travel times. Because the capacity of air and sea lanes are practically infinite, the presence of even a relatively large change in their use is not likely to produce platform-to-platform interactions that would

TABLE 1 RELATIONSHIP BETWEEN CAPACITY, CONTROL, AND THROUGHPUT VARIABILITY

Mode	Capacity	Control	Travel Time
Air	Unlimited	Centralized	Independent
Sea	Unlimited	Centralized	Independent
Rail	Unlimited	Centralized	Independent
Surface	Limited	Autonomous	Dependent

measurably reduce travel time. For this reason, representations of these processes that assume statistical independence or linearity are not likely to contribute to significant modeling error.

Surface travel on roadways, however, is highly sensitive to vehicle-to-vehicle interactions. Gridlock is the most well-understood example of this phenomena. However, traffic engineers have understood for years that there is a significant, nonlinear relationship between vehicle density (cars per mile of roadway) and the rate of flow on that roadway (cars traversing per unit of time). While the specific characteristics of this relationship are sensitive to each roadway, the characteristic shape is so common as to be a domain standard. It is referred to by traffic engineers as the fundamental diagram reflecting the consistent nonlinear relationship between vehicle density and expected travel speed and rate of flow.

Representations of vehicle travel in traffic models that do not incorporate this significant nonlinear relationship can contribute to significant error in travel time predictions. This fundamental system characteristic drives the relationship between traffic count studies (data collection in the domain) and system characterization in regional traffic models.

Railroads are somewhat unique in that, although they are capacity-constrained like roadways, they do not typically reflect the same uncertainty in estimated travel time. This is almost certainly due to the fact that, as a highly regulated utility, the set of commercial carriers behave as though they were centrally controlled. Therefore, although travel is practically constrained by a finite infrastructure, it is believed that in practice, current demand for rail utilization (combined with strong centralized control) reflects a system in which capacity is not stressed. This system, under current capacity/demand relationships should produce travel times for individual trips that are statistically independent of the behavior of other carriers in the system.

Table 1 summarizes the relationship between capacity, control, and throughput variability.

The implication of the previous observation is that estimates or calculations of point-to-point travel times for individual air, sea, and rail platforms can probably be conducted independently without a significant effect on the predictive qualities of the model. For this reason, expected value treatment of travel time in models for these modes are probably adequate. However, traffic models that fail to explicitly treat either the underlying cause or the effect (fundamental relationship) of these vehicle-to-vehicle interactions are vulnerable to producing inaccurate predictions of system throughput and vehicle travel times.

Characteristics of Port (Node) Service Times

Transportation nodes are of two general classes: those that require a service cost (time) penalty and those that do not. Examples of the latter include transportation way-points that affect direction or speed only. This discussion focuses on nodes that provide services to carriers that require an explicit time penalty. Examples of these services are staging (waiting for a transportation mission), onloading and offloading of cargo, and carrier service (vehicle and crew).

As with travel time on links, when capacity is constrained, total time for service (time waiting for service plus service time) can be affected by the activity of other carriers. More specifically, when the purpose of the stop is to acquire services for which there is some practical limit, the carrier will, typically, queue for service. Because military and commercial carriers typically require special facilities to onload and offload cargo, this service is vulnerable to "queuing behavior." The same is true for carrier services such as fueling, maintenance, etc. Although staging time is not typically sensitive to the effects of queuing behavior, it can be sensitive to the effects of variability in arrival times of cargo to be transshipped. This general phenomena in which delays in one carrier's schedule contribute to subsequent delays in other carriers' schedules is referred to as "cascading."

TABLE 2 IMPLICATIONS OF CAPACITY CONSTRAINTS

Mode	Capacity	Control	Service Time
Air	Limited	Centralized	Dependent
Sea	Limited	Centralized	Dependent
Rail	Limited	Centralized	Dependent
Surface	Unlimited	Autonomous	Independent

It can be shown that the effects of delay in the arrival of inbound traffic as well as the characteristic behavior of queues contributes to nonlinear relationships for service times at nodes. These nonlinear relationships are the result of carrier-to-carrier interactions. Cascading phenomena reflect the fact that when transportation activities are not independent, random early arrivals for one element do not, typically, offset the effects of random delays caused by other, related, elements. For this reason, expected value representations of travel time contribute to an optimistic bias. When there is significant variability in transit times or service times or both for the objective system, this bias can cause the model to overestimate the throughput of the system. The degree to which the prediction overestimates the true value is compounded by the extent to which cargos are transloaded and by the relationship between service demand and service capacity. More simply, a transportation system with relatively unlimited service capacity supporting a plan without staging and transloading will be relatively insensitive to this bias when modeled. However, complex, multimodal transportation plans that stress the system's service capacity (such as executing a deployment plan for a major defense contingency) are likely to be significantly impacted by this bias. To the extent that the system controller effectively accounts for this uncertainty and bias in the schedule, then it is realized implicitly.

Queuing theory shows that relatively modest amounts of variability can contribute to significantly greater delays in total service time than would be predicted by deterministic methods. As with the fundamental relationship that characterizes the nonlinear relationship between vehicles for surface transportation, it is likely that the vehicle-to-vehicle relationships that affect service activities for airports/bases are equally nonlinear. For this reason, deterministic relationships at these transportation nodes are likely to produce throughput estimates that significantly overestimate true system capacity.

Table 2 summarizes the implications of capacity constraints, and to some extent control methods, on modeling service cost (time) of alternative transportation systems. The assumption here is that, for transportation modes in which service capacity is constrained, models that treat carrier service times independently are likely to produce inaccurate predictions. Additionally, because of the sensitivity of system throughput to the effects of cascading, the characteristics of the scheduler play a significant role in the overall performance of the system. More specifically, the objective of the scheduler is to produce a demand schedule that minimizes the effects of cascading in the presence of uncertainty.

It is our observation that air transportation systems are the most sensitive to the nonlinear affects of travel and service time variability. For this reason, representation of service activities exert a considerable influence on the predictive qualities of air transport simulations.

Modeling Summary

The preceding discussion and examples were provided to show that some transportation phenomena, under some operating conditions, are highly sensitive to vehicle-to-vehicle interactions. When these conditions exist, simplistic model representations can lead to predictions about system performance that are not valid. However, the world of practical modeling and simulation is constrained by real limits on the complexity of the code and the time required to exercise the analysis tool. There will be conditions under which a deterministic representation of surface travel time satisfies the prediction requirements of a given decision, and there will be conditions and occasions when it does not. One of our ongoing research projects is motivated by a desire to find disciplined methods for making intelligent choices about the relationship between alternative model representations (levels of complexity) and the validity of a model's output with respect to the questions being asked. We propose methods that will allow model developers to stipulate, with confidence, what these conditions are.

TABLE 3 CHARACTERISTICS OF COMMERCIAL AND MILITARY AIR TRANSPORTATION SYSTEMS

System Characteristic	Commercial	Military
Operational Performance Data	Substantial	Uncertain
Demand	Stable	Dynamic
Load Relationships	Independent	Dependent
Delay Tolerance	Hours	Days

Differences Between Commercial and Military Air Transportation Systems

For both systems, performance is typically based on some function of arrival times (travel and service time). We believe that, although the problems are quite similar, there are aspects of the two systems that can affect modeling. These system characteristics include the characteristics of the demand for system capacity, load relationships, delay tolerance, and the availability of operational performance data (Table 3).

With respect to demand, commercial air transport systems are relatively stable within the time frame of practical scheduling. Military demand for system services during operational contingencies is highly dynamic. This contributes to a significant level of prediction uncertainty on a daily and weekly basis. This phenomena is compounded by the fact that, unlike most commercial cargo loads, military loads are typically not independent. By this we mean that the system goal is to have all of a unit's cargo arriving within some specific time frame. Because unit cargos are typically spread over many missions, a delay or schedule change may impact many missions. This is less often the case for commercial systems.

Two additional factors create differences in control activity for commercial and military systems. First, the relatively stable route structures and travel activity for commercial systems supports a relatively stable and substantial source of operational performance data for the system. The unique characteristics of military contingencies contributes to a relatively sparse database for the expected performance of the operational system. This compounds the prediction requirements for the system scheduler. The good news is that unlike commercial customers who measure delay in minutes or hours, realistic military schedules are not particularly sensitive to delays of this duration. For strategic deployment, the system customer is rarely sensitive to delays that do not exceed a day.

Summary

The purpose of this brief discussion was to motivate discussion about differences between the modeling and analysis requirements of alternative transportation modes and of military and commercial travel. Our observation is that air transportation models and analysis will be particularly sensitive to the complex carrier-to-carrier relationships that affect service cost. Differences between military and commercial system goals will likely contribute to different control logic in their schedulers.

Comments Concerning ITS

The concept of Free Flight for commercial air routes has a number of potential implications with respect to these observations. First, to the extent that variation in flight paths produces variation in arrival times for aircraft at airports, it provides a source of uncertainty that can measurably affect system throughput. This effect can be realized either through the direct impact of variation on service-queuing activities at airports, or implicitly through a requirement to incorporate more "slack time" in the schedule to offset the potential impacts of this variability. Either way, this potential source of variability can create a reduction in system throughput. Second, to the extent that one pilot's "planning freedom" is a source of planning uncertainty for other aircraft flight plans, it might provide a source of aircraft-to-aircraft interaction that could cause air traffic models to become more complex in order to produce accurate predictions.

Technology Transfer from Basic Research (N. Glassman)

The Air Force Office of Scientific Research (AFOSR) is the basic research agency for the Air Force—it controls all of the funds spent by the U.S. Air Force on basic research.

During the last several years, however, the distinction between basic and applied research has become blurred as program managers have come under increased pressure to demonstrate results—or in our terminology, transitions. Further, the definition of "transition" has become increasingly restricted to ensure that claimed transitions, which are published yearly, are real.

Philosophy

For the program manager, the challenge is not only to find interesting research that has the potential for application or transition, but to find mechanisms that ensure successful transition. Of course, the easiest method is to require the proposer or principal investigator to specify a transition path in the proposal—that is to require that he make the connection with the Air Force or industry beforehand. This is a difficult requirement for many university researchers, but the specification of such a mechanism definitely is a positive factor in proposal evaluation.

Another successful mechanism involves our close connection to the Air Force laboratories. Many of our topical thrusts are centered at laboratories, with a laboratory researcher doing basic research as part of a larger effort. Then, other research performed by universities or industry can be undertaken with the laboratory as a centerpiece. Because the Air Force laboratories are intimately involved with Air Force applications, securing the cooperation of laboratory scientists and their approval through the proposal review process almost assures an eventual successful transition.

Brokerage

Of course, as a program manager, one task is to broker research. That is, if I receive a theoretical proposal that I want to fund, I can search through the Air Force or industry to find a potential application and take a chance that my insight will prove to be correct. On the other hand, when I come across an interesting applied problem, I can formally or informally solicit proposals related to it. As a result of all of these techniques, and probably some others that I have neglected to mention, I have had several recent successes in the transition game. Let me mention a few of them:

1. Over the years, I have worked fairly closely with the Air Mobility Command. AFOSR provided the command with consulting support when they leased the original KORBX machine, and has helped the command develop models and optimization algorithms to rationalize their transshipment networks. AFOSR is now supporting research on optimization under uncertainty, so-called robust optimization, and I hope to ultimately transition to these models.

2. I have been able to form a consortium of Rice University, IBM, and Boeing that applies nonlinear optimization to a number of problems faced by Boeing. The current one of interest is in the design of helicopter wings to minimize vibration.

3. Although not directly related, research that AFOSR has supported has resulted in new algorithms for multitarget tracking. It improves the performance of Air Force radars by 3dB, without any changes in hardware, and is now being considered for inclusion in new Air Force systems.

In conclusion, the rapid transitioning of results is of crucial importance to the military research community and we are constantly seeking improved transitioning methods.

Technology Transfer from an Airport Operator's Perspective (G.W. Blomme)

An informed environment in which all relevant civilian and military knowledge can be identified, accessed, and shared will effectively facilitate civilian airport safety, security and operations worldwide. This process is the domain of technology transfer—a process that must be improved so that information sharing can be more effectively used to facilitate airport-critical development at minimum cost. Minimizing the costs of security programs, for example, can in turn expedite additional development and generate additional benefits to airport customers.

Let me cite examples. During the past year I have been involved in several safety and security projects that most likely could have been expedited if airport and information systems colleagues and I had ready access to information generated by noncommercial sources such as the FAA's recently established Centers of Excellence and other research institutions as well as declassified military documents. In all likelihood improved airport perimeter security systems and other matters of airside and landside security could directly benefit from knowledge databases already developed by noncommercial sources. Further, time-intensive standard procurement policies of airport operators can be offset to some extent by making more relevant information more readily available. These benefits will only increase in the future as FAA's Centers of Excellence generate more studies, more findings, and more recommendations. The same conceptual thinking that applies to security systems, in regard to facilitated review of research done to date, also applies to control systems and other types of operating support systems.

Some more examples: The entire civilian transport field including the air transport system, is quickly moving into the area of Intelligent Transportation Systems, including "smart vehicles," electronically monitored vehicle tracking systems, and "smart cards" to facilitate customer processing. This is another area where easy retrieval of noncommercial knowledge databases can facilitate airport systems development.

The feasibility of conversion and public use of future military base closings can be more quickly assessed with "prepackaged" knowledge databases relating to environmental conditions and other local and/or topical situations being provided in advance by the military. Further, it is possible that even the schedules for decommissioning military equipment, including ground vehicles, might be useful to civilian transportation authorities if information databases were readily available to transport operators. The importance of technology transfer from military and noncommercial research centers to the public domain is evidenced by the advance bulletin for the 1998 International Air Transportation Conference, where military-to-civilian airfield conversion, the military's role in assisting civilian airport sponsors, and university centers for airport research are prominent among the suggested topics.

The knowledge databases that I am describing can be disseminated and shared through conventional conferences such as the University of California Institute of Transportation Studies' Technology Transfer Program, "1997 Noise Program," in San Diego; interactive CD-ROMs such as the CD-ROM that the Volpe Transportation Center is planning to use for distribution of airport layout plans; satellite transmission such as that currently used by the American Association of Airport Executives' (AAAE) Airport Training & Safety Institute for its Airport News & Technology Network (ANTN) programming; and the Internet, making full use of 24-hour bulletin boards monitored at regular intervals, rescheduled chat room sessions, and "push" technologies wherein information changes at specific Web sites automatically trigger E-mail notifications to interested parties.

Technology Transfer from the Air Force (D. Merrill)

General Ronald Fogleman, then Air Force Chief of Staff, stated his views in his *Global Engagement* report published in November 1996. Based on the Joint Chief of Staff Chairman's *Joint Vision 2010,* a roadmap was drawn for DOD military operations into the 21st century. The Air Force defines global engagement as four areas of importance and six core competencies.

Four Areas of Importance

The four emphases from the Air Force leadership are

- To take care of people within the community (first priority);
- To enhance reliability and modernize Air Force equipment;
- To recognize and plan for global infrastructure need; and
- To focus internal Air Force operations on mission and core competencies.

Six Core Competencies

The strength of the U.S. Air Force resides in the following:

- Preservation of air and space superiority through control of air and space;
- A capacity for global attack and power projection that gives adversaries anywhere on earth reason to reconsider hostile actions against U.S. allies;
- Precision engagement to minimize damage and lives lost and maximize effectiveness;
- Information superiority: the United States always knows more than its adversary and knows it faster;
- Agile combat support: the United States is prepared to operate anywhere in the world; and
- Rapid global mobility—gets forces to the fight quickly and reliably.

Air Mobility Command (AMC) plays a key role in all six core competencies, but rapid mobility is AMC's "bread and butter."

General Walter Kross, commander of Air Mobility Command and commander-in-chief of the U.S. Transportation Command, outlined four AMC objectives and seven key acquisition programs and program initiatives.

Four Major Themes and Goals of Air Mobility Command

- The United States is ready to perform global missions through several means:
  - Strategic Airlift, allowing the United States to carry heavy combat equipment to an austere environment at a great distance;
  - Theater Airlift, supporting theater warfighting commanders with rapid air movement;
  - Aerial Refueling, projecting global power nonstop from the Continental United States;

- Airdrop Operations, delivering to locations that have no infrastructure or delivering packages that can secure needed infrastructure;
- Aeromedical Evacuation, providing for the rapid, effective care of injured forces; and
- Operational and Executive Support Airlift, designed to be responsive to the unique needs of senior leadership and national command authority.

- The United States is committed to continual improvement of key processes.
- Modernization of AMC allows the United States to operate in the 21st century.
- 1997 is the Year of the En Route System.

Seven Key Acquisition Programs and Program Initiatives

The following technologies are planned to make the above possible:

- Acquisition of 120 C-17 transport aircraft,
- New large and small aircraft loaders (specifically the 60K loader and Next Generation Small Loader),
- Global Air Traffic Management Systems for aircraft (the Future Air Navigation System or "FANS"),
- More effective global information management systems,
- Modernization of the KC-135 tanker fleet (Project nickname: Pacer CRAG), and
- Moving the C-130 tactical transport fleet back into AMC from the Air Combat Command (thus enabling AMC to establish all Air Force airlift standards—including theater airlift).

Overall, the Air Force provides people with substantive quality of life improvements, particularly safety and protection through operational risk management.

Technology Transfer from an Aircraft Manufacturer (J.W. Kelsey)

Let me provide some observations from a major developer of aircraft for both the commercial and military sectors.

Large Potential Air Traffic Growth

It is clear that there will be significant growth in both passenger and cargo traffic. Individuals are placing increased value on personal mobility. At the same time, they are also putting greater importance on the value of time. The issue then becomes: can the system grow to meet the demand and expectations?

Can the Air Transport System Grow to Meet the Projected Demand?

There are major challenges facing all of us. Among them are safety, air space congestion, terminal congestion, economics, and environmental and political constraints.

Aircraft Technology Initiatives

Some of the new systems being developed are

- Propulsion Control Aircraft (PCA),
- Intelligent Damage Adaptive Control System (IDACS),
- Free Flight (Future Air Navigation System),
- Enhanced Synthetic Vision, and
- Improved Flight Crew Situational Awareness.

Advanced Aircraft Concepts

Meanwhile, new vehicles are being considered. Included in the list are

- High Speed Civil Transport,
- Blended-Wing-Body, and
- Super-Short/Vertical Takeoff and Landing.

These technological trends have profound impacts on future aviation.

CONCLUSION

Although the topic of technology transfer is often overworked, the panel discussion illuminated some possibilities toward an intelligent air transportation system. The following summation is offered:

1. The U.S. government, under the commitment to live within it means, is looking for ways to do more with less. Although DOD has been at the cutting edge of technological advances, a reverse direction of technology transfer is becoming more evident. The Global Reach mission of the U.S. Air Force, for example, will be increasingly dependent on the Civil Reserve Air Fleet as well as on Air Force assets.
2. This argues persuasively for technology transfer between the civilian and military communities.

Technology transfer between the Department of Defense and the civil sector is a way to maximize benefits from a limited budget. We should continue to concentrate on upgrading the aviation system to benefit both the military and civilian users.

3. *Main Point 1.* The first step in aviation technology transfer is to promote inter- and intra-governmental communication. This is in response to the facts that (a) diverse communities utilize aviation technology, (b) these users include the FAA and the DOD, and (c) users should all work together toward efficiently improving the aviation system.

4. *Main Point 2.* More cooperation instead of pure competition is a way to better use scarce resources. As an example, universities' research capabilities could effect cooperation among airlines to better use scarce slots at busy airports. Several other possible focal points and considerations are (a) Desert Storm experience points toward the airlift system bottleneck occurring at terminals; (b) civil-sector research on airport capacity offers many opportunities to expand terminal throughput; and (c) at domestic airports, competing airlines could cooperate and benefit through the use of gaming models, perhaps with the FAA serving as the broker to effect win-win situations.

5. *Main Point 3.* Future requirements point toward adapting airspace design and control strategies for nonground-based navigation. A principal example is advancing the cooperative use of navigational aids such as the Global Positioning System to help the FAA develop and implement Free Flight. (Experimental implementation of Free Flight is being planned for Alaska and Hawaii, where the FAA will equip selected aircraft with the hardware and software needed to evaluate concepts. The FAA is also planning several other experiments by 1998. For example, narrow- and wide-body aircraft are being separated, and the 250-knot speed-limit below 10,000 feet is being lifted. Also, different noise footprints may have to be considered in the future.) Although the concept of Free Flight—shifting from current ground-based navigation and control to space-based systems with the users in primary control—is sound, a number of challenges and opportunities remain.

6. *Main Point 4.* Free Flight encourages the transfer of reliable and quality software to pilots and local users. DOD's software experience could be very helpful in:

- Interoperability, verification, validation, and accreditation;
- The transfer of quality, reliable software from the FAA to the pilots and local authorities; and
- Facilitating the concept of Free Flight by assisting the FAA with verifying, validating, and accrediting these software packages;

7. *Main Point 5.* The bottom line is practical and rapid implementation of the technology transfer process. Examples of technology-transfer opportunities include

- Basic gaming research to encourage dialogue and cooperation,
- Civil aviation using advanced navigational systems technology pioneered by the military, and
- Facilitating Free Flight through software interoperability between FAA and local users.

In conclusion, the basic premise is that all parties can do more with less if they share their technologies. FAA, NASA, and DOD should carefully watch the direction of the National Center of Excellence in Aviation Operations Research—made up of Berkeley, MIT, the University of Maryland, and Virginia Tech as well as industrial partners and affiliate universities—for their successes and failures. More working groups can be formed to exchange information, with the eventual goal of further stimulating technology transfer.

APPENDIX

TOWARD AN INTELLIGENT AIR TRANSPORTATION SYSTEM: THE ROLE OF TECHNOLOGY TRANSFER

Contact Information for Participants

Panel

Chairman and Editor

YUPO CHAN
Department of Operational Sciences, Graduate School of Engineering
Air Force Institute of Technology
2950 P Street, Wright-Patterson AFB, Ohio 45433-7765
Tel. 937-255-6565 extension 4331, Fax 656-4943, E-mail: ychan@afit.af.mil

Members

GEORGE BLOMME
President, Airport Planning and Technology Systems
PO Box 934, Rancho Mirage, California, 92270-0934
Tel. 760-770-7207, Fax 760-770-2924, E-mail: georgeblomme@msn.com

NORMAN FUJISAKI
Federal Aviation Administration (ASD-430)
U.S. Department of Transportation, 800 Independence Ave. SW, Washington, D.C. 20591
Tel. 202-358-5198, Fax 202-358-5543, E-mail: norman.fujisaki@faa.dot.gov

NEAL D. GLASSMAN
Air Force Office of Scientific Research
Bolling AFB, Washington D.C. 20332-6448
Tel. 202-767-5026, Fax 202-404-7496, E-mail: glassman@afosr.af.mil

ROSE HSU
Sabre Decision Technologies, Mail Drop 7390 TSG
1 East Kirkwood Blvd., Southlake, Texas 76092
Tel. 817-264-3500, Fax 817-264-3504, E-mail: rose_hsu@sdt.com

ADIB KANAFANI
Institute of Transportation Studies
University of California–Berkeley
109 McLaughlin Hall, Berkeley, California 94720-1720
Tel. 510-642-3585, Fax 510-642-1246, E-mail: kanafani@ce.berkeley.edu

JAMES W. KELSEY
Advanced Aircraft Programs, Advanced Transport Aircraft Systems
McDonnell Douglas Military Transport Aircraft (now Boeing)
2401 E Wardlow Road, Long Beach, California 90807-5309
Tel. 310-593-3973, Fax 310-982-0815, E-mail: bkelsey@soca.com

DAVID MERRILL
USAF Air Mobility Command (XPY)
Scott AFB, Illinois 62225
Tel. 618-256-2208, Fax 618-256-2502, E-mail: merrilld@hqamc.safb.af.mil

JOHN D. MORRISON
Los Alamos National Lab
P.O. Box 1663, MS F602, Los Alamos New Mexico 87545
Tel. 505-667-1554, Fax 505-665-2017, E-mail: morrison@snark.lanl.gov

Transportation Research Board

A. H. (Rick) Childs
Chairman, Intergovernmental Relations in Aviation Committee
Av-Consultant and Associates
21 Robin Drive, Cape May, Court House, New Jersey 08210-1301
Tel. 609-861-5568, Fax 609-465-2942 (call ahead)

Joseph A. Breen
Senior Program Officer, Aviation
Transportation Research Board
2101 Constitution Ave., NW, Washington D.C. 20418
Tel. 202-334-3206, Fax 202-334-2003, E-mail: jbreen@nas.edu