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FORECAST AND ANALYSIS OF INTERNATIONAL AIR TRAFFIC IN RELATION --ETC(U)
DEC 77 R POZDENA, D GROSS, J GORHAM, D YEE DOT-FA75WA-3574
UNCLASSIFIED FAA-RD-77/131-2 NL

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Report No. FAA-RD-77-131-2

FORECAST AND ANALYSIS OF INTERNATIONAL AIR TRAFFIC IN RELATION TO TRANSOCEANIC COMMUNICATION REQUIREMENTS. Appendix II.

SUMMARY REPORT, APPENDIX II

Randall/Pozdena, Dorothea/Gross, James/Gorham Dennis/Yee

AD A052808

AD NO. DDC FILE COPY

December 1977

99 p.

Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161.

DOT-FA75WA-3574

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
Washington, D.C. 20590

DDC RECEIVED APR 18 1978 A

389 941

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FAA-RD-77-131,II		

4. Title and Subtitle	5. Report Date
Forecasts and Analysis of International Air Traffic in Relation To Transoceanic Communication Requirements Appendix II	December 1977
	6. Performing Organization Code
7. Author(s) Randall Pozdena, James Gorham, Dorothea Gross, Dennis Yee	8. Performing Organization Report No. MSU-4004
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
SRI International 1611 N. Kent Street Arlington VA 20009	11. Contract or Grant No. DOT-FA75WA-3574-1
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Systems Research and Development Service Washington, D.C. 20590	13. Type of Report and Period Covered Appendix to Summary Report FAA-RD-77-131
	14. Sponsoring Agency Code DOT/FAA/ARD-230

15. Supplementary Notes

16. Abstract

This appendix presents a more extensive description of the methodology and assumptions used in developing the SRI air traffic activity forecasting system. Specifically, it describes assumptions concerning the future market environment of aviation, the forecasting system developed to estimate levels of air traffic and derive peak instantaneous airborne counts, and the results of tests conducted to assess the effects of changing parameter assumptions on the forecast results.

DDC
RECEIVED
APR 18 1978
A

17. Key Words	18. Distribution Statement
Global air traffic forecasts and interactive demand/supply models, Aircraft movements, International travel determinants, Instantaneous airborne counts, FIRs, IAC area zone peaks.	Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	98	

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METRIC CONVERSION FACTORS

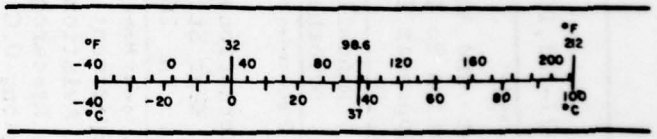
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



APPENDIX II

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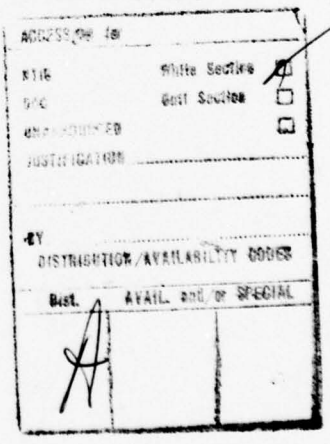

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1. INTRODUCTION

This document is one of two appendices to the summary report, "Forecasts and Analyses of International Air Traffic In Relation To Transoceanic Communication Requirements".[1] The summary report provides a concise discussion of the methodology, forecasts, and analyses of air traffic for the Atlantic, Pacific and Indian Ocean basins for the years 1975 through 1995.

The purpose of this supporting statement is to provide a more detailed discussion of the assumptions and methodology used in developing our air traffic activity forecasting system. APPENDIX II consists of the following sections:

- Future Aviation Market Environment--describes our assumptions concerning the future market environment of aviation. It focuses on the travel demand environment, the institutional environment of the air transportation market, and the technological and resource environment of the air transportation market.
- Air Traffic Activity Forecasting System--describes in detail the forecasting system developed to estimate levels of air traffic and derive peak instantaneous airborne counts.
- Sensitivity Analysis--describes the results of tests conducted to assess the effects of errors in various parameter assumptions on the forecast results.

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[1] Available through NTIS, Report Number FAA-RD-77-131: Authors: Pozdena, Gorham, Gross and Yee.

2. FUTURE AVIATION MARKET ENVIRONMENT

The future market environment of aviation may be characterized in terms of the following attributes:

- The travel demand environment
- The institutional environment of the air transportation market
- The technological and resource environment of the air transportation market.

Our forecasting system has been constructed so that alternative assumptions concerning the future nature of these attributes may be directly rendered as parametric inputs to the forecasting system. The purpose of this section is to describe the translation of subjective inferences about the future environment into specific parametric assumptions.

a. Travel Demand Environment

The demand for air transportation services is conditioned by a wide variety of economic, social, and political circumstances. The macro-influence of these forces is quite pronounced. The extent of the impact of these forces is illustrated by recent world economic events. In 1973, with the advent of the energy crisis, real GNP growth was negligible in the OECD countries (vs. 6.3 percent in 1972) and world tourist arrivals fell by nearly 3 percent.[1] In addition to affecting the total propensity to travel (in relation to the propensity to perform other economic

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[1] Source: OECD and the World Tourism Organization.

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activities), these circumstances affected the relative attractiveness of certain kinds of travel and hence the travel in specific markets. As pressures on U.S. dollars increased relative to European currencies, there was a pronounced shift in U.S-originated traffic from European to U.S. and Latin American destinations. As political and social alliances change, the affinity felt between various world population subsegments changes. This, in turn, affects the quantity of transportation interaction observed in particular markets.

A fundamental problem that had to be resolved in this IAC forecasting effort was the relative emphasis that should be placed on traffic flows and traffic generation. IACs are spatially oriented. What is sought is the determination of how many aircraft can be expected to be present in the airspace over a particular piece of geography at a particular period in time--past, present or future. The geography may be a land mass such as continental Africa or India, a whole ocean basin (Atlantic, Pacific or Indian), a subdivision such as the North Atlantic or the Southern Indian Ocean, or a specific FIR such as Gander or Oakland. The aircraft population of a given segment of airspace at any time depends on how much traffic is generated between the regions that might use flights traversing this geographic airspace, and the hours and days at which aircraft are flown to accommodate this traffic and how they are routed. Charter and not-for-hire flights have definitive departure and arrival times subject to many of the same determinants and restraints as route-type flights even though randomly determined. Traffic is generated between pairs of points based on the need or desire of people to have people or goods at other places at particular times. The influences on tripmaking--and shipments--that are fundamental in explaining traffic generation are often quite market specific and require detailed analysis of intercity or area interaction and attraction for precise determination. For example, the level of flight activity between the United States and the Caribbean is over half of that between the United States and all of Europe; this is certainly greater than would be forecast by a macro

or gravity model with basic economic and demographic variables interactions as the specification. The special characteristics of the Caribbean destination (such as accessible beaches, comfortably primitive surroundings, and sunshine) and the special characteristics of the travelers (such as their taste for sunshine and many of the other attributes of the location) combine to create a higher level of interaction than the model alone would indicate.

The routing of traffic, however, particularly overocean between large regions, is determined by nonmarket factors such as the limitations imposed by bilateral agreements between countries for the exchange of air transport rights, time zone differences and curfews, and nonspecific market forces such as the need of carriers to match loads and aircraft sizes and accumulate loads at particular points and times to maximize load factors. If our task here were to measure intercity or interarea traffic generation, regardless of how it flows, we would be justified in performing a very detailed analysis of the important individual air travel markets. Such analyses should involve as much consideration of qualifiable and quantifiable demand influences and effects as possible.

In this forecasting effort, we are dealing with a highly aggregative concept, the IAC. Because of its spatial nature, even insignificant markets can make significant contributions to the peak IAC. One can imagine a relatively heavy stream of traffic over a region which does not contribute to a peak IAC because the temporal distribution of this activity is random; on the other hand, relatively light but highly synchronized traffic might constitute that region's peak. Therefore, there is no <u>a priori</u> sense of which are the "important" markets to be analyzed. All must be analyzed to the same degree of detail or sophistication to attain consistent sensibility in the IAC measures derived.

This study is concerned with worldwide markets to which roughly 250

countries with regularly "scheduled" international service contribute. Since each country can conceivably be paired with every other, there are 250^2, or over 60,000, individual intercountry markets. Even if 90 percent of these could be dismissed as insignificant in themselves, as a total they may determine most of the peaking characteristics observed spatially and temporally. In fact, the distribution of activity at a level even finer than between countries may determine peaking characteristics. Thus, flight data on a city-to-city basis must be analyzed to ensure proper accounting for the spatial distribution of aircraft that may contribute to the peak IAC for any geographic area. Since the published schedules of the world's airlines that appear in the Official Airline Guide (OAG)[1] are the most uniform and solid basis for identifying existing intercity air movements, SRI's IAC model is driven by the detailed itinerary data available on the OAG tapes.

Without the criteria of market importance to reduce the number of city pairs or even pairs of countries to be analyzed, any concept of detailed market-by-market analysis would have to be rejected as unmanageable.

Furthermore, as is the case in any demand modeling effort, the description of the future demand environment involves uncertainty which can only be reasonably embraced by performing a sensitivity analysis on the underlying demand assumptions. With an aggregative forecasting goal, a high degree of disaggregation compounds the sensitivity analysis problem. If the range of possible alternative futures of the demand environment for individual markets is at all large, the family of scenario combinations is extremely large, and the range of aggregated impact of the extremes of individual market assumptions may be absurdly wide.

However, detailed market-by-market analysis of intercity or intercountry traffic generation is not justified for the purposes of aggregate

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[1] Copyright 1975, by the Reuben H. Donnelley Corporation, New York, N.Y.

peak IAC forecasts by IAC areas and ocean basins. Due to the interaction of limitations imposed by bilateral agreements and carrier scheduling practices for charter as well as regularly "scheduled traffic," together with other institutional pressures discussed below, overocean traffic moves between a relatively small number of hub airports serving regions that include many ultimate origin and destination cities and even several countries.

Countries generally seek, through bilateral agreements for the exchange of air rights, to yield up the minimum in rights to serve their cities that is necessary to secure the rights sought for their airlines, often government owned--strictly quid pro quo. Carriers assemble loads from many communities for charter or route-type overocean flights. Generally, the longer the distance flown the larger the area--both geographically and in absolute numbers of travelers/shippers--drawn on to support flight schedules. The combined effect of these forces is to restrict long-haul (over 400 nautical miles) overocean traffic to movements between a few hub airports serving regions that include many ultimate origin and destination cities and countries.

The traffic volumes carried on the aircraft movements originating or terminating at major hub airports such as New York, Montreal and Rio de Janeiro in the Western hemisphere; London, Paris, Rome, Copenhagen and Moscow in Europe; and Cairo, Bombay, Singapore, Hong Kong and Sydney in the rest of the world cannot be explained alone by the interaction of the traffic generating capacity of the city pairs linked. These volumes are rather the product of the entire interregional traffic generation and traffic flows.

To best accommodate these important characteristics of the analysis, therefore, SRI's forecasting model is an aggregate model rather than a microanalytical market model. As described later, the market demand forces are represented by the general surrogate measures of per capita

GNP and total population of the market regional endpoints. The future demand environment is directly conditioned by the forecast rate of growth of these basic variables. These rates on a country-by-country basis were developed by SRI's LRPS[1] and appear in Appendix B of Supporting Statement A. The model, as it was implemented, permits variation about these rates; in the final versions of the forecast model a range of $\pm$ 10 percent of these figures was employed uniformly across all countries' growth rates.

These assumptions permit uniform treatment of the forecasting problem, narrow the range of sensitivity parameter variations, and pivot the forecasting effort on predominant statistical relationships that have been demonstrated to prevail in the air transportation marketplace. The disadvantage is that while aggregate demand conditions may be adequately described, the individual market forecasts lack the benefit of close, analytical scrutiny. This, in turn, makes difficult, without extremely subjective assumptions, identification of the need for wholly new transoceanic routes not now operated. The possibility that such new routings may come into being and assessment of their possible impact on peak IACs can again be considered in subsequent revisions of these forecasts or of the models themselves after experience has been gained with the interactive demand/supply modeling system developed in this research.

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[1] LRPS (Long Range Planning Service, now called Business Intelligence Program, an SRI proprietary service on technological and socioeconomic developments and impacts) generally obtains its forecasts from a wide variety of sources and the data base is fairly complete. Where they were not available from LRPS, United Nations data and forecasts were used. Forecasts were not available for all of the countries encountered in the aviation data samples; in these cases, the average growth rate of the region or a related country was used. The data might be regarded as representative of a "most likely" socioeconomic scenario, and as used were varied to test sensitivity to "more optimistic" and "more pessimistic" scenarios.

In the context of the overall work effort, however, as pointed out, the closer scrutiny was neither possible nor desirable. Also, the forecasting model operates to forecast growth rates only (referenced to "scheduled" air carrier activity) and functions from a real and known base. We believe that, under the constrained data, analytical, and research product circumstances, the overall result provides a reasonable demand modeling system for estimating peak ocean basin and FIR IACs.

b. Institutional Environment of the Air Transportation Market

The functioning of the international air transport industry depends on a complex set of institutional arrangements among the involved countries and their constituent carriers. These arrangements for for-hire services basically determine routes, rates and conditions of carriage, the latter extending increasingly to the total capacity offered by carriers in particular markets and the type of aircraft that may be used.

The basic instruments for these institutional impacts are bilateral agreements between governments for the exchange of routes, on conditions of carriage and rate and other related agreements reached through the International Air Transport Association. Bilateral agreements negotiated between pairs of countries are the basic instrument for exchange of air rights between them. These agreements designate the routes and pairs of points that may be served and usually the number of carriers of each country that may operate on these routes. These agreements also determine whether the authorized routes will include points in third countries either between or beyond the bilateral countries (so called fifth and sixth freedom traffic). Capacity limitations in bilaterals often are designed to limit ability to penetrate these fifth and sixth freedom markets by tying capacity offered to the needs of direct traffic between the bilateral partners (third and fourth freedom traffic.)[1]

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[1] Abolition of U.S. fifth freedom rights beyond the U.K. and capacity constraints were major objectives sought by the U.K. in the recently concluded U.S./U.K. Bermuda II bilateral agreement. These objectives were only partially attained--least of all in capacity controls.

Most foreign carriers are wholly or partially government owned. Since bilaterals are negotiated between governments who then designate the carrier to perform the service, all international carriers are subject to considerable government influence--sometimes dictated more by overall national interests than the development of air transportation as such. Bilateral terms are designed to protect national carriers as well as gain rights for them and, therefore, often restrict conditions of carriage permitted to foreign airlines in ways they do not constrain national carriers.

Countries/communities also impose fees for use of airports and air navigation and traffic facilities and operating restrictions such as approach and departure paths, airports of entry and curfews on hours of operations. Some of these are partially designed as protective of national carriers, some (see overflight discussion in methodology section) to restrict passage. Environmental forces have brought into sharp question the right of countries or communities/airports to impose air and noise pollution standards not covered by route bilaterals or other bilateral or international agreements including outright prohibition on the operation of particular aircraft types such as the Concorde SST.

Some countries/airlines, particularly in Europe, have entered into pooling agreements to share the operation of schedules and sometimes to pool revenues. Third party carriers are excluded from carriage of traffic on such routes. Even U.S. carriers--forbidden pooling agreements --have negotiated capacity restriction agreements with foreign carriers.

Bilaterals in the past have primarily established authority for operations by route-type carriers. Charter carriers have had difficulties arranging service rights and have complained of discrimination in favor of national or foreign route-type operators, particularly where curfews impose some degree of rationing of entry slots. With the spread of charter operations and increasing number of countries with national

charter carriers, the prospects for inclusion of charter carrier rights in existing or separate bilateral agreements[1] have brightened and these constraints may soon be alleviated if not completely removed. A major factor at work here is efforts to increase tourist revenues, sometimes even at the expense of national carriers.

The International Air Transport Association (IATA) is the principal mechanism for the establishment of rate agreements for route-type (scheduled) carriage of passengers and cargo. These agreements normally require government approval even where, as in the United States, the carriers are privately owned. Therefore, carriers often approach IATA meetings already thoroughly briefed on what their governments will and will not accept. There is a basic conflict within IATA between carriers seeking rate structures they believe will foster long-term growth in air transportation (and even these may differ on the most appropriate strategy) and those carriers/governments seeking maximization of short-term benefits, such as earnings in foreign currencies. Due to the IATA unanimity rule (now being challenged), basic conflicts may prevent agreements and produce an "open"[2] rate situation. "Open" rate situations are increasingly common and longer lasting. Also, some governments may not accept IATA decisions and may instruct their carriers to establish rates not sanctioned by IATA, even to the extent of imposing them on foreign carriers. Such conflicts have led to threats of withdrawal of operating rights and other constraints (the U.K. vs the U.S. in 1976).

The charter carriers are not generally members of IATA even though many IATA carriers have charter carrier subsidiaries. IATA has recently

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[1] Bermuda II Conference between U.S. and U.K. agreed upon discussion to formalize exchange of charter rights and a date for the initial discussion has been set.

[2] Failure of carriers to reach agreement through IATA, hence open, non-IATA agreed rate.

acted not only to permit but to encourage charter carriers to accept some form of IATA affiliation, so far without much success.[1] Carriers sometimes act in defiance of IATA (as in the recent--successful--case of PAA over agents' commission rates) and even drop out of IATA permanently or for periods of time when they believe it serves their best interest. For example, the Icelandic carrier Loftleidir is not an IATA carrier and many carriers in South-East Asia are not in IATA. The U.S. cargo carrier Seaboard World Airlines withdrew from membership.

Since the content and extent of international coordination of air transportation--within or outside IATA--will influence the future operating environment of the operators in important ways, our forecasting effort required an appraisal of the future nature of the institutional environment of air transportation. Our conclusions are predicated on a weakening rather than increased authority of IATA in air transport affairs and, in the long-term, an increased tendency of government actions to permit competitive and capacity growth. We base this assumption on the generic difficulty involved in arriving at agreements among rival carriers and their governments as stakes involved in the rivalry increase. We believe that the instability of cooperative structures such as IATA and bilaterals that seek to restrain growth in competition will increase in the future as a result of the following forces:

- As small markets grow and can support more direct flight services (as opposed to feeder services), the total number of intercountry agreements will increase.

- As markets become larger and more carriers participate in providing service, the number of bilateral agreements that must be struck in each market will increase; the outcome of bargaining and negotiation is less likely to be a simulation

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[1] Interestingly, Pan American World Airways--perhaps the world's largest charter operation--has recently sought membership in the International Air Carrier Association, the international association of charter carriers.

of pure cartel tariff and capacity policies than a simulation of competitive pricing and service policies.

- Continued growth in charter operations and in the links between charter and route-type operations will strengthen the drive for provision of charter carrier rights through existing or special bilateral agreements.

- As markets become larger, the returns perceived by a "maverick" carrier investigating opportunities for increasing market share will increase. Heavy discounting or other promotional activity will have larger perceived payoffs. In a sense, the negotiation process is a gaming process, and increasing the payoff of individual players for violating cooperative strategies will increase the likelihood of noncooperative outcomes.

- While our forecasts generally predict growth in the air transport industry, growth over the next two decades will occur under unfavorable circumstances relating to energy, environment, carrier borrowing power and airframe technology that will constrain the industry's profitability. This is likely to enhance interest in unilateral strategies as carriers strive for maintenance of market shares.

These forces are already at work, of course, and are reflected in the 1974 collapse of regular sessions of the North Atlantic intergovernment price floor discussions. In the face of substantially depressed airline earnings in the previous year, the final fare package (which was not agreed on until early 1975) included lower 45-day individual excursion fares, reintroduction of youth fares in some markets, and a new, advance-purchase excursion fare. In additon, recent estimates by IATA of the revenue "drained" by carrier non-compliance with negotiated tariff structures ranged from $100 million to $300 million annually.[2]

The recent U.S./British agreement entitled Bermuda II is in

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[1] IATA, Reports and Proceedings of the 31st Annual General Meeting, Oslo, October 1975, p. 10.

[2] Ibid.

many senses a contradiction of these assumptions. Attacked by many within the Administration as well as the Congress and industry for its increased restraints on competition, it is held up by the new CAB Chairman as an example of what not to do. The opposition of some British and many U.S. interests to the compromises reached in Bermuda II is some gauge of the rising pressure against governmental constraints on air service capacity.

It is impossible, however, to ignore the existence of other pressures for tightening constraints, such as the demands of the Japanese and the Italians with whom negotiations are virtually deadlocked. So long as the present slowdown in world economic activity continues, there will continue to be conflict between those who would constrain and those who would reduce constraints on aviation activity and capacity offered. In the long run, however, we believe that constraints will be lessened. The Laker Skytrain experiment, the partial liberalization in the U.S.-Belgium Agreement and regulatory reform sentiment in the United States are indicators of such developments. IATA is again deadlocked on North Atlantic rates and louder calls are rising for its abolition.

A likely outcome of a diminution of the power of coordinated economic policies on air traffic levels and flight frequency is an increase in worldwide capacity and downward pressure on fares. This appears to be the result of enhanced competition in the North Atlantic where significant capacity is offered by non-IATA "scheduled" and "non-scheduled" carriers and in the Far East where non-IATA carriers proliferate. It remains to postulate the degree to which capacity would increase under a scenario involving deterioration of coordinating forces within the industry.

We approached this problem in two ways. First, we postulated that if there were a potential for increased competition, it would probably be strongest in markets served by a small number of carriers; larger, multicarrier markets have already been significantly invaded by what the "scheduled" carriers call "excess capacity"—both their own and that of "nonscheduled" competitors. We tested the hypothesis statistically by performing estimates of the "scheduled" traffic mode with the number of carriers serving the market as an additional variable. Thus, among markets of similar density, we would expect higher flight frequencies in those with a greater number of rival carriers. While the coefficient of this variable in our estimates was of the proper sign, the coefficient itself was statistically indistinguishable from zero, indicating that the influence was weak or perhaps lost in correlations with other variables in the formulation. Another effect at work is that small markets tend to have significant capacity offered because the governments involved are interested in promoting other, related economic activity (such as tourism and foreign exchange accumulation). Interregional service by each international carrier will normally include at least one stop in the national country. In any event, it appears that, for "scheduled" services, the effect of gradual "decartelization" on capacity would not be dramatic.

A greater potential exists in the addition of charter capacity as a result of the "scheduled" service interests' loss of power in the negotiating process. Here, we anticipate that several related developments could influence the forecast traffic levels. First, we feel that the distinction between charter and "scheduled" carriers will become less clear in the future, with "scheduled" passengers and charter passengers sharing the same aircraft (part charters); the influence of this institutional change on total flight frequency will be similar to that which would result from relatively unrestricted entry of independent charter

services.[1] Second, we feel that the intergovernment service and fare agreements will ultimately permit relatively unrestricted participation of charter carriage in the marketplace. While it will continue to be distinguished from the low-elasticity economy and first-class fare markets, by affinity, layover, or other restrictions, we believe that charter will come to be viewed as another rate service that is complementary to rather than competitive with "scheduled" services.

We have embedded these institutional assumptions in our model by permitting growth in the "nonscheduled" passenger market to follow a pattern (in relation to the overall demographics of the market) that was statistically developed for "scheduled" traffic.

Other institutional impacts on the air transport industry include changes in the ground facilities charges or restrictions placed on aircraft as a result of problems such as airport congestion, environmental restrictions, and curfews. The curfew issue could not be approached directly in this research because of the difficulty and impracticality of identifying the influence of the restrictions on the extremely large number of separate flight plans on which our model draws for the IAC forecasts. However, the impact of curfews on airline schedule patterns is embedded in the OAG tapes that drive the SRI IAC Counting Model. The cost-related issues are discussed in the discussion of sensitivity analysis.

It has been argued[2] that limitations in the ability of airports in

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[1] The United States government is currently considering legislation to make charter (supplemental) carriers eligible for certificated route-type authority without losing certificated charter rights and vice versa for carriers holding route-type certificates.

[2] Testimony of Dr. R. Shaw, Assistant Director General-Technical, International Air Transport Association: before the House Subcommittee in February 1977. Transportation, Aviation/Weather, Committee on Science and Technology.

New York and London to accept additional flights will themselves operate as constraints on peak air traffic activity. All forecasts have been developed without consideration of the limitation of such constraints. Developing technology such as Wake Vortex detection, avoidance, and control can increase the capacity of existing airports. Improved positioning, navigation, communication, and surveillance systems can increase capacity of existing oceanic flight tracks by permitting closer spacing of flights. Much of the traffic moving between New York and London and other major hubs does not originate or terminate in these areas and could use alternate routings if the existing major traffic route segments become congested either en route or at either terminal.

Carrier scheduling practices are also part of the institutional framework within which interregional aircraft movement patterns are determined. What is controlling is not the total traffic available in particular markets. It is how the carriers decide to schedule service to accommodate this traffic within the constraints and limitations imposed by bilateral and/or IATA agreements governing routes, rates and conditions of carriage. Scheduling of aircraft type and size and the timing of schedules are also affected by the location, availability and service requirements of fifth and sixth freedom traffic that may be carried on the same or connecting schedules. Scheduling is also affected by curfews and other operating restrictions and by time zone differentials.

To maximize load factors, carriers seek to size aircraft and schedules to expected loads and to assemble loads that will closely match the capacity of the aircraft operated. This drive affects charter as well as route type scheduling and tends to limit service to a few collection/distribution points. Thus, the combination of institutional factors--bilaterals, curfews and carrier scheduling objectives--tends to concentrate traffic flows and overocean aircraft movements to a limited number of route segments, with traffic collected and distributed over significant geographic regions at each end of the transocean movement.

As traffic increases to a level that will support direct services, the number of these routings may be expected to increase in the future. While it is not clear how oceanic controllers handle this increasing crossover traffic generated by new routes and new routings, it appears that it must merge on existing North Atlantic tracks during part of its overocean journey. This is particularly true of traffic moving from Western Europe to Southern United States, the Caribbean and Central America and traffic moving from Eastern Canada and the United States to Africa and the Middle East. Similarly, shift of Japan/Australia traffic from the present crescent movement through Hong Kong and Singapore to increased nonstop service will intensify peaking in IAC areas P-1, P-2 and P-9 while decreasing peaking in IAC area I-1.

In the light of the foregoing complex of considerations, it is our judgment that neither institutional nor physical constraints are limitations that should be considered in long-term traffic or aircraft movement forecasts. They may affect the spatial dispersion of instantaneous airborne counts, but probably not the timing of them, within the broad peaks characterizing the three major ocean basin flight activities.

Finally, an analysis of institutional forces must evaluate the possible impact on international operations of the prospect for significant change in the economic regulation of air transportation by the United States government. No proposal that has serious chance for adoption contemplates significant direct change in the economic regulation of international operations of the United States carriers. This is because of the existence of significant foreign competition and the direct tie-in of economic rights and operations with multinational and bilateral agreements and treaties. However, with combined Administration and Congressional support, it seems likely that governmental regulations of domestic U.S. fares and rates as well as the entry of new and existing carriers into new domestic routes will be substantially loosened in the near future. Whether such developments produce economic disaster as

some foresee, or whether they result in an increase in the economic activity and a strengthening of U.S. domestic air transport operations as others hope, they are bound to impact international operations affecting both rate and route determinations.

Pan American has already been awarded some domestic fill-up rights under existing proceedings without benefit of changes in the neighboring statutes. Strengthening of the domestic operations of any carrier in the international theater will in the long run augment its competitive impact in international transportation. Measures such as proposals to substantially deregulate both cargo and charter operations and the probable certification for route-type operation of some existing U.S. charter (supplemental) carriers together with any further growth in the part charter movement will further break down the distinction between charter and route-type operations.

The favorable, and perhaps some unfavorable, results of greater freedom in rate experimentation together with route authority changes can be expected to spill over from the domestic to the international arena. Any significant increase in the number of domestic carriers will increase the number of applicants for international service and will intensify the competition of existing U.S. carriers operating domestically and internationally in the international competitive theater. Decontrol may also have some significant technological impacts which we will consider below. The combined impact of the foregoing forces is in our judgment likely to permit or even induce an increase in flight frequencies. The combined effect of the institutional assumptions, including expected growth and charter activity, has been embedded in our model.

Another significant institutional force affecting the type and frequency of operations are the regulations designed to minimize the impact of aircraft noise. Although this is the underlying reason for many curfews at foreign airports, the impact of United States Federal

and local governmental regulations is perhaps more far reaching in their effects. They have severely limited supersonic aircraft operations and are likely to have significant impacts on aircraft technological development. For the latter reason they will be considered under the technology discussion below.

c. Technological and Resource Environment of Air Transportation

Aircraft technology and availability and cost of input resources will also have important influences on future aircraft operating patterns. The size and physical and economic performance characteristics of the aircraft likely to replace some of the aircraft presently in international overocean service in the next twenty years will be a major factor in determining future aircraft movement counts.

Prior to the early 1970s, the air transportation industry enjoyed a position that few service industries could match; relatively rapid growth of world prosperity had created a growing demand for its services and advances in the technology of propulsion, aircraft designs, and avionics permitted the industry to respond to this demand with a product that was increasing in quality and decreasing in price in real terms. The introduction of jet air transportation in the late 1950s and the 1960s had not only materially improved comfort and reduced transit times, it had drastically cut engine maintenance and overhaul costs and frequencies as well as sharply increased employee productivity.

Introduction of wide-bodied aircraft with higher bypass ratios and more fuel efficient engines did not bring comparable gains and these aircraft, at least initially, could not be used effectively to realize even their more limited increased potential because of the slackening economic growth and the impact of the oil shortage in 1973, 1974, and 1975. The advent of the oil embargo in 1973 rudely awakened the industry to the precarious nature of its technoeconomic situation. Even though

by dint of service curtailment and drastic fuel economy operation and maintenance programs air carriers were able overall to carry more passengers with less fuel and made more money in 1974, this position was not held into 1975. The combination of a slackening in the forces that condition the demand for air travel with the rise in the cost of fuel resulted in a significant drop in worldwide "scheduled" passenger traffic growth; in 1975, growth was only about 4 percent in comparison with the 7 to 10 percent enjoyed annually earlier in the decade.[1]

Transatlantic air traffic had been a poor relation in the traffic growth and revenue yield picture in 1974 and was even more a disaster in 1975. It had borne the combined brunt of fuel shortages, higher than domestic fuel price increases, and overcompetition and capacity more heavily than at least U.S. domestic air transportation.

Further complicating both domestic and international capacity/traffic (hence load factor) ratios, was the flood of deliveries of new large-capacity aircraft. Aircraft types designed and ordered on the basis of traffic growth rates in the 1960s provided capacities too large for the traffic loads collectable in the 1970s. Orders by U.S. carriers, that have historically accounted for 50 percent of the market, were flat.

In 1976, however, traffic growth began to pick up, resulting in a recent upturn in orders. This has been induced in part by governmental regulations requiring compliance of existing aircraft fleets with FAA noise regulations, over an approximate eight-year period. These new aircraft, however, are existing-technology aircraft rather than new designs.

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[1] IATA, World Air Transport Statistics, 1974 and Aviation Daily 1975-76.

There is a wide range of technology available, at least on the drawing boards, that could be applied to reduce fuel consumption and unit flight costs by improving propulsion and aerodynamic efficiency and lift/drag ratios. These include reduced structural weight through use of composites and other advanced materials; improved airfoil design (supercritical wing) that can reduce wing weight and lower drag; engine system improvements such as variable cycle engines; and basically more efficient structure and laminar flow control.

Two engineers at Lockheed have suggested that advanced improvements in aerodynamics, materials and propulsion might yield a 22 percent reduction in direct operating costs (DOC) or a saving of roughly 10 to 15 percent in total costs.[1] With rising fuel costs and the probability of continued increases, the emphasis is on increased fuel efficiency.[2] NASA AMES has an active contract research program on methods to increase fuel efficiency that includes three manufacturers: McDonnell Douglas, Lockheed, and United Technology Laboratories plus United Airlines. It has designed a paper "Reduced Energy Transport" (RET) whose lower swept wing and operating speed are questioned by some airlines. Nevertheless, two recent NASA papers estimate significant technological gains in fuel efficiency (measured in seat-miles per gallon) for the RET as well as for conventional aircraft, as shown in the following chart (Figure B-1).[3]

Airframe and engine manufacturers are conducting in-house as well as NASA and DoD contract research. Both Pratt & Whitney and GE have more

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[1] G. Sim and R. Hopps, "Commercial Transports: Decade of Derivatives," Astronautics and Aeronautics, February 1975, pp. 24-32.

[2] Aviation Week and Space Technology, 28 April 1975, p. 105. See also Aircraft Technology Bibliography.

[3] Ardema, M.D. et al. (NASA AMES), "Conceptual Design of Reduced Energy Transports," AIAA Paper No. 75-303, 24 February 1975, Figure 14. See also Mascy, Alfred C. and Williams, Louis J. (NASA AMES), "Air Transportation Energy Consumption Yesterday, Today, and Tomorrow," Paper No. 75-319, 24 February 1976.

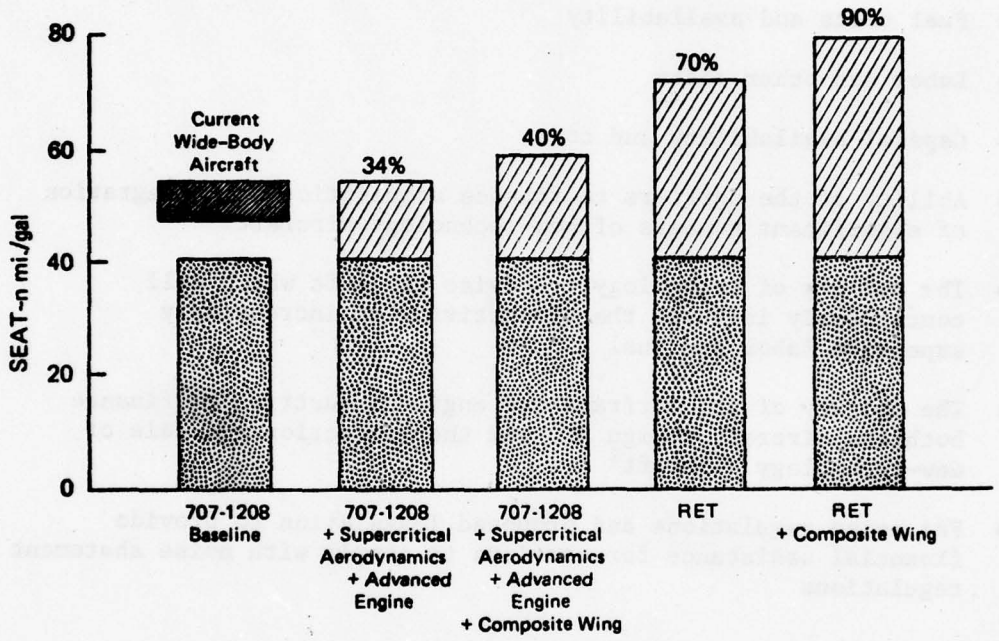

FIGURE B–1 RELATIVE FUEL EFFICIENCY

fuel efficient engines in the advanced stage. Boeing and McDonnell Douglas have designs for B-707/DC-8 replacements that take partial advantage of new technology. European manufacturers are considering advanced-technology aircraft also.

The ability of the air transport industry--including the manufacturing segment--to respond to air travel demands with new, innovative aircraft concepts is constrained by several limitations:

- Fuel costs and availability
- Labor and other costs
- Capital availability and cost
- Ability of the carriers to finance acquisition and integration of significant numbers of new-technology aircraft
- The ability of technology to devise aircraft which will continuously increase the productivity of increasingly expensive labor and fuel
- The ability of the airframe and engine industries to finance both the aircraft design R&D and the production and sale of new-technology aircraft[1]
- FAA noise regulations and proposed legislation to provide financial assistance for carriers to comply with noise abatement regulations

In the final days of the Ford Administration at the direction of the President, the FAA issued regulations requiring air carriers to bring their aircraft into compliance with existing noise regulations over a period ranging in some instances to eight years. These regulations did not apply to existing supersonic aircraft and the impact on international

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[1] For an evaluation of these issues, see J.E. Gorham, et al., "The Economic Impact of Energy Shortages on Commercial Air Transportation and Aviation Manufacture," Stanford Research Institute Report for FEA, 1975. NTIS Nos.: Vol. 1 - PB246-271, Vol. 2 - PB246-272.

operations was delayed, pending efforts to secure international agreement on noise standards. Carriers have three ways of meeting these requirements. One is by the insulation of sound-absorbing material (SAM), called retrofit, in the nacelles of the engines. This will reduce the noise somewhat with some weight and fuel penalty. The second means is by replacing existing engines by quieter and probably more fuel efficient engines. This had previously been rejected by the FAA based on studies that led it to conclude that such action would not be cost effective. The third alternative is to retire the noisy aircraft and replace them with aircraft that meet existing noise requirements.

Although hearings were held by then Secretary of Transportation Coleman on carriers' ability to finance compliance with these regulations, no specific means of financing assistance were provided. The Ford Administration took the position that were the Congress to substantially deregulate air transport route entry and ratemaking, the carriers' earnings would increase sufficiently to provide adequate funds for compliance with the noise abatement program.

While the Carter Administration has also linked regulatory reform and financing of compliance with noise regulations, it has endorsed the concept of special funding to assist the air carriers in achieving compliance. Representative Anderson of the Subcommittee on Aviation of the House Committee on Public Works and Transportation has introduced legislation proposing financial assistance for retrofit or replacement of engines or engine aircraft to comply with noise regulations. His bill is based on a variant on a carrier proposal to switch 2 percentage points of the 8 percent airline ticket tax from the aviation/airways trust fund to a special funding for noise abatement compliance. Extensive hearings have been held and the bill has been amended several times to attempt to bring it into closer agreement with both Administration, airport and industry views. No comparable legislation is under consideration in the Senate at the present time.

Carriers in general oppose spending money on bringing old aircraft that are close to retirement into compliance with noise regulations whether it is retrofit with SAM or replacing engines. However, they have been extending the service lives of a number of older aircraft and there is no replacement for some types in service at the present time. On balance, finances permitting, they would prefer to replace rather than bring existing aircraft into compliance.

Bringing air carrier fleets into compliance with existing noise standards, however financed, is likely, because of the timetable imposed, to result in significant fleet additions of existing-technology aircraft. Some carriers, as noted earlier, have already begun to take such steps, notably United, American, Delta and Braniff. Under existing timetables they have little option, since new-technology aircraft are not presently available. Some, such as Eastern, are considering the foreign-built aircraft, the A-300. Regardless of the merits of the noise program, the danger of this trend is that there may be significant replacement of older, noisier aircraft in U.S. air carrier fleets with existing-technology aircraft which barely meet our present noise regulations. This might make it difficult, if not impossible, for most of these carriers to buy advanced-technology aircraft if such become available in the next decade.

Noise regulations are also restricting operations of the Franco/British SST to the United States, making it difficult to determine the economic viability of the present generation SST. It is therefore necessary to make a judgment whether these constraints will be lifted and whether the aircraft will prove economically viable if permitted to operate between major international air traffic hubs. The present operations into Washington, D.C. area Dulles Airport have met with strong traveler acceptance. Load factors have been good. It is understood, however, that the British and French carriers are both still losing money on these operations.

It is probable that some form of liberalization in economic regulation of rates and routes by the United States Government will be adopted either during the present or the next session of Congress. These developments will undoubtedly have significant technological impacts. Testimony at the hearings in May of 1976 before the House Subcommittee on Aviation and Transportation Research and Development on the Future of Aviation pointed up the possible dilemma for airframe manufacturers. The impact of regulatory reform, through removal of restrictions on size of aircraft operated by commuter airlines, on one hand and possible reduction in market shares of existing carriers, on the other, could lead domestic operators to an increased demand for smaller capacity aircraft. Many domestic carriers have already found their B-747s too big for their route structures under existing regulations and have disposed of them.

At a recent meeting a United Airlines spokesperson declared that their immediate requirement was for a 185-200 passenger replacement for the DC-8s and some B-727s. Other domestic operators have indicated similar interests.

International operators, particularly in the light of attempts at limitations on the number of frequencies, and if there is a further pickup in traffic growth, may favor larger capacity aircraft. Pan American has been replacing larger capacity B-747s with the longer range, lesser capacity B-747SP. This has permitted nonstop service in many Pacific markets previously impossible and created a demand on the part of other carriers such as JAL for competitive purchases. Also, the low fare service kicked off by the Laker Skytrain experiment may argue for medium to large capacity aircraft, rather than jumbos. Manufacturers will find it difficult to design and build aircraft for both domestic and international requirements and must compromise.

Thus the desire for schedule flexibility and the probable impact on

market shares in domestic operations of liberalization of entry of new and existing carriers into new routes may result in the next generation of aircraft with capacities lower than the B-747 and even the DC-10, L-1011, and A-300. It is notable that the A-300 manufacturers are considering a smaller capacity version and other European new-technology aircraft emphasis is in the intermediate size bracket.

d. Assumptions Respecting Future Aviation Environment

The foregoing discussion has analyzed the forces at work in the travel market environment, the institutional environment of the air transport market and the technological and resource environment of the air transport market. We concluded that although the models developed for this research by SRI could be improved to make them more sensitive to the need for new routings, the aggregative interactive demand/supply models developed were suitable for estimating major traffic flows that determine the several ocean basin and major area instantaneous airborne counts.

In our forecasts we have assumed two scenarios respecting technological change and cost impacts--an "optimistic" and a "pessimistic" set of assumptions. These scenarios differ principally in the possible application of technology to improvements in fuel efficiency and other factors affecting unit operating costs, the extent of the savings that may be attained and the timing of introduction of advanced-technology, more fuel efficient aircraft.

(1) Optimistic Scenario

In this scenario we assume that the new aeronautic technology discussed above will be utilized and will provide reductions in direct operating costs. This will come in two stages; first, incorporation of some advanced technology in derivative aircraft and later full-blown advanced-technology aircraft. Aircraft technological developments over

the four five-year forecast periods under optimistic assumptions would involve the introduction of new-technology aircraft as follows:

- 1975-80: This period would be characterized largely by continued employment and some new buys of existing-technology aircraft--largely B-727-200s--but with profit-sensible increases in aircraft gauge, largely involving the B-747, B-727SP, DC-10, L-1011, and the A-300B.

- 1980-85: In this period a B-7X7, B-7N7 and a DC-X-200 with an approximate 180-passenger capacity might be introduced. Another possibility is a four-engined A-300B with a new wing and fuel efficient engines (such as the GE/SNECMA, CFM-56 or P&W/MTU/Fiat JT10D) with a capacity of about 210 passengers. The fuel efficiency gain of 20% would be offset somewhat by the additional cost of the improved aircraft characteristics, for an average total cost saving of 4 to 5%, including capital charges.

- 1985-90: Further U.S.-designed advanced-concept aircraft with 200-passenger, long-haul capability, supercritical airfoils and new fuel efficient engines might be introduced. A European analog with four CFM-56/JT10D or other 10-ton engines and 200-passenger capacity in a long-haul version is another possibility. Additional average total cost savings of 4-5% over the previous period's aircraft are possible. Medium-haul designs will also take advantage of wing modifications and fuel efficient propulsion systems. These might include a BAC-111-800 with two JT10D engines, stretched to 145 passengers, a Dassault-Breguet Mercure 200-2 with CFM-56 engines and 147-passenger capacity, and an AS Trident 4 with 10-ton engines and a 142-passenger capacity, and U.S. B-7X7/B-7N7/DC-X-200 derivation

- 1990-95: Optimistically, this period might see the introduction of entirely new families of aircraft with total fuel savings of 10-15% over the base period. The end of the period may mark the advent of an advanced, perhaps even fuel efficient and environmentally acceptable SST. This is likely to be of joint US/European manufacture.

During the forecast period, the SST would be operating over the Atlantic and Pacific basins in both the Russian Tu-144 and Franco-British Concorde versions. The SST would displace flights that currently serve business travel demand in restricted markets. The time saving enjoyed by SST patrons would have the greatest value to this traffic segment and

there would probably be no net traffic generation effects as a result of SST flight activity, because this segment's demand for air travel is highly inelastic and relatively insensitive to service and fare levels in the aggregate. Tracing the influence of the SST traffic on the peak IAC calculations is difficult. We have assumed in our draft modeling effort that the SST contributes to the same business travel peak as the conventional jets it displaces. We consider a second generation SST till the very end of the forecast period unlikely because of the long development leadtime and the high cost ($3 to $5 billion)[1] of development.

(2) Pessimistic Scenario

Our worst case for aircraft technological development embodies the following assumptions:

- Introduction of fuel efficient aircraft (such as the B-7X7, B-7N7, and the DC-X-200) is delayed until 1985-90.
- The fuel efficiency attained is only a 12-15% saving over the base.
- No advanced-technology aircraft generation occurs in the forecast period.
- There is limited use of the SST, with none to the United States--existing experimental service proving an economic and ecological disaster meeting implacable community opposition.

The unit operating cost saving assumptions in these scenarios are converted to negative rates of growth of the "fixed cost" factor in the forecasting model. The rates of growth are calculated to yield the percentage savings discussed in the scenario over the forecast period;

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[1] J. E. Gorham, et al., "The Economic Impact of Energy Shortages on Commercial Air Transportation and Aviation Manufacture", Stanford Research Institute for FEA, 1975.

that is, the saving is completely realized only at the end of the period.

If the impact of compliance with noise regulations, however financed, is to cause substantial purchases of present-technology aircraft over the next five years, this would push toward the pessimistic scenario and delay the introduction of new technology aircraft at least to the 1985-95 decade. If, however, it proves practical to retrofit or replace aircraft engines to achieve noise compliance, at least the Boeing and McDonnell Douglas B-7X7/B-7N7/DC-X-200 aircraft may find a significant market in this next decade. Regulatory reform in the United States, in the configuration in which it seems most likely to be adopted, would tend to increase the demand for aircraft in this size bracket (175-200 passengers) and, as noted, European designs are aimed at the same capacity market. Although there has been some recent interest shown in a 600-passenger aircraft, we do not believe that there will be a significant market for a large-capacity aircraft (700-1,000 passengers) during the next 20 years. We do not expect a large market for the present-generation SSTs (Russian or Franco/British) under either scenario even if U.S. noise restrictions are resolved. We think that developmental problems and investment fund availability as well as the probable need for U.S./European cooperative agreements will delay development and introduction of a second-generation, probably reasonably fuel efficient SST until beyond 1995.

The other major areas of uncertainty about the future operating environment concern the likely trends in the cost of fuel and labor. Discussions of these trends and those of other cost components follows.

(3) Fuel

The IATA fuel monitoring program indicates that while international aviation fuel prices increased by 3-1/4 times from early 1973 to July 1974, the rates of growth in aviation fuel prices have

stabilized, and in 1975 were "in line with general cost increases."[1] We do not anticipate fuel price increases of the magnitude of 1973-74. We expect the trend in these prices to correspond roughly (in real terms) with average international price increases.[2] In our sensitivity analysis, however, an optimistic and pessimistic scenario of fuel prices is explored in which the real increases are 1 percent per annum above and below other international price index changes. There is a direct and separate treatment of fuel prices in the forecasting model.

Obviously, extreme scenarios of embargo or other severe restrictions on petroleum supplies would have severe negative influences on activity and IAC estimates. We believe that these conditions would have severe impacts on world economic development in general, but that they are unlikely or at least short-lived possibilities.

(4) Labor

Increases in unit labor costs to the air carriers have been disguised considerably by the increases in productivity that jet aircraft have generated. As the rate of productivity increase slows (as the growth in average gauge slows), the labor components of operating cost will become more significant components of the average unit costs (such as on a ton-kilometer basis), and the average flight cost growth rate will approach more nearly that of its components. In all of the scenarios, labor cost is assumed to grow at a rate similar to overall international prices (i.e., zero real growth).

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[1] IATA, The State of the Air Transport Industry, 1975, p. 3.

[2] This in itself is a somewhat pessimistic assumption compared to historical trends. The cost of aviation fuel in early 1973 was the same in current dollars per gallon as it was during World War II. (Source: ICAO Bulletin, July 1975, p. 16).

(5) Other Cost Components

Interest and other financial expenses of the air carriers have typically represented only about 3 percent of airline costs, while airframe depreciation and landing and enroute charges together represent nearly 10 percent. We anticipate that expenses in both of these categories will increase in the future at a rate slightly above general price indices. In the case of the latter category, this is an anticipated consequence of increased attempts to recover facility costs through user charges.

In sum, the combined labor and other nonfuel cost components are expected to make total flight costs (for a given aircraft gauge) grow slightly more rapidly than the general price level. In the sensitivity analysis, this percentage (in real terms) is varied from 0.0 to 1.5 percent on a compounding per annum basis.

e. Application of these Assumptions to the Forecasts

Our model permits incorporation of alternative assumptions concerning these parameters in several ways:

- The flight-cost relationship recognizes that the cost of a flight increases somewhat less than in proportion to the size or the stage length of the aircraft. If a new airframe design significantly altered these cost elasticities, they could be input directly in the model formulation.
- The flight cost model is parameterized directly for a fuel price index in real terms.
- The flight cost model is parameterized directly for a unit or fixed cost growth factor to represent (in real terms) the change in the overall labor and capital costs of operating a flight.

The translation of the technological and resource future of the air transportation industry into parametric assumptions then permits the model to select the likely rate of change in the gauge of the aircraft fleet, the average fare, and the flight frequency that would be observed in each market.

3. AIR TRAFFIC ACTIVITY FORECASTING SYSTEM

This section describes the forecasting system developed to estimate levels of air traffic and derive peak instantaneous airborne counts for the busy hour of the busy day by ocean basin and IAC area for 1975 through 1995.

The section is divided into the following subsections:

- Overview of the forecasting system
- Description of the forecasting methodology
- Description of the instantaneous airborne counting methodology
- Special considerations

a. Overview of the Forecasting System

The forecasting system estimates peak instantaneous airborne counts (IACs) of flights over ocean basins and their geographic subareas. To achieve this objective, it was necessary to consider the influence of five different types of traffic and the aircraft movements operated to accommodate them. These include "scheduled" traffic (passenger and cargo), charter traffic (civilian and military (MAC) traffic), and not-for-hire (general aviation) traffic.

The Official Airline Guide (OAG) is the only comprehensive source of data on flight frequency by airline type, origin and destination location, elapsed trip times and take-off times. It provides these data in tape format for "scheduled" movements of route-type air carriers.

This is the basic data set that was used to estimate peak IACs. All data obtained for other types of traffic were used to develop relationships of these traffic flows to "scheduled" movements through a series of interacting forecasting models. This enabled the development of total traffic movements from projections of "scheduled" flights.

Our forecasting system consists of four modules[1] or components: the ICAO data processing module (DPICAO); the forecasting module (FORCAS); the OAG Data processing module (DPOAG); and the instantaneous airborne counting module (IAC). Figure B-2 is a flow diagram, illustrating the relationship between each module. The primary function of each module is described in the following pages.

(1) ICAO Data Processing Module (DPICAO)

The DPICAO is a data processing module which sorts and compiles raw data from the ICAO data base and a socioeconomic data base (prepared primarily from United Nations, U.S. Agency for International Development (AID) and SRI sources). It generates data bases of traffic activity by country pairs and by region pairs. Both data bases can be used as input to the FORCAS module.

The Country Pair Forecasting Data Base contains socioeconomic and baseline air traffic parameter levels for many country pairs. When this base is processed by the FORCAS module, forecast growth rates and levels of air traffic activity between each country pair are computed.

The Region Pair Forecasting Data Base contains socioeconomic and baseline traffic activity levels for world region pairs. Similar

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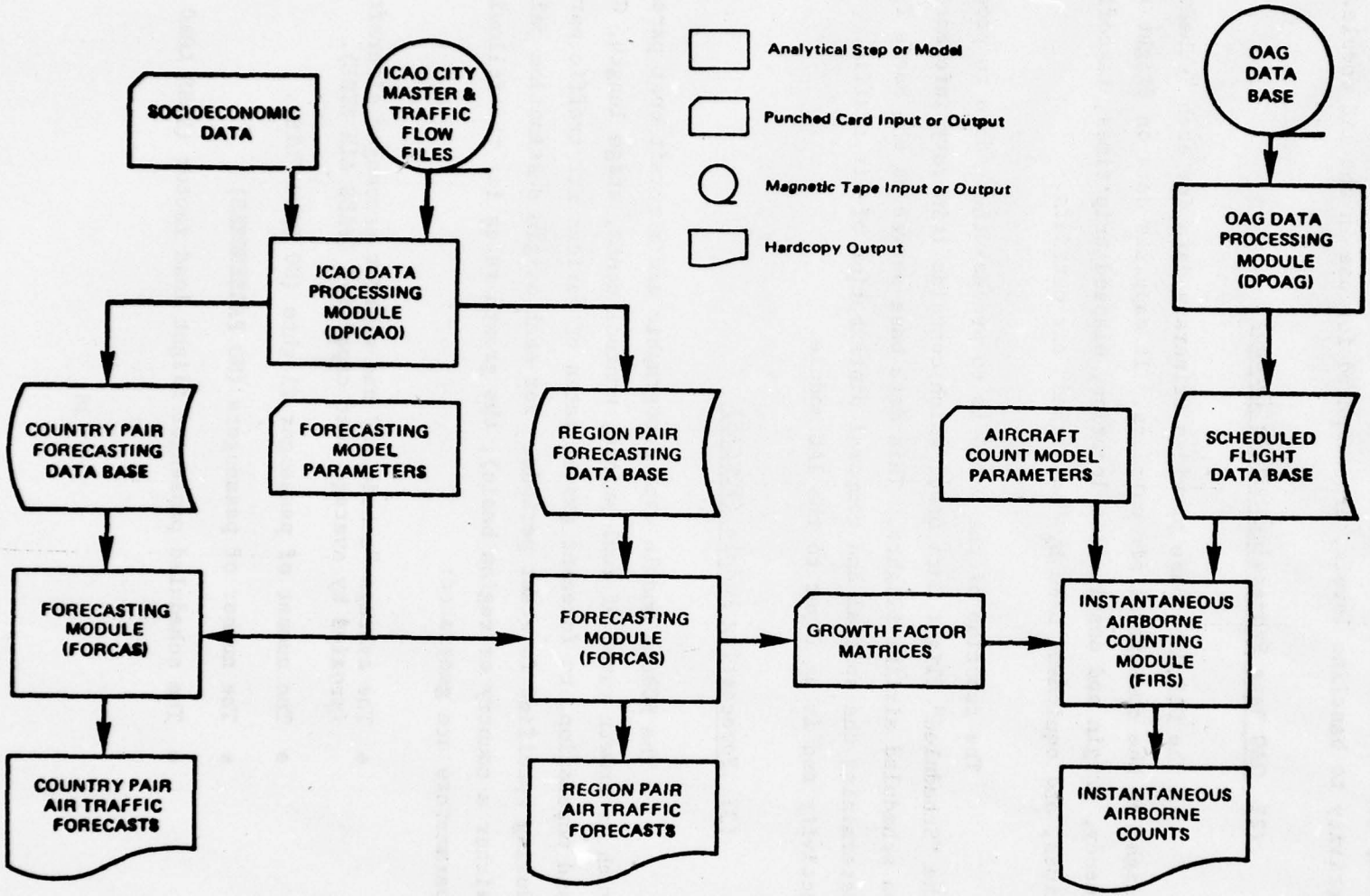
[1] See SRI report "Computer Methodology for Forecasting Worldwide Aviation Activity (COMFAA)," by John C. Bobick and Robert S. Garnero, March 1977, Report No. FAA-AVP-77-14.

Figure B – 2 AIR TRAFFIC FORECASTING SYSTEM



to the case of the country pair data, the FORCAS module processes the region pair data and provides, in printed form, forecast growth rates and levels of air traffic activity between each region pair. In addition, growth factors, which are ratios of forecast levels of traffic activity to baseline levels, are computed for use in the IAC module.

(2) OAG Data Processing Module (DPOAG)

The OAG data base provides itinerary data for each "scheduled" flight by the commercial air carriers. It supplies data on flight frequency, origin and destination location, elapsed trip times, takeoff times, and equipment used by "scheduled" air carriers.

The function of the DPOAG is to process these data to produce the "Scheduled" flight data base, which contains itinerary information on scheduled airline flights. This data base serves as the basis for determining the spatial and temporal distribution of air traffic activity and is an input to the IAC module.

(3) Forecasting Module (FORCAS)

The FORCAS module uses demographic and aircraft cost parameters, such as growth rates of fuel prices, nonfuel costs, stage length, GNP, and population, to forecast growth rates of various air traffic parameters during specified forecast periods. For each origin destination pair (on either a country or region basis), the growth rates for the following parameters are generated:

- The average "scheduled" and charter passenger aircraft size (proxied by average seat capacity) (PASS AIR SIZE).
- The number of passenger flights (NO PASS FLTS).
- The number of passengers (NO PASSENGERS).
- The scheduled passenger flight load factor (PASS LOAD FACTOR).

- The average cost per flight (COST PER PASS FLT).
- The average "scheduled" fare (PASS ECON FARE).
- The average size of cargo aircraft (CARGO AIR SIZE).
- The number of all cargo flights (NO CARGO FLTS).
- The cargo flight load factor (CARGO LOAD FACT).
- The tons of cargo (mail and freight) carried by cargo flights (TONS OF CARGO).

The forecasted levels of these parameters are computed by compounding the annual growth rates using as baseline levels the values found in the Region or Country Pair Forecasting Data Bases. When operating on a region-to-region basis, the module also computes growth factors for various traffic activity parameters. A growth factor is the ratio of the level of a traffic parameter at a forecasting date to that at the base date. These growth factors serve as input into the IAC module to estimate peak IACs.

The FORCAS module uses an interactive econometric supply-demand module to derive the above mentioned air traffic parameters. These parameters pertain only to "scheduled" traffic. To derive forecasted levels for other types of traffic the module applies a proportional factor to projected "scheduled" traffic. A detailed description of this forecasting methodology is provided in the next subsection.

(4) Instantaneous Airborne Counting Module (IAC)

The Instantaneous Airborne Counting Module (IAC) estimates aircraft activity in terms of peak instantaneous airborne counts (IACs) over a specified region. The module consists of a computerized flight-tracking model that uses a comprehensive set of input variables to compute measures of air traffic flow and the rates at which aircraft enter and leave a region.

The IAC module utilizes the "Scheduled" Flight Data Base generated by the DPOAG as its source of current "scheduled" flight activity. Growth factors matrices generated by the FORCAS module are then merged with this data base to estimate IACs.

As described earlier, each growth factor in a matrix gives the ratio of flights at a forecast date to flights at the base date for an origin-destination region pair. If for example, the passenger growth factor between regions X and Y is 1.5 in 1990 relative to a base date of 1975, each flight "scheduled" in 1975 will become 1.5 flights in 1990, with takeoff times, elapsed times, and aircraft track identical to the 1975 flight.

The IAC module then counts the number of aircraft in the air at specific time intervals within particular areas to estimate peak IACs. Essentially, the IAC model flies the aircraft through the ocean basin and asks its location in latitude and longitude every six minutes. These six-minute counts are then aggregated into 24 groups of ten to determine peak hour instantaneous airborne counts for ocean basins and subareas within them. The IACs represent boundary estimates of activity contributed by all traffic categories analyzed in this research.

Data defining flight basins and IAC areas are also inputs into the IAC module. A basin is defined by specifying latitudinal and longitudinal boundaries.[1] IAC areas are predefined areas for which measures of aircraft activity (IACs) are accumulated. They serve to divide the ocean basins into manageable segments enabling a more thorough analysis of aircraft activity.

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[1] For this research effort, the boundaries of the Atlantic basin are 10° east to 80° west; of the Pacific basin are 120° west to 120° east; and of the Indian basin are 120° east to 60° east.

b. Forecasting Methodology

To forecast levels of air traffic and associated growth rates, SRI has developed a market-derived econometric model that permits association of the changes in important variables with changes in the use of air transportation. This approach is important because of the large potential variance in certain key factors that affect air transportation, such as the price of fuel.

In contrast to SRI's market-derived approach, other methodologies have tended to derive estimates of future aircraft activity by examining historical trends in aircraft movement along various routes and extrapolating traffic into the future using the calculated historical growth rates. This methodology is acceptable under severe data conditions, but does not permit incorporation of the effects of large changes in economic or institutional variables that influence air traffic and aircraft movements.

SRI's econometric model is not intended to capture every detail of the behavior of air carriers on the routes, but rather to permit modeling of the sensitivity of air carrier activity to influential forces capable of being forecast. Institutional or economic peculiarities of specific markets will affect their absolute level of activity more significantly than they will affect rates of growth. Hence, our model provides a useful analytical foundation on which to build judgment and specific market data.

This methodology is most applicable to the "scheduled" civilian air passenger and cargo transportation market, and less so to military air, civil charter and not-for-hire markets. This is because available flight information on the latter three traffic markets is extremely limited. This prevents the calculation of the peaking characteristics of these traffic segments with the same degree of accuracy as the data for "scheduled" passenger and cargo flight permit (OAG data base).

The primary data deficiency is information on the hourly and diurnal patterns of these types of activity.

The degree to which the activity entailed in these segments of traffic is synchronous or asynchronous with the cycles of "scheduled" traffic will substantially affect the timing and placement of the peak airborne counts. In general, without more specific data, we are able to make definitive assumptions about the contribution of this traffic to the peak only under a rather specific set of conditions.

We approached the problem of a lack of itinerary information by assuming that all "nonscheduled" services performed by "scheduled" and "nonscheduled" airline operators and by general aviation operated in a diurnal pattern analogous to that of the "scheduled" airlines' services.[1] We perceive this assumption as a boundary assumption and believe it will yield a high-side estimate of IACs but will not affect proper identification of the heavily loaded IAC areas--that is, it will probably overestimate the peak, but will properly locate the peak in space. Given the ultimate use of the information (the parameterization of satellite communications systems), we feel that this assumption provides the most useful information obtainable under the constrained data circumstances. Any other assumptions would require considerably more justification than is possible with the present data base.

The validity of this assumption is supported in a general way by the limited available data. For the largest segment of "nonscheduled" activity (the "for-hire" services of "scheduled" and "nonscheduled" operators), the route patterns and schedule patterns correspond roughly to the "scheduled" service patterns. SRI obtained detailed flight

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[1] That is, for example, if 10 percent of "scheduled" traffic on a particular route have a specific departure time and elapsed time, 10 percent of "nonscheduled" services are assumed to be performed with a similar schedule.

data describing the "nonscheduled" services of several major scheduled carriers (TWA, American, and Braniff) and two major "nonscheduled" operators (Trans International Airlines and Saturn Airways--since merged). The limited sample, the hardcopy nature of the data, and the lack of consistent formatting among the various carriers which responded to our inquiries prohibited us from performing rigorous machine testing of our hypotheses, but inspection of the data indicated that the "nonscheduled" passenger activity entailed itineraries and equipment similar to that observed in the same markets. This admittedly limited sample of disaggregate data supported our assumption of synchronous peaking in this activity. Table B-1 obtained from ICAO data indicates the similarity of equipment used by "commercial" (route-type) and "nonscheduled" (charter) carriers.

TABLE B-1

NUMBER OF AIRCRAFT IN NONSCHEDULED SERVICE: 1973
(Aircraft with Maximum Takeoff Weight of Nine Tonnes or More)

Operators	Turbo-Jet	Turbo-Prop	Piston-Engined	Total
All commercial operators	4,533	1,538	1,545	7,616
Percent of total	60%	20%	20%	100%
Nonscheduled operators				
57 reporting fleet data	256	73	55	384
Percent of total	67%	19%	14%	100%

Note: Excludes USSR and People's Republic of China.

Source: ICAO, Digest of Statistics, No. 196, p. 7 (1973)

Even if the assumption of synchronous behavior of "scheduled" and "nonscheduled" activity is incorrect, the level of activity in civil movements of a "nonscheduled" nature is probably not sufficient to influence substantially the timing and location of flight activity peaks

over the analysis region due to the relatively pronounced peaking observed for "scheduled" services. The "scheduled" services contribute (and will continue to contribute) the bulk of "for-hire" "nonscheduled" flight activity, as indicated in Table B-2. For example, the peaking of "scheduled" flight activity in the Atlantic basin is currently quite pronounced diurnally (with the peak hour IAC for the basin and the constituent IAC areas generally 2 to 15 times the IAC in the lowest off-peak hour) and spatially (with the greatest IAC area IAC being roughly ten times that of the lowest IAC area). Thus, while "nonscheduled" traffic could possibly influence the peak definition if it has service

Table B-2

TOTAL AND INTERNATIONAL TRAFFIC CARRIED BY ALL OPERATORS: 1972 AND 1973
(Millions of Tonne-Kilometers Performed)

Type of Operations and Class of Service	All Operators (% of total) 1972	1973
Total (international and domestic)	69,500 (100%)	77,200 (100%)
Scheduled services	57,400 (83%)	64,500 (84%)
Nonscheduled services	12,100 (17%)	12,700 (16%)
International	38,200 (100%)	42,800 (100%)
Scheduled services	27,600 (72%)	32,000 (75%)
Nonscheduled services	10,600 (28%)	10,800 (25%)

Note: Excludes USSR and People's Republic of China.

Source: ICAO, Digest of Statistics, No. 196, p. 5 (1973)

*The service speed of nonscheduled operators averaged 670 km/hr versus the 685 km/hr of scheduled carriers [ICAO, Digest of Statistics, No. 196 p. 70 (1973)].

patterns that are even roughly similar to those observed for "scheduled" services, it is likely that these services will compound the "scheduled" activity peaks rather than shift them substantially in space or time. Our assumption of synchronous service patterns will then provide a useful upper bound on basin and IAC area activity measures for the peak periods.

We believe that the best compromise in the face of the uncertain influence of changes in aircraft operating characteristics, route structure, and communications is the "worst case" assumption that future traffic growth will exhibit a temporal pattern similar to that observed today. This becomes a "worst case" in the sense that it will assign to the current peak periods and airspace regions more traffic than the "peak-broadening" forces described above will permit in actuality. Again, this boundary number has more certain meaning and reality than an arbitrary specification of the direction and magnitude of peak shifts in space or time.

(1) Forecasting Scheduled Passenger Aircraft Movement

The methodology for forecasting scheduled passenger aircraft movement entails estimating the parameters of a model which considers the behavior of air travelers and air carriers. In effect, the market decision process is a simultaneous interaction of demand and supply where:

- Tripmaking between two cities is influenced by the cost and frequency of flights and by qualitative service variables (say, the size of the aircraft), in addition to the demographic characteristics of the origin and destination.
- The price and frequency of service (and the size of the aircraft used)[1] depend, in turn, on the demand for tripmaking.

[1] Aircraft size is also a function of fleet composition of carriers serving the route. Equipment purchases are dictated by system needs and compatibility, in addition to specific route requirements. However, the longer average length of transoceanic flights makes dedication of equipment to the route a stronger possibility.

Econometrically, this interaction requires the estimation of a simultaneous equation system from observed air traffic activity data in order to discover how tripmaking and aircraft movements would change in response to forecast changes in causal variables. However, several institutional realities require modification of the model:

- The fare is regulated by agreement among the various carriers. Hence, it is a variable that is taken as given in the short run by both travelers and air carriers. It is not determined endogenously by market interactions in a continuous fashion, but is adjusted over time to accommodate the structure to the carriers' prior financial condition, but lags cost changes.
- The response of an air carrier through fleet changes occurs with a lag because of the nature of the planning and aircraft acquisition process faced by the air carriers.
- The limited competition in fares at any instant tends to make air carriers focus on provision of capacity as a mechanism for increasing market shares, but the bilateral agreements often constrain the capacity decisions. This leads (as will be outlined below) to conclusions about the profit maximizing behavior of the air carriers that affects the response of aircraft movements to changes in tripmaking behavior or changes in cost.

We will consider first demand relationships and then supply (air carrier) behavior. The factors that condition the demand for air travel include the characteristics of the service offered (travel time, flight frequency, aircraft size, fare charged), the characteristics of the origin and destination (population, income, tourist attractions, and the like), and the purpose of the trip (business, pleasure, military).

One must consider many factors in an analysis of travel demand to explain fully the magnitude of observed tripmaking. Previous studies of air passenger travel demand have included religion, destination, sunshine, number of historical sites, and other such data as explanatory variables. For a forecasting effort, however, the data to which travel will be correlated must themselves be capable of being forecast, and the

historical data must be relatively reliable and complete. These demands on the data tend to constrain somewhat the usable range of explanatory variables. Because we are primarily interested in accuracy in forecasting changes in, rather than levels of, activity, we explored the use of those variables that have been shown in previous studies to be of primary importance in conditioning air travel demand and are, in addition, capable of being forecast. These variables included the following:

- Flight frequency
- Aircraft size
- Fare
- Distance
- Incomes at origin and destination
- Population at origin and destination
- Travel time.

Considerable evidence indicates that the demand for air travel is largely dependent upon these variables. Although variables like population and income are proxies for a variety of the attributes of origin and destination or the attributes of the traveler, portraying demand in a more detailed way could be more accurate. However, because of the diversity of the motivations of transoceanic tripmaking, the poor quality of data for certain markets, and the large number of markets to be modeled, the variables in the above list composed the primary demand exploration effort.

We found that a concept of route capacity that combined flight frequency and aircraft size was a more significant explanatory variable than considering the variables separately. Moreover, the high correlation between distance, fare, and travel time encouraged us to eliminate the latter as a variable in the model. We also developed a novel procedure that permitted us to estimate price elasticities using distance data.

The forecast development proceeded, then, with a simple model incorporating the effects of demographic and economic factors on the air carrier industry. Basically, the model consists of a passenger demand relationship and a flight cost relationship. The demand relationship relates scheduled passenger trips (Q) per period on a route to the average fare (P), the number of flights (F), the size of the aircraft (S), the product of per capita incomes in the origin and destination region (Y), and the product of populations in the origin and destination region (X).

The supply side of the market is summarized in a relationship explaining how air carrier costs are related to the flight offered. The flight cost relationship recognizes that the cost (C) of flights on a route depends on the number of flights (F), the average size of the aircraft (S), the stage length (D), and the price of fuel per gallon (G).

The air carriers are assumed to be cost-conscious in their decisions as to what size aircraft to use and what number of flights to dispatch per period. The air carriers are assumed to make adjustments in their fleet with a lag. Fares are also assumed to be adjusted by the carriers with a lag; the previous year's revenues and costs are compared, and fares are adjusted in attempts to maintain a normal profit margin.[1]

The entire structural system is of the form:

$$Q_t = dP_t^b (F_t S_t)^c Y^e X^f \quad , \tag{1}$$

$$C_t = gF^a S^h D^i G^j \quad , \tag{2}$$

$$\left(\frac{P_t}{P_{t-1}}\right) = \left(\frac{P_t^*}{P_{t-1}}\right)^n \quad , \tag{3}$$

$$\left(\frac{S_t}{S_{t-1}}\right) = \left(\frac{S_t^*}{S_{t-1}}\right)^m \quad , \tag{4}$$

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[1] The model assumes a Koyck distributed lag in the size and fare adjustment portions of the model--that is, the desired quantity and the actual quantity are adjusted using weights distributed over previous year's information. The weights decline exponentially over time. The nearest year's weight is estimated as part of the model.

In the above equations, a cross indicates the desired level.

Using the assumed behavioral characteristic of profit consciousness, one can derive desired levels of Q, F, S, and P in terms of the other variables by forming the project function, differentiating it with respect to the service variable, and solving for the optimum value in terms of the other variables. Relationships between these and other variables are parameterized econometrically over a sample of routes (a cross section). The econometric procedure used was the two-stage least squares procedure. This procedure was necessary because of the simultaneity of the structural equation system. The structural system was estimated in a reduced form consisting of relationships between the endogenous and exogenous variables of the system. To eliminate collinearity in the system, a relationship between average fare (P) and distance (D) of the form $P = kD^1$ was substituted for P. The estimated equations were of the form detailed below.

$$F = K_1 D^{A2} S^{A3} Y^{A4} X^{A5} g^{A1} G^{A6} \ * \quad , \tag{5}$$

$$Q = K_2 D^{A8} S^{A9} Y^{A10} X^{A11} G^{A7} G^{A12} \ * \quad , \tag{6}$$

$$S = K_3 D^{A14} S_{t-1}^{A15} F^{-A16} Q^{N7} g^{A13} G^{A18} \ * \quad , \tag{7}$$

$$C = K_4 D^{A19} S^{A20} G^{A21} \quad , \tag{8}$$

$$P = K_5 F^{A22} \cdot \frac{C}{Q} \quad . \tag{9}$$

These equations are derived from Equations (1) through (4), so that:

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* Since the data base was a cross section, these variables and their parameters did not enter in the estimation. However, their values can be determined by using the estimates of the structural parameters.

$$A1 = \frac{b}{(a-c)}$$

$$A2 = \frac{\ell(b+1)-i}{a-c}$$

$$A3 = \frac{c-h}{a-c}$$

$$A4 = \frac{e}{a-c}$$

$$A5 = \frac{f}{a-c}$$

$$A6 = \frac{-j}{a-c}$$

$$A7 = \frac{ab}{a-c}$$

$$A8 = \frac{\ell(ab+c)-ic}{a-c}$$

$$A9 = \frac{c(a-h)}{a-c}$$

$$A10 = \frac{ea}{a-c}$$

$$A11 = \frac{fa}{a-c}$$

$$A12 = \frac{-jc}{a-c}$$

$$A13 = 0$$

$$A14 = \frac{(\ell-1)(\ell-m)}{h}$$

$$A15 = m$$

$$A16 = \frac{-a(\ell-m)}{h}$$

$$A17 = \frac{(\ell-m)}{h}$$

$$A18 = \frac{-j(\ell-m)}{h}$$

$$A19 = i$$

$$A20 = h$$

$$A21 = j$$

$$A22 = a$$

Equations (5), (6), and (7) were estimated using an instrumental variables technique. Equations (8) and (9) were estimated using ordinary least squares.

The structural parameters (a, b, c, d, and so on) can be solved using the reduced form parameter estimates (A1, A2, and so on). A sample of transatlantic routes was used to estimate the parameters of the reduced form equations. These and the implied value of the structural parameters are tabulated in Table B-3.

For forecast purposes, we desired a rate-of-growth forecasting format (rather than an absolute level format) of the model that forecasts rates of growth of the endogenous variables Q, F, and S, as functions of the rates of growth of the exogenous variables Y, X, g, D, and G. Since Equations (5) through (9) are in log linear form, one can show that a rates-of-growth model is of the form:

$$\dot{F} = \dot{g}\,B1 + \dot{D}\,B2 + \dot{Y}\,B3 + \dot{X}\,B4 + \dot{G}\,B5 \quad , \tag{10}$$

$$\dot{Q} = \dot{g}\,B6 + \dot{D}\,B7 + \dot{Y}\,B8 + \dot{X}\,B9 + \dot{G}\,B10 \quad , \tag{11}$$

$$\dot{S} = \dot{g}\,B11 + \dot{D}\,B12 + \dot{Y}\,B13 + \dot{X}\,B14 + \dot{G}\,B15 \quad , \tag{12}$$

where the "dotted" variable refers to the percentage change of the variable return rather than its absolute level, and where,

$$B1 = A1 + A3\,\frac{(A13 - A1A16 + A17A7)}{B16} \quad ,$$

$$B2 = A2 + A3\,\frac{(A14 - A2A16 + A17A8)}{B16} \quad ,$$

$$B3 = A4 + A3\,\frac{(A17A10 - A16A4)}{B16} \quad ,$$

$$B4 = A5 + A3\,\frac{(A17A11 - A16A5)}{B16} \quad ,$$

$$B5 = A6 + A3\,\frac{(A18 - A16A6 + A17A12)}{B16} \quad ,$$

$$B6 = A7 + A9\,\frac{(A13 - A1A16 + A17A7)}{B16} \quad ,$$

Table B-3

MODEL PARAMETERS

Estimated	Derived	Economic Interpretation
A2 = -0.6277	A1 = -0.7522	--
A3 = 0.4599	A6 = -0.4144	--
A4 = 0.8636	A7 = -0.7971	--
A5 = 0.5317	A12 = -0.3337	--
A8 = -0.5918	A13 = 0	--
A9 = 1.307	A18 = -0.1013	--
A10 = 0.9359	A22 = 1.0598	--
A11 = 0.5635	a = 1.0598	Returns-to-scale factor
A14 = 0.0125	b = -0.1915	Price elasticity of demand
A15 = 0.2857	c = 0.8052	Flight elasticity of demand
A16 = -0.7300	e = 0.2199	Income elasticity of demand
A17 = 0.6687	f = 0.1359	Population elasticity of demand
A19 = 0.8713	h = 0.7436	Size elasticity of flight cost
A20 = 0.7436	i = 0.8713	Distance elasticity of flight cost
A21 = 0.1055	j = 0.1055	Fuel price elasticity of flight cost
	ℓ = 0.8843	Elasticity of fare with distance
	m = 0.2857	Fraction of undesired fleet that can be adjusted in one year

$$B7 = A8 + A9 \frac{(A14 - A2A16 + A18A8)}{B16} ,$$

$$B8 = A10 + A9 \frac{(A17A10 - A16A4)}{B16} ,$$

$$B9 = A11 + A9 \frac{(A17A11 - A16A5)}{B16} ,$$

$$B10 = A12 + A9 \frac{(A18 - A16A6 + A17A12)}{B16} ,$$

$$B11 = \frac{(A13 - A1A16 + A17A7)}{B16} ,$$

$$B12 = \frac{(A14 - A2A16 + A17A8)}{B16} ,$$

$$B13 = \frac{(A17A10 - A16A4)}{B16} ,$$

$$B14 = \frac{(A17A11 - A16A5)}{B16} ,$$

$$B15 = \frac{(A18 - A16A6 + A17A12)}{B16} ,$$

$$B16 = (1 - A15 - A17A9 + A16A3) .$$

In addition, changes in average flight cost ($\dot{C}$), economy fare ($\dot{P}$), and average load factor ($\dot{ALF}$) can be calculated using the following equations:

$$\dot{C} = \dot{D}\ A19 + \dot{S}\ A20 + \dot{G}\ A21 + g , \quad (13)$$

$$\dot{P} = \dot{F}\ A22 + \dot{C} - \dot{Q} , \quad (14)$$

$$\dot{ALF} = \dot{Q} - \dot{F} - \dot{S} . \quad (15)$$

Again, the "dotted" variables indicate rates of change rather than the absolute level of the variable. These rates of growth are used to generate expected future activity levels by applying them (compounded) to a known base.

The validity of the model is evidenced in several ways. First, the estimated relationships describe the sample data with quite acceptable levels of confidence. Considering the cross-sectional nature of the sample, the t-statistics of the individual parameters and the coefficients of determination are very high, indicating high reliability.

Second, the estimated coefficients of the model are consistent in sign and magnitude in every case with what theory would indicate. For example, the returns-to-scale parameter (a) is roughly 1.06, indicating moderately decreasing returns to scale. This parameter value is consistent with the nature of the air carrier production process, which entails heavy outlay in flight expenses (aircraft, crew, fuel, and the like) versus ground expenses, thus making most expenses proportional to the scale of operation. The average price elasticity of demand (b) for total scheduled traffic was estimated to be roughly -0.19. This indication of low elasticity is supported by evidence from other researchers studying international air travel demand.[1] In addition, estimates of some parameters, such as L (the elasticity of fare with distance), while estimable via the model, are also directly estimable,[2] and a comparison permits an internal cross-check. The model estimates an elasticity of 0.8843, while direct estimation implies a value of 0.883. Other values, while not justifiable directly, are of a reasonable magnitude and the proper sign.

Finally, the model was used to "backcast" historical events, and the actual and forecast estimates were compared. The model functioned well in this aggregate test.

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[1] See, for example, Kanafani et al., Demand Analysis for North Atlantic Air travel, ITTE, Special Report, University of California (April 1974). This study, performed for IATA, found elasticities of total traffic in the range of -0.1 to -0.3 for various fare types (see Table B-12).

[2] Fare data are not needed to estimate the model. Hence, a sterile check on the validity of the model's internal estimate of L is to estimate $P = kD^L$ directly from data on P and D from the sample used. The result was $P = 0.3198\ D^{0.883}$ ($R^2 = 0.9851$).

The forecasting system SRI developed in this research was used initially to develop forecasts for the Atlantic basin and then to forecast aircraft hours by aircraft type for the High Altitude Pollution Program (Report No. FAA-AVP-76-18). This same forecasting system was then used to develop forecasts for the Indian and Pacific basins. However, we did test the feasibility of reestimating the model parameters using data specific to the Indian and Pacific basins because:

- The differences in the structure and economic circumstances of air travel between the Atlantic basin and the Indian and Pacific basins may affect some parameters
- The presence of large non-IATA carriers (charging nonconference rates) such as Cathy Pacific may alter the parameter assumptions inherent in the model developed for the Atlantic basin.

Upon reestimating the parameters of the model, the basic assumptions of the original model were not contradicted. Furthermore, the reestimated parameters were found to be statistically unreliable, justifying the use of the more reliable original parameters, that were found superior from both a statistical and a conceptual point of view. Thus a single model was used globally.

The primary reason why the reestimated parameters were unsatisfactory is because available data for the Indian and Pacific basins are too aggregated to truly represent origin and destination characteristics. Specifically, the model is structured in a way which assumes that the economic and demographic conditions at the end points of a trip are factors that determine the level of activity observed between the two points. However, the only useful traffic flow data base is ICAO aggregate passenger flows by segments between specified city pairs rather than true origin-destination data. For example, available data do not allow the model to treat Tokyo and Hong Kong as major gateways to other destinations in the Pacific basin such as Bangkok or Jakarta or Calcutta, but rather as ultimate destinations. This skews

the estimation process toward lower income and population elasticities than would otherwise be the case.[1]

(2) Forecasting the Dimension of Charter Air Passenger Service

Charter air passenger services have grown rapidly, particularly in the dense North Atlantic markets. The significance of charter carriers in the transoceanic routes is strongly dependent on the attitudes of participating countries toward such services.[2] With the current overcapacity that characterizes most international carriers, "scheduled" carriers may tend to resist the inroads of charter carrier competition while offering their own capacity at a lower rate.

If future bilateral agreements contain significant restrictions on the use of charter service, the dimension and quality of these restrictions will obviously influence the level of charter services offered and consumed. It is our expectation, however, that in the future formal agreements will be negotiated for charter services either as one package or as clearly recognized parts of the bilateral agreements.[3] Therefore charter service rights will be protected, and permitted to

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[1] The reason that the elasticities will be lower than they should be is because the traffic from the United States to Bangkok via Tokyo will have to be explained (statistically) by the (higher) U.S. and Tokyo income data. Since the relatively low level of traffic is associated with the (high) Japanese and (high) U.S. income characteristics, the elasticity is interpreted as being low. In fact, if true origin-destination pairs were known, the amount of traffic would appear to be more sensitive to the level of incomes in Bangkok and high elasticities would be estimated.

[2] Officials of Trans International told SRI representatives that the Japanese give preference to certificated carrier charters over charter carrier charters in aircraft landings and takeoffs at places like Tokyo. This is particularly important because the hours of operation at many points, including Tokyo, are limited by curfews.

[3] The recent US/UK bilateral, Burmuda II, while not adopting a firm timetable for negotiation of charter rights, did apparently agree that such rights should be formally negotiated.

grow normally.

The IAC model that is described earlier operates at present on the basis of OAG (Official Airline Guide) scheduled flight data when calculating the placement of aircraft over the globe. Incorporation of "nonscheduled" activity in the IAC model, at the same level of precision as "scheduled" activity, requires flight itinerary data in a format similar to OAG data. Unfortunately, such precise data are not available for the "nonscheduled" portions of the market. Hence, our IAC modeling and our activity forecasting for this segment of the market are necessarily imprecise.

Charter markets have evolved to permit sellers to differentiate the trip product and to sell trips to users with a willingness to trade convenience for price reductions. A charter passenger is selected for his reluctance to pay high prices and his willingness (or ability) to bear the "scheduling" inconvenience associated with the terms of the charter passage. This fare structure is what economists call third-degree price discrimination; a small number of markets are identified, and the fares charged in each market are determined with price elasticities of the various markets in mind. The prices charged by a price discriminator are related to the elasticities of demand associated with the travelers in each market in the following fashion:

$$\frac{P_1}{P_2} = \frac{(1 - 1/e_2)}{(1 - 1/e_1)} \quad ,$$

where

P_1 = the fare charged to Group One,
P_2 = the fare charged to Group Two,
e_1 = the price elasticity of demand of Group One,
e_2 = the price elasticity of demand of Group Two.

Thus, the higher the elasticity of demand, the lower will be the relative price charged a particular market segment. The large differences in

charter and "scheduled" service fares are an indication of the disparity between the various markets' elasticities (the North Atlantic charter fares have been as little as one-third of the economy fare).

The industry model applied to "scheduled" traffic could be applied just as usefully to charter traffic. Because of the differences in patron sensitivity to price and service, the estimated parameters would be different (A1 through A22). We anticipate different rates of growth of charter activity versus "scheduled" activity if economic forces ultimately prevail; that is, a constant ratio of charter to "scheduled" passenger flight activity would not be in keeping with theoretical expectations.

Ideally, therefore, the relative level of charter and "scheduled" activity should be derived from a model that takes direct account of the different sensitivities of these markets to economic forces. However, the available data did not permit separate specification and estimation of a charter model in the degree of detail offered in the "scheduled" model. Instead, North Atlantic data, a part of which is presented in Table B-4, were used to estimate a relative share model for the Atlantic Ocean basin with the following form:[1]

$$R_{ij} = e^{-5.52} (Y_i Y_j)^{1,763} \quad , \qquad (16)$$

where

R_{ij} is the ratio of charter flights to scheduled flights between geographic areas i and j,

Y_i and Y_j are the per capita GNPs observed at i and j, respectively, in thousands of 1973 dollars.

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[1] The passenger data in the table were converted to flight data using passenger-per-flight information for IATA-member scheduled and charter services. The origin and destination were taken to be North America and Europe, and corresponding per capita GNP averages were developed for each of the data years. The source of the data was SRI's Long Range Planning Service (LRPS).

Table B-4

HISTORICAL LEVELS OF SCHEDULED AND CHARTER ACTIVITY IN THE NORTH ATLANTIC
(Number of Enplaned Passengers, in Thousands)

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Scheduled operators												
IATA scheduled	1,760.0	1,919.5	2,272.2	2,422.2	3,069.2	3,611.3	4,197.5	4,987.4	5,258.1	5,996.8	7,201.0	7,531.9
Non-IATA scheduled Loftleidir	53.0	58.0	69.2	74.6	94.6	128.6	144.4	162.4	164.1	176.3	247.3	262.3
Total scheduled	1,813.0	1,977.5	2,341.4	2,496.8	3,163.8	3,739.9	4,341.9	5,149.8	5,422.2	6,173.1	7,448.3	7,794.2
Nonscheduled operators												
IATA nonscheduled	168.2	256.5	315.2	414.1	482.0	480.5	502.9	517.1	495.1	779.7	816.6	1,059.0
Non-IATA nonscheduled	30.0	30.0	30.0	45.0	174.0	197.5	303.0	510.0	753.0	1,499.3	2,076.0	2,403.9
Total nonscheduled	198.2	286.5	345.2	459.1	656.0	678.0	805.9	1,027.1	1,248.1	2,279.0	2,892.6	3,462.9
Total passengers	2,011.2	2,264.0	2,686.6	2,955.9	3,819.8	4,417.9	5,147.8	6,176.9	6,670.3	8,452.1	10,340.9	11,267.1

Source: Journal of Transport Economics and Policy, p. 238 (September 1973).

The charter formulation (formula 16) used in the Atlantic basin analysis was conceived with the aim of replicating relatively high levels of charter activity observed in the basin while being sensitive to factors which influenced the charter share of total activity.

The Indian and Pacific basins appear to be characterized by considerably lower charter shares. As Table B-5 indicates, the reported shares of charter activity are generally lower in this basin than elsewhere. However, the data in Table B-5 are very rough since there is incomplete reporting and less consistent membership of carriers in international aviation organizations.

Table B-5

ESTIMATES OF THE SHARE OF CHARTER ACTIVITY IN SELECTED AREAS

Route or Area	Charter Share* (Percent)
North America/South America	3.2
North America/Central America	9.7
North Atlantic	7.8
Mid Atlantic	2.0
South Atlantic	3.8
Europe-Northern Africa	1.4
Europe-Southern Africa	1.9
Europe-Middle East**	4.3
Europe-Far East and Australasia**	3.3
South Pacific**	4.8
Within Far East and Australasia**	4.4

* Defined as the ratio of available tonne-kilometers delivered in nonscheduled and scheduled services.

** Routes included in the Pacific and Indian basins.

Source: IATA Statistics

Moreover, the ICAO "nonscheduled" data, the only charter data that are available for the Indian and Pacific basins, are by nationality of carrier and not specific to routes. Therefore it is thus not possible to estimate a model specific to these basins. However, the use of a different model specification permits some accommodation of the forecasting process to the circumstances of the Indian and Pacific basins. A semilog formulation permits simulation of relatively rapid early growth from the low base with a tapering of the rate of increase of the charter share. This formulation was:

$$R_{ij} = A + B \log Y$$

where

$A = -0.45$
$B = 0.299$
$Y = Y_1 Y_j$ (see formula above)

This format was used to generate basic year charter shares in the Pacific and Indian basins by region pair. These shares were then increased at a rate implied by a rate-of-change transformation of the basic model.

These charter models do not embrace all of the demographic forces that act upon this ratio in an environment of relatively free entry of charter services. They do recognize the basic dependence of charter services on fairly highly developed and "wealthy" markets; for a product like air transportation services to be profitably differentiated, the market must be extensive enough to permit the simultaneous offering of a wide variety of fare and convenience/inconvenience combinations. As the size of the coefficients on the GNP terms indicates, the proportion grows rapidly with growth in the potential for an extensive market. From the data, however, a saturation point appears evident even in a relatively "free" market such as the North Atlantic.

This formulation of charter activity essentially treats the

relative extent of charter activities as independent of the level of "scheduled" activity. Obviously, this is not precisely the case; there is some degree of substitutability between the "scheduled" and charter markets, and a certain portion of the observed charter traffic was diverted from "scheduled" service. However, some of our statistical evidence indicates that the level of substitutability is not high. For example, the "scheduled" demand elasticity (estimated at -0.19) is very low, indicating that the "scheduled" demand market is relatively insensitive to fare. Kanafani, who estimated the fare elasticity for the entire (scheduled plus charter) market, found the overall elasticity to be similar (-0.12).[1]

Moreover, when the level of "scheduled" flights is included in the formulation in Equation (16), while the coefficient is the expected negative sign (that is, as "scheduled" flights increase, ceteris paribus, charter flights decrease, and vice versa), it is much smaller than would be expected if there were one-to-one displacement of charter activity by "scheduled" flight activity. With a relative level of charter-to-"scheduled" service of between 0.10 and 0.25, the elasticity coefficient should be between -4 and -10; instead, it is only around -1.3 and, due to the small sample, is not a significant estimate.

Thus, while there is some substitutability between charter and "scheduled" traffic, the data do not indicate a strong relationship, and we will proceed with our forecasts using the "scheduled" and charter models as if they could be operated independently.

This estimated relationship between charter and scheduled flights was embedded in the forecasting portion of the model to permit differential forecasting of charter flight activity growth.

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[1] Kanafani, et al., op.cit.

(3) Forecasting the Dimension of All-Cargo Flight Activity

The factors influencing cargo activity are similar to those influencing passenger flight activity; the fundamental demographic factors of income and population and shipper sensitivity to tariffs and service level condition the level of activity demanded and supplied. As with charter activity, we decided to parameterize a simple model that related the rate of growth of cargo flight activity to the rate of growth of passenger flight activity. This decision was made because of the difficulty of parameterizing a separate, complete model in the degree of detail of the "scheduled" passenger model.

Using data from IATA on the North Atlantic, we econometrically derived a relationship of the following form:

$$\dot{CGO} - \dot{SF} = 0.1136 - 0.4172\dot{S} - 1.110\dot{Y}$$

where

$\dot{CGO} - \dot{SF}$ is the difference in the rate of growth of all-cargo flights and scheduled passenger flights,

$\dot{S}$ is the rate of growth of scheduled passenger aircraft size,

$\dot{Y}$ is the sum of the rates of growth of per capita GNP in the United States and Europe.

The model was tested by using this relationship to predict the actual relative rates of growth of all-cargo and scheduled passenger flights in the North Atlantic. This yielded results quite close to actual. The difference in actual rate of growth of flights in all-cargo versus scheduled passenger service (per annum, 1962-1972) in the North Atlantic was 0.0151; the <u>forecast</u> was 0.0167.

This model, too, was embedded in the forecasting module of the IAC model, permitting differentiation between the forecast rates of growth of cargo and passenger flights. The cargo rate of growth was

constrained to be greater than or equal to the rate of growth of scheduled flights.

(4) Forecasting General Aviation Activity

At the time our forecasting methodology was being developed, data on worldwide general aviation activity were not available because no system existed for collecting the data on a worldwide basis, although the FAA, the International Civil Aviation Organization (ICAO), the Aircraft Owners and Pilots Association (AOPA), the General Aviation Manufacturers Association (GAMA), and others were attempting to generate interest in developing general aviation data capability.

Most countries do not develop or record much data on general aviation. ICAO discussed this circumstance at its last division meeting in October 1975. AOPA is trying to interest ICAO in a study of the number of pilots and hours flown in general aviation by country, and GAMA wants to expand the relevance of general aviation data by setting up an international organization and becoming part of ICAO. The only data on general aviation (Table B-6) that could be supplied by ICAO are total world data (excluding the USSR and the People's Republic of China) on aircraft, pilot licenses, and flight hours.

Table B-6

TOTAL WORLD GENERAL AVIATION ACTIVITY

	1970	1971	1972	1973	1974
Aircraft (thousands)	170	197	205	219	230
Hours flown (millions)	31	33	33	36	38
Private pilot licenses (thousands)	450	470	500	530	550

Note: Excludes USSR and the People's Republic of China.

Source: ICAO

Officials at GAMA and AOPA expressed some concern over the validity of even this roughly aggregated information.[1]

The best statistics on general aviation activity are those developed by the FAA as part of facility activity statistics and instrument flight rule traffic statistics for the U.S. Air Route Traffic Control Centers. These statistics do not, however, permit direct analysis of the pattern of general aviation activity in a manner directly amenable to incorporation in an IAC calculating procedure. Route activity data are required for such a procedure; even most of the available U.S. data are in the form of activity measures (departures, operations, overs, and the like), undifferentiated by routing characteristics of the flights except for differentiations between local and itinerant airport operations [or in the case of instrument flight rule (IFR) data, domestic and oceanic overs]. Some of the most recent data are also disturbed by the events of the recent energy crisis.[2]

Economic analyses of general aviation activity have been performed using U.S. data, and the level of general aviation activity in a region has been found to be related to many of the same demographic forces that determine air carrier activity levels. Baxter and Howry,[3] for example, found airport general aviation activity levels in a county-by-county cross section to be related to county population, per capita income, and other area demographic quantities, in addition to factors

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[1] This overview of the state of general aviation was developed partly as a result of conversations by project team member D. Gross with the following: K. Gorman, FAA; M. Murtaza, ICAO; B. Wood, GAMA; and C. S. Logsdon, AOPA.

[2] We therefore use pre-1973 (1971) data in our statistical analyses.

[3] N. D. Baxter and E. P. Howry, "The Determinants of General Aviation Activity: A Cross-Sectional Analysis," Transportation Research, Vol. 2 (1968).

related to the convenience of operating general aviation aircraft (the availability of airport facilities, whether or not the facility is shared with air carrier operations, and so forth).

The FAA has developed a U.S. domestic general aviation industry model that attempts to relate activity levels to a slightly different set of demographic variables in a formulation that takes into account pilot and equipment supply variables.[1]

Neither the Baxter and Howry and the FAA models (both oriented toward domestic U.S. operations) nor the data on which they are based are directly useful to the problem at hand; we must be able to forecast the level of general aviation activity between various world regions. The evidence from previous forecasting efforts, however, suggests that a formulation for general aviation activity between two points or regions might incorporate the following hypotheses:

- General aviation activity is, to some degree, competitive with commercial air carrier activity. We expect, ceteris paribus, that the level of general aviation activity in a particular market will be inversely related to the convenience and directly related to the price of commercial air carriage.
- Most probably, general aviation activity in a market is positively related to the level of economic activity at the origin and destination of the flight.
- The level of general aviation activity relative to commercial air carrier activity declines rapidly with increases in average flight distance. This is an obvious consequence of the loss of the economic viability of small-gauge aircraft when the stage length is large: The savings in convenient takeoff and arrival times are diluted over a longer total trip time; the generally shorter range of general aviation aircraft requires frequent refueling stops;

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[1] See T. Henry, S. Vahovich, and J. Tom, "A General Aviation Forecasting Model," FAA (processed 7 March 1975).

the consumption of fuel is relatively greater; and the instrumentation required is a more significant component of aircraft utilization charges.

- The fraction of the U.S. general aviation fleet with range capability that is likely to make satellite use immediately practical is small though growing (turbine aircraft grew from 1.95 percent of the fleet in 1971 to 2.38 percent in 1974) as shown in Table B-7.

Table B-7

RANGE CHARACTERISTICS OF THE U.S. GENERAL AVIATION FLEET: 1971

Type	Number Registered*	Average Range of New Aircraft** (miles)
Piston		
1 engine		
1-3 places	44,637	630
4+ places	64,463	831
Multiengine	15,529	992
Turbine		
Turboprop	1,492	1,223
Turbojet	991	2,366

*From the FAA Statistical Handbook of Aviation, Table 9.4 (1972). 1971 figures were used because later data reflect the oil crisis.

**A sales-weighted average from 1970 data in Aviation Week and Space Technology (March 8, 1971).

- The way in which general aviation activity will contribute to the loading of a communications network is unclear because one may argue that many of the advances of general aviation services (permitting unusual takeoff and arrival times, permitting service to noncommercially served airports and regions,

and the like) will load communication links at a time when commercial loads are low. On the other hand, the performance characteristics of general aviation aircraft differ from those of typical commercial aircraft on a route, so that while their takeoff and arrival times may be asynchronous with that of commercial activity, their flight paths may be synchronous.

To accommodate our forecasting efforts to the limited data available, we constructed a compromise general aviation forecasting relationship with the following form:

$$R_{ij} = aD_{ij}^{b}(P_iP_j)^{c}(Y_iY_j)^{d} \quad , \tag{17}$$

where

R_{ij} is the peak month level of general aviation departures between regions i and j,

D_{ij} is the distance between i and j in kilometers,

P_i is the population of origin i in millions,

P_j is the population of destination j in millions,

Y_i is the per capita income of origin i in dollars,

Y_j is the per capita income of destination j in dollars,

a, b, c, and d are parameters to be estimated.

Since no general aviation data exist on an origin/destination basis for international movements, the above equation could not be estimated directly, so values of the parameters had to be inferred from the scant available data and some transformation of the results of previous analyses. The assumed values of the parameters and their sources are detailed in Table B-8.

Little can be done to check the validity of this formulation directly because we have no accessible information on total general aviation traffic flows between points on the globe. However, an indirect check is possible by using the model to forecast the aggregate level of U.S. domestic general aviation activity. Statistics on estimates of this activity are available from the FAA. The results of this effort are detailed below.

Table B-8

PARAMETERS OF THE GENERAL AVIATION ACTIVITY FORECASTING MODEL

Parameter	Value	Source
c d	0.37 0.74	These parameter values were adapted from the coefficients associated with similar variables in the econometric study of U.S. general aviation activity by Baxter and Howry.* Since they did not use the product formulation used in our Equation (1) their coefficients had to be divided by 2.0 to conform with the origin/destination formulation. This is legitimate, since $(P_i P_j)^{m/2} = (P_i)^m$, when $P_i = P_j$, as in their formulation.
b	-3.39	This parameter was estimated by assuming that the departure stage length distribution of general aviation flights was distributed in the same fashion as the range capabilities of the aircraft themselves. Thus, if X% of the general aviation fleet has a range capability of 2000 miles, it is assumed that flights of this length are in the same proportion to total flights. Using the data on the composition of the U.S. general aviation fleet** and data on the range characteristics of these aircraft types, a simple log linear regression was run on the number of aircraft against the range. The exponent of range is used as an approximation for b.
a	1.72×10^7 to 3.45×10^7	The value of this parameter was estimated by obtaining a professional assessment of the percentage of North Atlantic flights that could be attributed to general aviation. The National Business Aircraft Association (NBAA) estimates that general aviation (corporate and executive aircraft) activity represents the equivalent of about 1% to 2% of scheduled activity in this market. Since in 1970 the peak month scheduled activity between North America and Europe was roughly 3000 flights in the West-East direction*** and the population and per capita income of Europe and North America are known, an approximation of the parameter "a" can be solved for directly.

* See Baxter and Howrey, op.cit.
** See Table III-4.
*** SRI-derived information from manipulation of ICAO data tapes.

The SRI forecast and FAA estimates of general aviation operations for the United States for 1971 were as follows: SRI forecast--4,683,000 operations per peak month; FAA estimates 3,366,716 operations per average month. The source of the FAA estimates operations data is the FAA Statistical Handbook of Aviation, p. 215 (1972). Since SRI's forecasts are for departures, forecast departures were converted to operations were used:

$P_i = P_j = 206.4$ (millions) [Source: SRI-LRPS]

$Y_i = Y_j = \$5,624.5$ [Source: SRI-LRPS],

$D_{ij} = 250$ kilometers [the average stage length per departure was calculated from total general aviation operations and total mileage data in the FAA Statistical Handbook of Aviation, pp. 215 and 227 (1972)].

Note: The lower value of $a = 1.72 \times 10^7$ was used in this calculation.

Reasonably close correspondence exists between SRI forecast and FAA estimates of activity. While we recognize the shortcomings of such a test of the model, a preferred version requires data that are currently not available. Therefore, this report contains interregional general aviation activity forecasts that are based on the formulation described above.

(5) Forecasting of Military Airlift Command (MAC) Charter

As was anticipated, the data available on military charter movements in the basins of interest were extremely sketchy. The Headquarters of the Military Airlift Command, Scott Air Force Base, was contacted to explore the possibility of obtaining a transformation of their activity data base into a data format of use to our counting model. Unfortunately, for reasons not clear to us, the data, though in existence, were not made available. We did obtain, however, aggregate statistics on the outbound and inbound passenger traffic for the Atlantic area. We were advised[1] to use a factor of 185 passengers per plane in converting from passenger to flight frequency estimates.

We devised an allocation procedure that used the little subjective information available to allocate this activity on a macro-interregional basis. The allocation procedure had the following format:

$$R_{ij} = \frac{M_{ij} T_{ij}}{N_{ij}} ,$$

where

R_{ij} = the ratio of MAC flights to scheduled flights between region i and region j,

M_{ij} = the fraction of total MAC flights represented by MAC flights between i and j,

N_{ij} = the ratio of scheduled flights between i and j to the scheduled flights between the United States and Europe,

T_{ij} = the ratio of MAC flights to Europe, to scheduled traffic to Europe.

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[1] By J. Reynolds, Headquarters, Military Airlift Command, Scott Air Force Base.

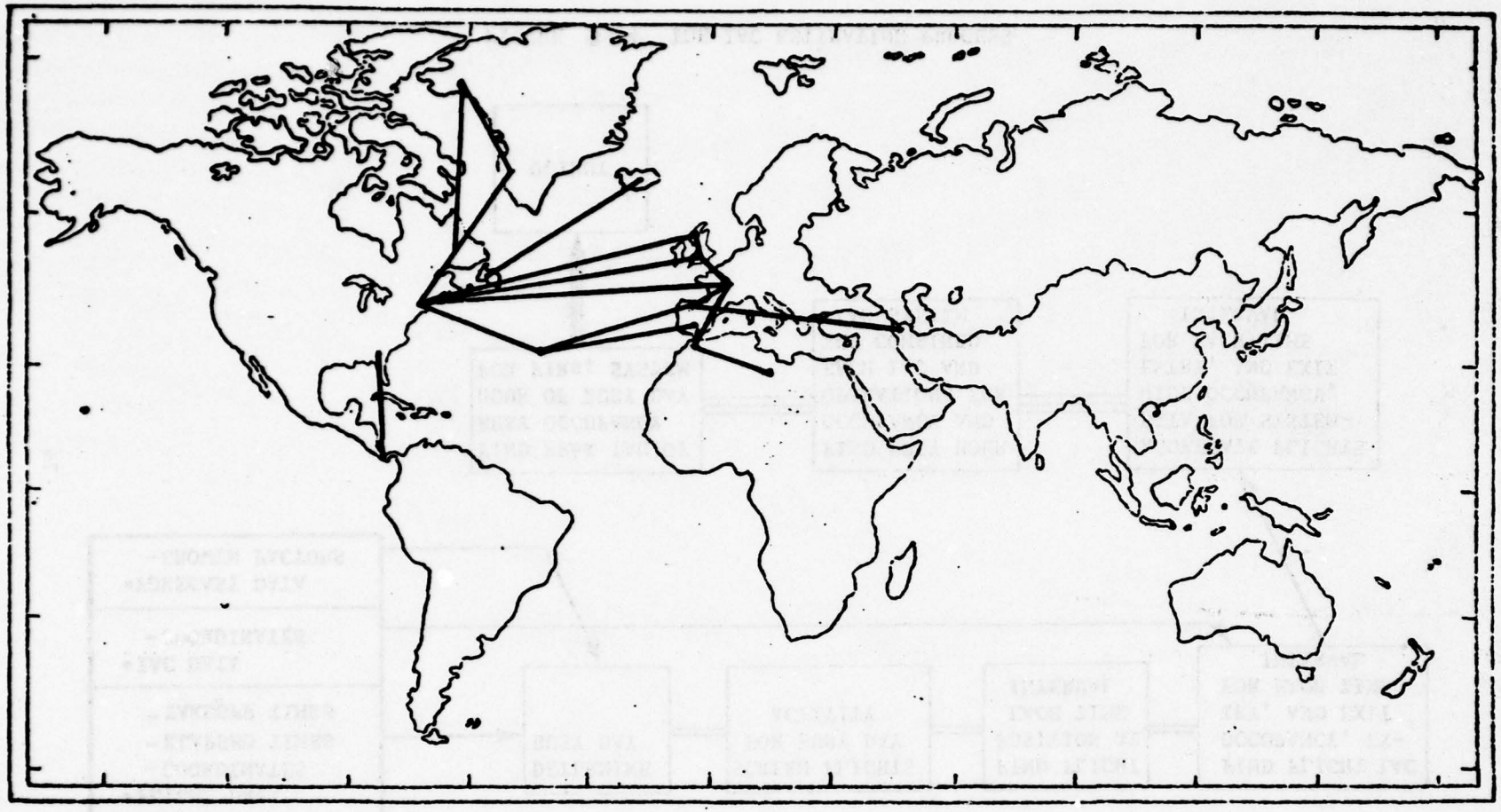
The U.S.-to-Europe base in this calculation was used because we had general evidence on the annual level of these flights. Only U.S.-to-theater movements were assumed; no intratheater movements were assumed. The various ratios assumed in the calculations are presented in Appendix C to the Atlantic Basin Report. No growth in the number of flights was assumed; however, the growth in the average aircraft size available for MAC charter allows a modest increase in the passenger movement under most scenarios. Figure B-3 illustrates the major Atlantic area MAC routes.

c. Instantaneous Airborne Count Estimation Methodology

SRI has developed a methodology for estimating peak IACs over a specified geopolitical region. The methodology is based on a computerized flight-tracking model that yields communication workload measures which include the density of individual aircraft over a particular region at specified, discrete points in time, and the rates at which aircraft enter and leave the regional airspace at these times. A flowchart showing the sequential behavior of this process appears in Figure B-4.

The methodology can be used to evaluate the sensitivity of air traffic flow to changes in satellite coverage and FIRs boundaries, to estimate satellite channel or alternative communication system capacity, and to estimate workload requirements of various ground control/communication stations. Potential applications of the methodology include an interface with automatic plotting packages to produce instantaneous aircraft location plots and alphanumeric information on a two-dimensional map, and the uses of the system's data base to test and evaluate the impact of airline schedule changes on the oceanic air traffic environment.

This discussion focuses on the application of the IAC forecasting methodology for the Atlantic, Indian and Pacific Ocean basins and their constituent IAC areas. These are shown in three maps that appear as Figures 3, 9, and 24 in the Summary Report.



Source: U.S. Congress, House Armed Services Committee Hearings, MILITARY AIRLIFT 1970, No. 91-511

FIGURE B – 3 MAC INTERNATIONAL CONTRACT CARRIERS--MAJOR ATLANTIC FLOW PATTERNS: 1970

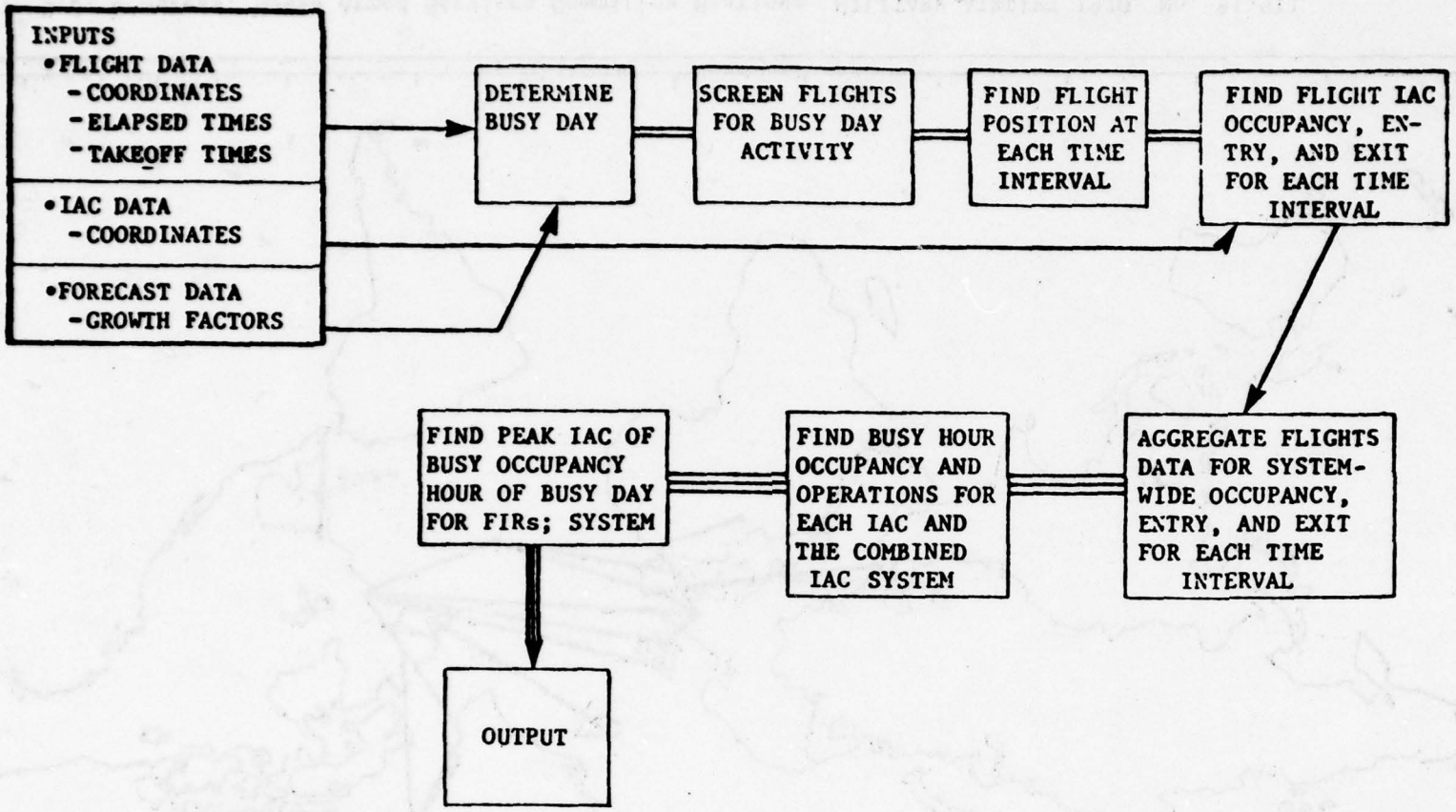


FIGURE B-4 THE IAC ESTIMATION PROCESS

Inputs to the IAC module are the boundary coordinates of each basin and each IAC area within each basin, origin and destination region coordinates, takeoff day, takeoff time, and elapsed time for each flight over the three ocean basins and forecast growth factors from the econometric model.

The Mercator projections of IAC area boundaries are restricted by computer requirements to rectangular shapes, but nonrectangular regions such as FIRs can be approximated by subdividing the FIR into rectangular components that correspond most closely to desired geographic areas. The user can "redraw" the grids to test various political and operational hypotheses by simply introducing the appropriate coordinate changes to the input set.

The route/region air activity forecasts are read into the model in the forms of multiplicative growth factors. The growth factor for an economic region is applied to the appropriate origin/destination set so that one flight between regions X and Y during the base year (growth factor = 1.0) will be treated by the model as one flight times the flight growth factor for that particular forecast year. If, for example, the flight growth factor between the regions containing X and Y is 1.0 in 1975 and 1.5 in 1990, each flight modeled in 1975 will become 1.5 flights in 1990, with takeoff times, elapsed times, and aircraft locations between origin X and destination Y assumed identical to the 1975 flight. The flight's presence over an IAC area at a particular instant in 1975 will be translated into 1.5 flights at the identical location and time in 1990. Separate runs of the model must be made for each forecast year, or whenever the growth factor input set is changed.

The basin busy day is determined from a data base consisting solely of scheduled airline flight takeoff times and dates adjusted to Greenwich mean standards. The airlines generally change their published flight schedules about four times a year to accommodate

seasonal variations in demand, but little, if any, change occurs in weekly flights within each season. The weekly distribution of traffic is therefore assumed to change only four times a year commensurate with seasonal changes in the OAG schedules, leaving 28 candidate busy days distributed over four season-weeks.

Accordingly, the busy day is defined here as that day from 0 to 2400 Greenwich Mean Time (GMT) during which the "scheduled" airline traffic is the highest.

The busy day defined above is a true, aggregate, systemwide busy day for each basin as a whole that does not necessarily coincide with the component route busy days or the respective IAC area busy days.

A "flight" is defined as the presence of an aircraft over a basin during any one of the seven GMT days making up the busy season-week. An aircraft over the system at 2400 GMT will thus be tabulated as a flight during each of the Greenwich days beginning and ending at that time.

Each flight operating during the busy day is tracked from takeoff to landing by an algorithm that determines its longitude and latitude coordinates at six-minute intervals. Each flight is assumed to follow a great circle track[1] between the takeoff and landing coordinates of each published flight segment making up its routes. Thus, a flight between New York and Rome stopping over in the Azores for fuel will be modeled in two great circle segments: one from New York to the Azores and one from the Azores to Rome. The algorithm itself is a recursive process based on a series of straightforward applications

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[1] If a flight deviates significantly from a great circle route to avoid flying over restricted territory (such as the People's Republic of China or parts of Southeast Asia) the model is incapable of recognizing such deviation.

of spherical trigonometric expressions that uses segment end-point coordinates and elapsed times to find the great circle distance (GCD), outbound heading (OBH), and time-dependent position coordinates of each flight segment.

The process is shown in Figure B-5, in which a hypothetical one-segment route from point A to B is considered.

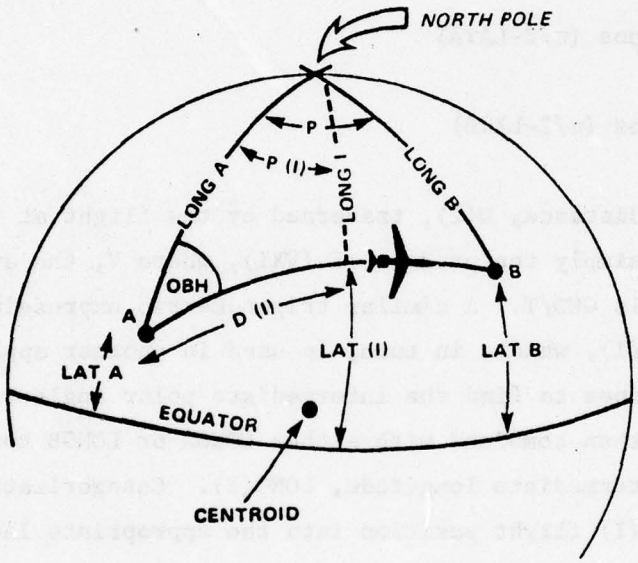


FIGURE B-5 SPACE/DISTANCE RELATIONSHIP FOR A TYPICAL GREAT CIRCLE ROUTE, A TO B

Without loss of generality, it can be assumed that A and B lie in the northern hemisphere and are separated by less than 180° in longitude. The input coordinates are LATA and LATB for the respective latitudes, P for the Longitudinal difference (LONGA-LONGB), and T for the elapsed route time. These are used to find D, the route GCD, which can be obtained from the spherical law of cosines:

$$D = K \arccos (\sin LATA \sin LATB + \cos LATA \cos LATB \cos P)$$

where K, a conversion factor, equals 60 nautical miles per degree of arc length at the earth's surface.

The law of cosines is used again to yield:

$$OBH = K \arccos (\sin [LATA] \cos D + \cos LATA \sin D \sin LATB)$$

where $\sin LATA = \cos (\pi/2 - LATA)$

$\sin LATB = \cos (\pi/2 - LATB)$

The intermediate distance, D(I), traversed by the flight at time I after takeoff is simply the product of (VXI), where V, the average flight velocity, is GCD/T. A similar trigonometric expression combining LATA, D(I), which, in turn, is used in another application of the law of cosines to find the intermediate polar angle P(I) at time I. P(I) is then combined with either LONGA or LONGB to arrive at the desired intermediate longitude, LONG(I). Categorization of each LONG(I), LAT(I) flight position into the appropriate IAC area "box" is accomplished by comparing the position with input IAC area boundaries until the smallest enclosing rectangular IAC area is found.

A six-minute sampling interval, ΔI, is used in the above equations. It represents a trade-off between the high computational costs entailed with successively smaller, more continuous time intervals, and the need to keep the distance flown during the sampling interval small with respect to IAC area dimensions. Large sampling intervals can introduce placement errors that place a flight just across an IAC area boundary when the counting is performed at the end of the ΔI interval, even though the flight occupied space over the previous IAC area during most of the interval. Large sampling intervals can also cause flights to be missed in the counting process when their tracks cross the

corners of the geographic regions. These problems are, of course, more likely to be concentrated in areas of light but nonetheless highly peaked traffic, in which missing or miscounting a flight could lead to significant percentage errors. On the other hand, routes with dense, uniformly distributed traffic flow characteristics will have counting errors at opposite ends of an IAC area that tend to cancel. For example, in the Atlantic region the percentage of lightly traveled routes is not as significant as in other regions, but the large absolute number of such routes still justifies the relatively small counting interval used herein.

The number of aircraft over the individual and combined IAC area at any particular six-minute ΔI interval forms the basis for determining the busy hour in terms of aircraft density over the region. In this process, the instantaneous counting of aircraft in a region at each time interval can be compared to a snapshot taken of the region of interest, with the number of aircraft appearing on the snapshot analogous to the traffic density over the specified area. Each aircraft on the snapshot is assumed to have occupied the region's airspace for 1/10 hour, $\frac{6 \text{ minutes}}{60 \text{ minutes}}$, with N/10 flight hours assumed for all N aircraft in the snapshot. The snapshots are then aggregated into 24 groups of ten to conform to the hourly, on-the-hour distribution of aircraft flight hours, with the highest of the 24 aggregate flight hours defined to be the busy occupancy hour of the busy day.

Equating the busy occupancy hour with the maximum, or peak hour occupancy, is a conservative hedge against the possibilities that an even busier hour can occur during another, nonbusy day in the basin, or "between" hourly measurements taken on the hour. The use of percentile criteria is thus precluded in this methodology, since the 90th percentile busy hour of the busy day could be the 80th percentile busy hour of another day that has several sharp hour-long peaks during periods of prolonged, light traffic density as shown in Figure B-6.

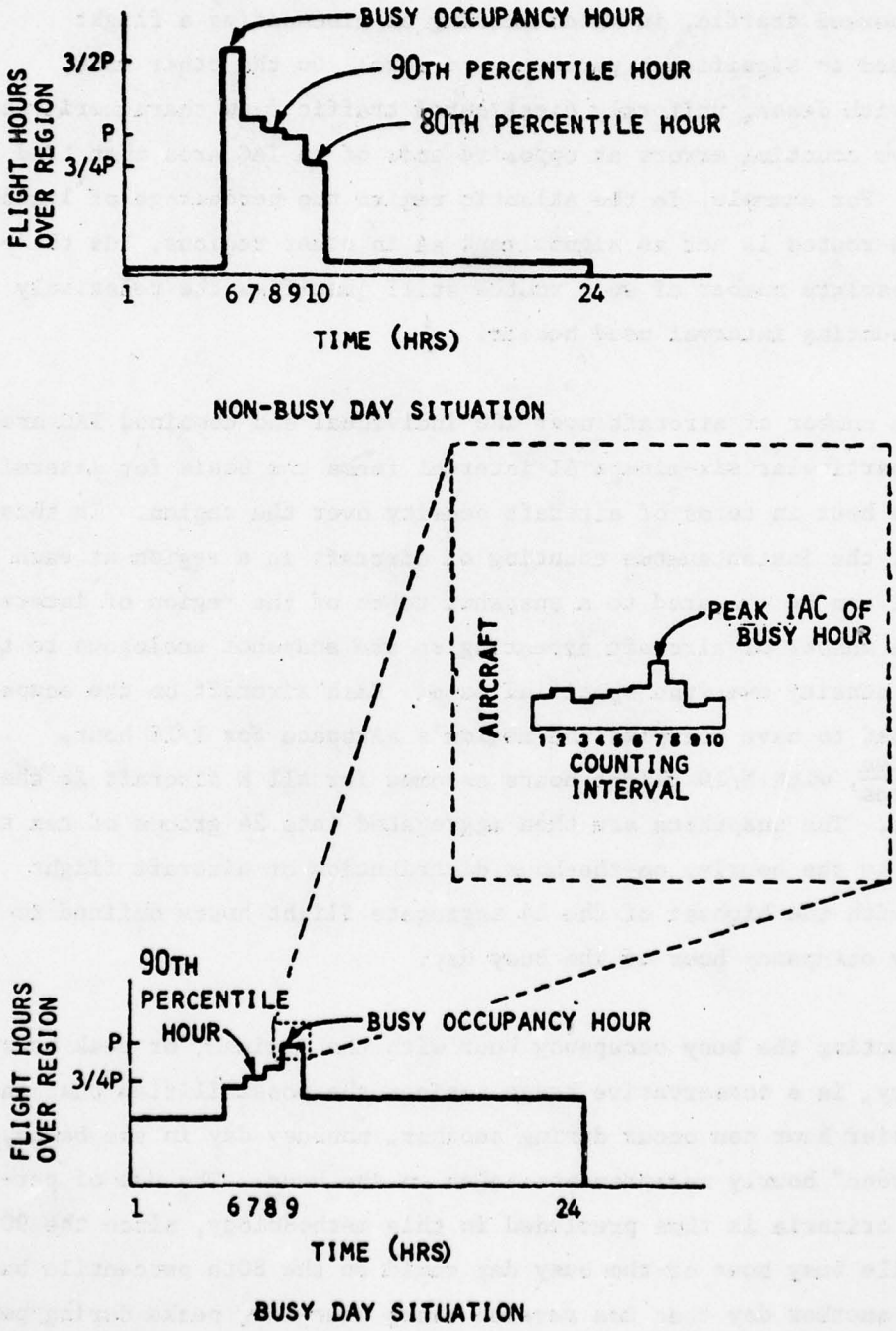
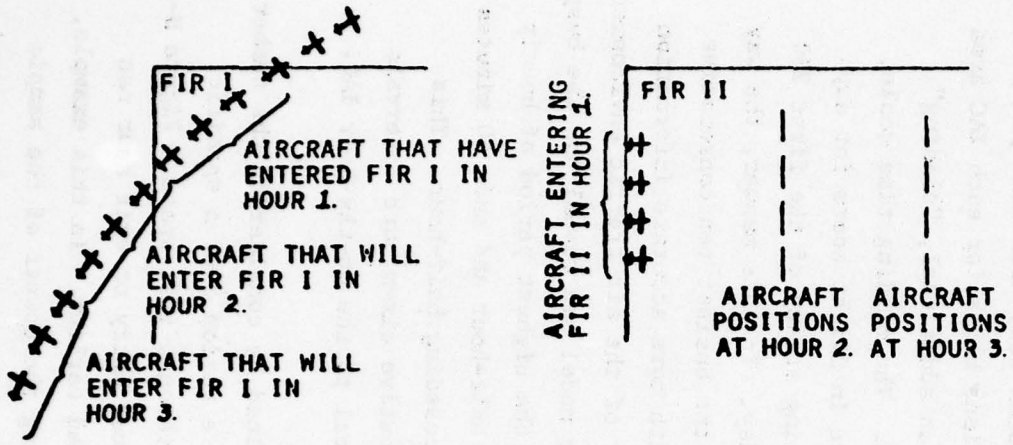


FIGURE B-6 BUSY OCCUPANCY HOUR OF BUSY AND NONBUSY DAYS

The peak IAC of the busy hour of the busy day is defined to be the highest aircraft occupancy, or density, over an IAC area or ocean basin system during the busy hour. It would be found on that particular snapshot, or counting interval, containing the most aircraft of the ten candidate "snapshots" comprising the busy hours, and is the primary exogenous input to the construction of a satellite workload model.

SRI has further modified the conventional busy hour concept by listing the busy aircraft entry and operations hours for each IAC area and for each ocean basin and by including an additional, "sliding" time scale to measure hourly flight counts. The sliding time scale refers to the ability to find the busy hour in flight hours for any ten contiguous six-minute intervals, starting at any of the first 230 counting instants (23 hours) of the busy day. In this manner, the way in which the busy "on-the-hour" hour fits the busiest ten consecutive six-minute intervals can be determined, with more accurate information becoming available on the peaking behavior of the air traffic environment under study. This feature of the counting model can reveal how the busy on-the-hour hour may not even be close to the highest period of hourly activity when that activity begins on the half-hour and ends 60 minutes and 10 counting intervals later on the succeeding half-hour. This means, of course, that the busy ten consecutive six-minute intervals may contain a peak IAC that is not identical to the on-the-hour IAC.

Another type of busy hour can be defined by considering the number of separate aircraft that enter and leave a region over a specific time interval, or the "flow" of aircraft through that space. Figure B-7 and the accompanying table show how the busy entry or exit hour can differ from the busy density hour described earlier. In this example, the steady, dense stream of traffic cutting the corner of the sample IAC I at the rate of four aircraft per hour will equal the entry rate of the fleet entering another IAC area of identical shape and size at Hour 1 on a track that traverses the entire length of the region, but will exceed this entry rate at Hours 2 and 3, when no aircraft enter



Hr.	FIR I		FIR II		SYSTEM (FIR I + FIR II)	
	Entries (a/c per hr.)	Occupancy (Flight-hrs.)	Entries (a/c per hr.)	Occupancy (Flight-hrs.)	Entries (a/c per hr.)	Occupancy (Flight-hrs.)
1	4	4	4	4	8	8
2	4	4	0	4	4	8
3	4	4	0	4	4	8
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.

FIGURE B-7 VOLUME/DENSITY RELATIONSHIPS

IAC area II. Then, the volume at IAC area I, defined to be (entries and exits 12), will be four aircraft per hour for Hours 1, 2, and 3, with an IAC of four aircraft at every six-minute snapshot yielding an occupancy of four flight-hours per region for each hour. IAC area II also shows an occupancy of four flight-hours for all three hours, but it is made up of the same four aircraft, while IAC area I will be occupied by four completely different aircraft at the end of each hour. Then, the busy entry hour of the three-hour, two-IAC area set is Hour 1, while all three hours qualify for the busy occupancy hour.

In certain traffic systems, such as isolated freeway sections of fixed width and no ramps, it is possible to determine the functional form relating volume (operations) to density (occupancy), but the oceanic air traffic system, with its complex, multidirectional tracks, makes it necessary to use a computerized "counter" to arrive at adequate volume measurements. This consists of a simple algorithm that keeps track of each IAC area boundary crossing made by each flight over each basin. Entries and exits for the system and the individual IAC areas are then accumulated for each of the 24 busy day hours and combined in the manner described above to yield volumes. Busy volume and busy entry hours are determined in the IAC model so that planners can, if necessary, develop a feeling for the number of aircraft that may be expected over an IAC area as a supplement to the information available from the occupancy-related (density-related) parameters.

The output from the IAC model includes the following:

- Tables containing the number of flights in the system, the busy entry hour, busy operations hour (volume), and busy "flight" hour evaluated on the hour for the aggregate system and each IAC area; the actual, cumulative entries, operations, and flight hours corresponding to the busy hours above, as well as the peak IAC for each of the busy flight hours.
- Data for histograms showing the percentage of the total flight hours occurring during each of the 24 hours of the busy day

for the aggregate system and each IAC area--essentially a discrete "density function," the sum of its 24 parts yielding unit, of 100 percent, for each distinct region.

- Separate tables showing the IACs for each of the six-minute intervals of the busy day for the aggregate system and each IAC area. These tables can be used to obtain IAC values and distribution information that is not explicitly available in other sections of the model output, such as the IACs for the busy operations and entry hours defined above.

- The starting six-minute time interval for the busiest ten contiguous intervals in each IAC area and for the entire, combined system. This interval number can be cross-referenced with the IAC table as a basis for getting flight-hour information on the ten intervals.

- For the Atlantic basin a set of tables for the IAC areas giving the IAC area entries by the origin and destination code pairs on the world region basis of the OAG codes in Appendix A.

  - For the Pacific and Indian basins, tables showing peaking characteristics of major routes vs all routes for all stage lengths and for flights longer than 400 n.m.

See the Summary Report for the location of these outputs.

d. Special Considerations

(1) Analysis of Restricted Overflights

The objective of this methodology was to determine those flights whose structure was such that it might be changed if it were permitted to overfly the Soviet Union or Communist Asia. The computer was used to remove a list of current flights whose structure surely would not be changed, and the remaining flights were studied for their overflight potential.

The flights were obtained from tape version of the Official Airline Guide. Each record on this tape describes a part of a flight, called here a leg, between two successive cities on the route of the flight. The legs of a given flight number are in sequence by the

three-letter codes of the departure and arrival airports of the legs rather than in sequence of stops (that is, the itinerary sequence).

The tape was processed in two passes by a special program called FILTER. During the first pass, FILTER eliminated from the tape all flights which satisfied any of the following:

- The origin and destination airports of each leg of the flight were in a single, readily checked hemisphere. If a flight was currently contained within the western or southern hemispheres or the hemisphere between 18° east and 162° west lognitude, it was eliminated from consideration.
- The legs could be arranged in a stop sequence and the great circle distance from each airport to the one after the next (if any) was less than 3,000 miles.
- The origin and the destination airports of each leg of the flight were in one of nine hemispheres that approximately bound the land area of the combined Soviet Union and China. The nine hemispheres are determined by great circles.

The output of FILTER formed a data file which contained the approximately 1,547 flights which had passed through these first tests.

Examination of this file indicated that a number of other tests should be applied since the list contained flights which, by inspection, were not candidates for potential overflights or could not be stop sequences. The difficulty in determining the stop sequence of flights was traced to the occurrence in the file of legs showing "discontinue" and "effective" dates which interfered with the ordering of the legs. All flights which had an alternative nonzero discontinue date were eliminated.

The second pass through FILTER also applied the following tests:

- If the airline code was one belonging to a Communist bloc nation (SU, LO, IF, LZ, MA, OK, AY, etc.) the flights were eliminated from the list, since they are not generally overflight restricted.

- Flights of one leg only were eliminated.

- If the country of origin or destination of any leg of the flight was in a current overflight area, the flight was eliminated. This included European Russia, Poland, Czechoslovakia, Hungary, Bulgaria, Rumania, Siberia, China, Mongolia, North Korea, and the Soviet Kuril Islands.[1]

The output of the second pass of FILTER contained 377 flights. It was feasible to review this list by manual means. The examination suggested that the main category of flights that might overfly if

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[1] A considerable amount of overflying already occurs. Also, in those areas where overflying is restricted through higher fees, the privilege may be available to carriers of most countries willing to pay these fees. The following tabulation illustrates the charges currently levied by Vietnam and Laos.

Overflight Charges Levied by Vietnam and Laos

VIETNAM

First 40 tons	$140
41-80 tons	140 + 2.40/ton excess
81-120 tons	236 + 3.00/ton excess
121-160 tons	356 + 3.60/ton excess
161-200 tons	500 + 3.00/ton excess
201 tons and above	620 + 2.40/ton excess

LAOS

First 40 tons	$125
41-80 tons	125 + 2.40/ton excess
81-120 tons	221 + 2.80/ton excess
121-160 tons	333 + 3.20/ton excess
161-200 tons	461 + 2.80/ton excess
201 tons and above	573 + 2.40/ton excess

Approximate charges: Boeing 707 = US$500.
DC10 = US$700-$750: Boeing 747 = US$1,000.

Source: Far Eastern Economic Review, January 1977

permitted is those that are currently routed through Anchorage. There are less than 100 of these. Since the total roster of flights was over 32,000, it was felt that modification of the model to simulate diversion to overflights was not warranted.

(2) Special Route Studies

The format of the model permits identification of region pair contributions to the activity in each of the IAC areas. These data are reported as the number of entries classified by the origin and destination region code of the flight. Since there are 10 world regions identified in the OAG format, there are thus 100 classifications possible.

This classification scheme, while useful in a general sense, is too coarse for analysis in the Indian and Pacific basins because of the number of distinct geographic areas which are aggregated into one of the OAG's world regions. Therefore, in the analysis of these basins, the sensitivity of the flight classification was extended considerably, permitting identification of the contribution of some special routes to the total activity observed in the IAC areas. These routes consist of the pairs of the countries or states shown in Table B-9.

Table B-9
SPECIAL COUNTRY OR REGION PAIRS

Temporary Code[1]	Country or State
1	Australia
2	Hong Kong
3	India
4	Japan
5	Pakistan
6	Saudi Arabia
7	Singapore
8	Thailand
9	Alaska
10	Hawaii

[1] The 10 regional codes used in the main model were employed so that this special analysis could be performed without major modification of earlier programming.

The classification of area entries by these routes was performed separately from the regular IAC model run due to the difficulties of storing the several thousand additional data elements that would be generated each run. The special runs operated on a reduced data base (including only the flights between the pairs identified in Table B-9) for the peak day established for the basin as a whole using all traffic. This permitted a separate calculation of the peaking behavior on these routes which could then be compared with the peaking for the basin using traffic as a whole.

4. SENSITIVITY ANALYSIS

As with any large-scale forecasting effort, the many aspects of uncertainty at each step in the forecasting process msut be assessed and their influence on the outcome evaluated. The sheer quantity of interacting variables in a study of this dimension can make sensitivity analysis difficult; the potential variation in the individual data elements is large enough so that an aggregation based on these variable microelements might be so wide-ranging as to be useless. On the other hand, because we are dealing with aggregation, the law of large numbers can work in our favor if the sensitivity analysis is performed at the aggregative or macro level. We performed sensitivity analysis on two basic aspects of the research: input parameter assumptions and traffic peaking assumptions.

a. Testing of Input Parameter Assumptions

Our demand modeling effort was specifically designed to reduce the number and reasonable range of parametric assumptions. Often in aviation forecasting models the fare, aircraft size, and load factor in addition to demographic variables are inputs to the mode. A "reasonable" range of variation in these three parameters along with the demographic variables in a sensitivity analysis can yield a range of variation in the aggregate traffic forecasts that is so wide as to be useless in analyzing policy.

The forecasting model in this research effort does not require parametric assumptions concerning fare, load factor, or aircraft size. It functions directly from demographic and aircraft cost parameters and simulates the determination of the other three variables, thereby reducing some unnecessary variation. The parametric variation is limited to the following variables:

- Fuel price growth rates
- Per capita GNP and population growth rates for the origin and destination countries.
- Nonfuel cost growth rates.

All monetary quantities are in real (deflated) terms so the analysis abstracts from background levels of inflation. The assumed real rates of growth of these parameters are presented in Table B-10 below.

Table B-10

FARAMETER ASSUMPTIONS OF FORECASTING MODEL

Parameter	Scenario	For Period Ending In: 1980	1985	1990	1995
Nonfuel cost growth	H	1.0	0.0	-1.0	-2.0
	L	2.0	1.5	1.0	1.0
Gross national product growth	H	10% above the base rate			
	L	10% below the base rate			
Population growth	H	10% above the base rate			
	L	10% below the base rate			
Fuel price growth	H	1.0	0.0	0.0	0.0
	L	2.0	2.0	2.0	2.0

Notes: H = high traffic (optimistic) case;
L = low traffic (pessimistic) case

All rates of growth are on a compound annual basis.

All financial rates of growth are in real terms (in 1973 U.S. dollar values).

The base rate referred to is the rate contained in the deomgraphic data base, using SRI sources. Where a 1990-95 rate was not forecast separately, the 1980-85 rate was assumed.

These variables were found to be independent of each other. This enables the forecaster to vary each assumption so that alternative scenarios of the future may be considered. Too frequently, important

variables are not in the model at all or if they are, they are subsumed in other variables where they cannot be separately experimented with by the forecaster. The capability of our model to accept different parameter assumptions reflects the model's usefulness and flexibility.

The methodology is, of course, sensitive to the assumptions made concerning these variables. If, for example, the rate of growth of real fuel prices that is assumed in Table B-10 is incorrect, this will influence the forecast growth rates. Table B-11 below shows what the effect of large errors in parameter assumptions does to the accuracy of the forecasts of flight frequency.[1]

Table B-11

EFFECT OF A 1 PERCENT ERROR IN THE PARAMETERS ON THE FORECAST ANNUAL RATE OF GROWTH OF SCHEDULED FLIGHTS

Parameter	Effect on Scheduled Flight Growth
Fuel price	0.5% error
Per capita GNP	0.8% error
Population	0.5% error
Nonfuel costs	0.7% error

As the table illustrates, large errors in the assumed parameters can have a significant effect on an individual forecast. If all of the parameter estimates were in error, the compound effect could be quite significant. This is a risk involved in any forecasting effort, but there are several aspects of our approach to the problem which mitigate the important of errors:

First, the socioeconomic growth rate assumptions are developed from United Nations data which have proven useful historically.

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[1] For example, if fuel prices are assumed to increase at 1 percent per year instead of 2 percent per year, per annum flight growth rates will be 0.5 percent too high.

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FORECAST AND ANALYSIS OF INTERNATIONAL AIR TRAFFIC IN RELATION --ETC(U)
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Second, while an assumption concerning an individual country's data may be in error, since we are forecasting on a region-to-region basis, the law of large numbers suggests that aggregate forecasts will be more accurate than any one of the individual countries' data. For example, in our assumptions concerning the growth rate of per capita GNP in Europe, we forecast annual growth rates that range from a low of 2.4 percent in a mature economy such as Great Britain to a high of 6.9 percent in younger economies such as Greece and Albania in the 1975/80 period. Being too high or too low for one individual country is not likely to be serious because there is an equal probability that we have erred in the opposite direction in another individual forecast.

Third, because we are forecasting in five-year periods rather than on a year-to-year (or month-to-month) basis, short-run inaccuracy is not crucially damaging to the forecast product. Currently, for example, the United States per capita income is growing at a real rate of over 6 percent per annum in a postrecession recovery. While our forecast (see Appendix B) over the next five years calls for an average rate of only 2.7 percent this is closer to long-term trends than the current rate. A forecast based on the long-term trend is more desirable for our purposes.

The most damaging scenario (i.e., the one that the model would be most sensitive to) is one which involves a worldwide event which causes <u>all</u> of our individual market assumptions to be in error. For example, if there is a significant worldwide boom or depression in our forecast period, all of the growth rates may be in error in a uniform direction. We have accommodated this possibility in our "high" and "low" forecasts by assuming a variation in the growth rates of per capita income and population that is variously 10 percent higher and 10 percent lower than found in Appendix B.

This imposes a significant variation over a 20-year period. For example, if a country's per capita income actually grows at 8 percent

a year over the entire 20-year period, the assumption of a 10 percent higher rate (i.e., 8.8 percent per year) and a 10 percent lower rate per year (i.e., 7.2 percent) brackets the actual level of per capita income by nearly 32 percent over the 20 years. While no accommodation to uncertainty is theoretically ideal, this bracketed assumption is quite generous, particularly since it is applied to all markets over the entire 20-year period.

We allow for even more significant error in the fuel and nonfuel cost growth factors. Assumed nonfuel costs in the "low" forecast case are roughly 1.5 times as large (in deflated dollars) as those in the "high" case after 20 years.

In the case of fuel, the price of fuel in the pessimistic (low) case is 1.4 times that of the optimistic case after 20 years. While there may easily be short-term cases which fall outside of these bounds, we feel that this is a generous "bracketing" of assumptions over the long run.

The net effect of these assumptions is to widen the range of uncertainty somewhat. The sensitivity of the model is such that the high or optimistic traffic estimate for the basin is roughly 1.7 times that of the pessimistic estimate (see Table 3 in the Summary Report, for example). Thus, in spite of relatively generous ranges of parameter assumptions, we have been able to produce controlled bounds on our traffic estimates. This is largely an advantage of the type of model that we have used which permits limiting the number of input parameters. More ad hoc models tend to generate wider bounds[1] which are of less utility in decisionmaking processes.

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[1] The UCLA Delphi study for the Climatic Impact Assessment Program, for example, produced high and low cases that differed by a factor of ten. (USDOT, CIAP Monograph 2, 9/75 pp. 8-67).

b. Testing of Traffic Peaking Assumptions

There is uncertainty at another level in this analysis which is caused by the special dimensions of traffic that we are forecasting, namely the peaking characteristics. This depends in large part on the degree to which the "nonscheduled" traffic flight patterns coincide with the "scheduled" traffic patterns. For reasons discussed in Section 3, above, calculation of peak IAC statistics from incomplete flight schedule data is not possible, and we have made the boundary assumption that the behavior of all nonscheduled traffic components is roughly synchronous with scheduled patterns. Unfortunately, as that discussion indicated, the alternative assumption of completely asynchronous behavior cannot be translated into the assumption that the nonscheduled traffic does not affect the scheduled traffic peak.

The only feasible means of establishing the sensitivity of the activity forecasts to this assumption is to analyze the effects of the *assumption made and the assumption that the nonscheduled segment of* traffic does not contribute to the peaks at all. To do this, we ran separate models:

- An "all-traffic" case which assumes that all traffic has a temporal distribution similar to the scheduled traffic
- A "scheduled traffic only" case which does not include any nonscheduled traffic in the peak counts.

The peak IACs are, of course, quite sensitive to this assumption over a period of twenty years since nonscheduled traffic is a significant component of total traffic. The effect of the different extreme assumptions is to compound the "reasonable" range of variation in the peak traffic statistics. Thus, in addition to a ratio between high and low estimates of about 1.7 caused by the assumed variations in the socioeconomic data, there is a range of variation of 1.6 to about 1.9 caused by the different peaking assumptions (see Table 3 in the Summary

Report). Thus our sensitivity analysis concludes that for peak IAC counts, a reasonable high count is roughly 2.7 and 3.2 times the reasonable low count for traffic in the Atlantic Basin over the full 20-year period. The total range of the variation in actual counts is displayed in Table 3, mentioned above.