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16. ABSTRACT

This study compares airplane productivity and utilization levels derived from commercial airline type schedules which were developed for two subsonic and four supersonic cruise speed aircraft. The cruise speed component is the only difference between the schedules which are based on 1995 passenger demand forecasts. Productivity-to-speed relationships were determined for the three discrete route systems; North Atlantic, Trans-Pacific, and North-South America. Selected combinations of these route systems were also studied. The study also examines other areas affecting the productivity-to-speed relationship such as aircraft design range and scheduled turn time.

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STUDY OF THE IMPACT OF CRUISE SPEED ON SCHEDULING AND PRODUCTIVITY OF COMMERCIAL TRANSPORT AIRCRAFT

E. Q. Bond,* E. A. Carroll,† and R. A. Flume††

SUMMARY

This study is an investigation to determine the impact of cruise speed on airplane productivity within the context of typical commercial airline scheduling. Schedules werer developed by Trans World Airlines, Inc., for North Atlantic and transpacific route systems, and by Braniff International for a North-South America route system. Each route system was scheduled independent of the others for two subsonic aircraft having design cruise speeds of Mach 0.7 and Mach 0.82, and for four supersonic cruise vehicles (SCV's) with design cruise speed Mach numbers of 1.4, 2.0, 2.2 and 2.7.

Schedules for the selected city-pairs of each route system were established based on 1995 passenger demand forecasts. Aircraft routing schedules were developed for each of the different speed aircraft to the same passenger demands with the object being to choose routings that required the fewest number of aircraft. Realistic scheduling criteria were included as much as possible in the scheduling. Based on purely intercontinental flights, high aircraft utilization levels were achieved for each of the different speed aircraft. The schedules show productivity improvement with increasing cruise speed to Mach 2.0 for all route systems. For speeds of Mach 2.0 and above, the productivity levels are approximately double those for the Mach 0.82 aircraft. Maximum productivity is achieved at Mach 2.0 for the North Atlantic routes, at Mach 2.2 for the North-South America routes, and at Mach 2.7 for the transpacific routes. Aircraft productivity analysis indicates the following:

- Increasing cruise speed is an effective means for improving aircraft productivity, but the maximum speed for which significant productivity gains are possible is primarily a function of the supersonic cruise distances. A chart illustrating the productivity improvement potential of cruise speed as a function of supersonic cruise distance is shown in Figure 20.

- A Mach 0.7 aircraft is significantly less productive than a Mach 0.82 aircraft when operating at distances in excess of 6482 km (3500 n.mi.).

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Supersonic aircraft in actual service will be required to cruise subsonically an average of 185 to 370 km (100 to 200 n.mi.) in order to avoid generating sonic booms over populated areas. It was found that removal of these subsonic cruise requirements would likely not affect the productivities of the three higher speed SCV's, but in some cases would allow for more desirable departure and arrival times.

Generally, the aircraft were fully utilized as long-haul transports so that attempts to increase utilization with short distance flights would reduce scheduled maintenance time allowances. Based on analysis of the time available each day for aircraft usage including the total turn-time requirements between flights, the study shows that a daily utilization of 12-13 hours is a practical maximum for an SCV with 11-12 hours a realistic upper limit.

Turn-time pertubation studies were conducted for the North Atlantic and transpacific routes with the following results:

- Decreasing the minimum allowable turn-time by 30 minutes from the study standard of 1.5 hours generally improves productivity for the 0.7, 0.82, and 1.4 aircraft but has no effect on the productivity levels of the Mach 2.0, 2.2, and 2.7 aircraft.
- Increasing turn-time by 30 minutes generally decreases productivity for all speeds except for the Mach 2.7 aircraft on the North Atlantic.

In addition to the individual route system studies, the possibilities for improving the SCV productivities by combining systems was investigated. The results of this investigation show a slight productivity improvement for the Mach 1.4, 2.0, and 2.2 aircraft over the average of the three individual route systems by raising the comparatively low North-South American unit productivities and lowering those of the North Atlantic and transpacific. It is therefor concluded that combining routes offers productivity improvement potential for a route system whose aircraft are under-utilized, but offers no productivity advantage to one whose aircraft are already fully utilized.

Passenger preferential departure and arrival times are more constrictive than airport curfews. It was found that the overall impact of such limitations is about the same for each of the different speed aircraft; however, the impact of scheduling constraints are generally greater on the Mach 1.4 and Mach 2.0 aircraft than on the two higher speed SCV's. This is indicated by the turn-time perturbation studies and combined route studies which show the two lower speed SCV's most affected by changes in these scheduling criteria.

The study results show that flight crew requirements become progressively less with increasing speed. Since crew pay generally increases with aircraft speed and weight this apparent economic advantage is questionable.

INTRODUCTION

Since 1972, a supersonic cruise aircraft research program has been conducted jointly by NASA, airframe, and engine companies for the purpose of developing the technology needed to build an economically and environmentally viable advanced supersonic transport. In addition, since 1974, NASA has been sponsoring research programs for more fuel efficient present and future subsonic aircraft. Both of these programs are primarily directed at U.S. commercial transport aircraft needs in the 1990's. A fundamental parameter under examiniation in these efforts is the choice of airplane design cruise speed.

Design cruise speed selection impacts the design, construction, and operation of an airplane. Because it usually costs more to build faster aircraft, the higher cost must provide commensurate improved capabilities. Higher design cruise speeds provide reduced trip times which historically are an incentive to increased travel. Another result of reduced trip time is potentially greater aircraft productiveness. Reduced trip time can allow more trips to be completed within a given time period, but the potential payoff for speed tends to diminish as speed increases. A Mach 2.0 transport aircraft reduces trans-Atlantic trip time by more than three hours from that of a subsonic jet; however, further increasing speed by a nearly like amount to Mach 2.7 produces only another 25 minutes savings. This latter trip-time reduction may not be sufficient to justify the more complex and costly aircraft needed to achieve it except within the context of system application where it may have a significant impact on aircraft productiveness. Therefore, determining the aircraft productivity-to-speed relationship is an important part of aircraft design cruise speed selection. Finding this relationship is somewhat complicated by the various restrictions and constraints that are a part of commercial airline scheduling. Factors such as airport curfews, time zone difference, market types, and passenger preferences must be included in a realistic assessment of a productivity-to-speed relationship.

One effective method for making productivity assessments is by comparing the productivity potential of airline-type schedules using different cruise speed aircraft. In 1974, Trans World Airlines, Inc. conducted this type of study with Mach 2.2 and Mach 2.7 aircraft (Reference 1). The study results indicated that the faster aircraft was not able to generate additional airplane revenue miles. It was concluded that because this study covered a limited route system, and was to some extent influenced by certain specific scheduling constraints and maintenance requirements, additional study was needed.

In consideration of the above study and other on-going relevant programs, NASA under took sponsorship of the study that is the subject of this report. This study was conducted jointly by Trans World Airlines, Inc., Braniff International, and the Lockheed-California Company.

The main objective of this study is to determine the impact of cruise speed on airplane productivity for commercially scheduled operations. Productivity-to-speed relationships were studied for three separate route systems and for combinations of these systems. The study also examines other areas that influence airplane productivity such as scheduled turn-time. The impact of cruise speed on flight crew requirements were also studied.

Airline-type schedules were developed by TWA for North Atlantic and transpacific route systems, and by Braniff for a North-South American route system. Each route system was scheduled independent of one another for six different cruise speed aircraft using performance data supplied by Lockheed. The study was conducted in three phases. The first phase included generating aircraft performance data, selecting city-pairs and routes, forecasting passenger demands for 1995, and setting the service frequencies between the selected city-pairs. During the next phase TWA and Braniff developed schedules for their individual route systems. Schedule development involved devising aircraft routing schedules for the selected city-pairs and projected passenger traffic demands with the object being to choose routings that require the fewest number of aircraft. The last phase was an investigation of the possibilities for improving the supersonic aircraft productivities of the individual-route systems by combining these route systems. This phase also included investigation of other methods for improving productivities of the supersonic cruise vehicles (SCV's) such as the effect of reducing turn-time.

It is recognized that high cruise speeds have been an incentive to increasing passenger traffic in the past, but such market elasticity to speed is highly speculative and therefore was not included in the passenger traffic projections for this study. It is also recognized that different fare levels could possibly exist between subsonic and supersonic aircraft passengers resulting in a division of passenger traffic for these two aircraft types. However, scheduling on the basis of different passenger traffic demands between the subsonic and supersonic aircraft would have precluded productivity comparisons between these vehicle types. Therefore, it was assumed that all passenger traffic were available to both vehicle types. As it is, the seating capacity differences between the subsonic aircraft resulted in having to develop additional schedules at the SCV seating capacity in order to make valid productivity comparisons between the subsonics and the SCV's.

The first section of this report provides a brief description of the study aircraft and conditions that apply generally to the scheduling. A more detailed description of the study aircraft and block time data are provided in Appendix A. Sections 3, 4, and 5 cover the scheduling and results of the three individual route systems: North Atlantic, transpacific and North-South America. These sections also include the applicable basic data. A typical aircraft routing schedule, passenger schedule, and flight crew schedule are presented in Appendix B.

Section 6 reports on the investigation of combined routes. Section 7 provides comparisons between the results from the individual route studies including commentaries. Also included is a summary of the study conclusions.

2. STUDY AIRCRAFT AND GENERAL SCHEDULING CRITERIA

The aircraft concepts selected for this study were adopted mostly from current or recent NASA sponsored study programs. Each of these different cruise speed aircraft are large commercial type transports similar in appearance to the ones shown in Figures 1 and 2. A list of the six study aircraft identified by their cruise speed is shown in Table 1.

TABLE 1. STUDY VEHICLES

(4800 n.mi. Design Range)

Cruise Mach no.	Vehicle	Passenger capacity
0.70	Low energy transport	400
0.82	Current widebody	246
1.4	SCV concept	290
2.0	SCV concept	290
2.2	SCV concept	290
2.7	SCV concept	290

These aircraft are preliminary design concepts except for the Mach 0.82 aircraft which is a derivative of an in-service, wide bodied transport.

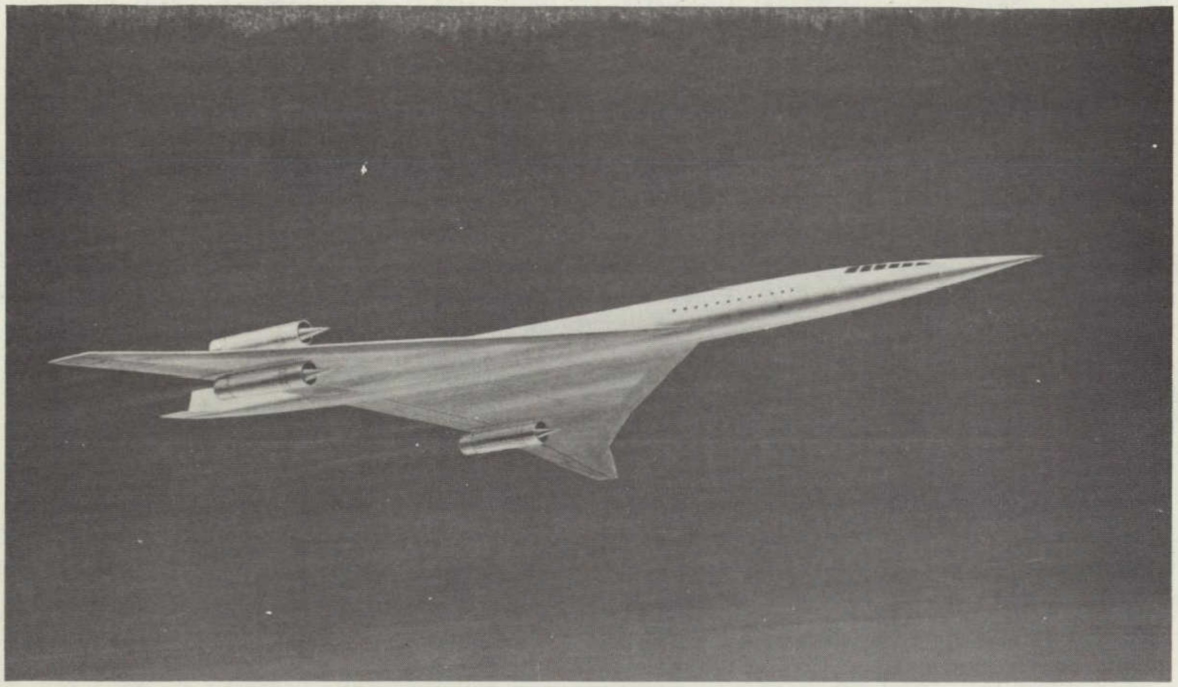


Figure 1. Supersonic cruise vehicle

Figure 2. Subsonic transport

2.1 Block Time Data

The scheduled block times are based on the flight profiles shown in Figure 3 for the subsonic aircraft and Figure 4 for the supersonic aircraft. The information provided in Appendix A allows for computing block time as a function of segment distance and wind. The designated cruise Mach numbers are the cruise speeds for an ISA + 8°C day. There are no speed adjustments as sometimes required due to the off-standard day temperature conditions.

Supersonic aircraft block time data in Appendix A are arranged so that they can be adjusted for different subsonic cruise distances at the departure or arrival ends of a flight. The data is also arranged so that cruise time can be separately identified to account for the time available for inflight meal service.

The block time data have a built-in 10 minute ramp-taxi time allowance for departure and 5 minutes for arrival. These time allowances are increased for some airports as described for the individual route systems.

2.2 General Scheduling Conditions

Real-world type considerations have been included as much as possible in the schedules developed in this study. A summary of conditions that generally apply to the scheduling are as follows:

- Aircraft maintenance requirements included
- Airport curfews observed
- Passenger preferential departure/arrival times observed
- No supersonic flight over inhabited land

Aircraft maintenance requirements refers to routing a fleet of aircraft so that each aircraft periodically spends extra time at airports designated as maintenance stations. The aircraft routing schedules include these maintenance lay-overs at intervals recommended by each airline's maintenance personnel.

Airport curfews, as they presently exist, are observed in the schedules. However, departure and arrival times are mainly selected for passenger preference purposes which are usually more restrictive than curfews. Passenger preferences are also a prime consideration for spacing departures so that morning and afternoon services are provided for city-pairs that have more than a single daily flight.

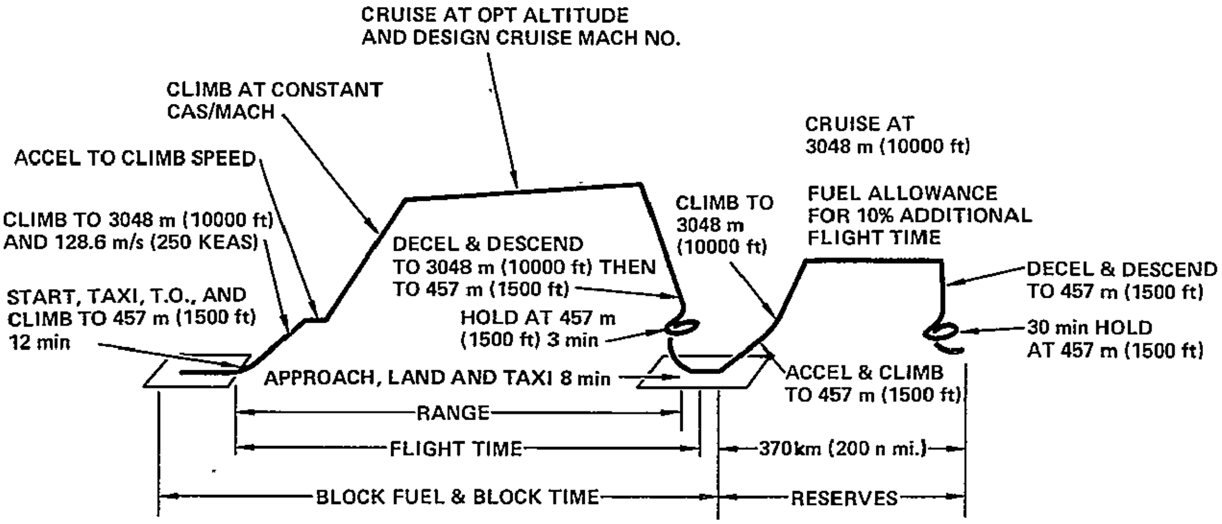


Figure 3. Subsonic vehicle flight profile

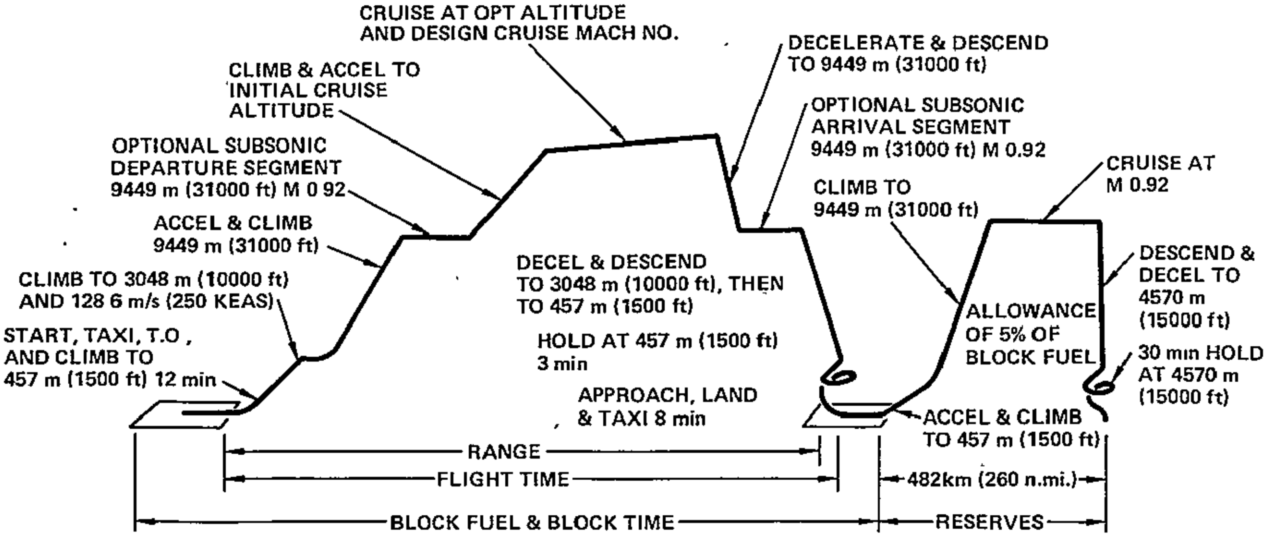


Figure 4. Supersonic vehicle flight profile

The schedules do not include supersonic flight over inhabited land. Additional comments pertaining to this subject are included with the individual route studies.

3. NORTH ATLANTIC SCHEDULES (TWA)

The cities selected for North Atlantic schedule development are the major U.S. and European cities currently or recently served by Trans World Airlines, Inc. (TWA). Each of the city-pair markets is sufficiently large to support at least one daily flight of the 290 seat capacity SCV, and in total, they represent approximately 70 percent of TWA's share of North Atlantic traffic. Figure 5 pictorially shows the selected North Atlantic routes. The following is a list of the selected city-pairs and their respective airport designations:

New York	(JFK)	-	Frankfurt	(FRA)
		-	London	(LHR)
		-	Madrid	(MAD)
		-	Milan	(MXP)
		-	Paris	(CDG)
		-	Rome	(FCO)
Boston	(BOS)	-	London	(LHR)
		-	Paris	(CDG)
Chicago	(ORD)	-	London	(LHR)
Philadelphia	(PHL)	-	London	(LHR)
Washington	(IAD)	-	London	(LHR)

The industry annual average growth rate in scheduled passenger traffic is estimated by TWA's Marketing Department at 5 percent from 1975 through 1995 providing a growth factor of 2.65.

The traffic base is 1975 TWA market data, adjusted in the cases where the market was not served or not served competitively during 1975. In arriving at the passenger demand for the year 1995 it has been assumed that each city-pair market will grow at the same rate and that the airline's share will remain constant as a percentage.

All classes of traffic are included in the 1995 forecast for both the subsonic and supersonic cruise aircraft. At the outset of the study, consideration was given to limiting the supersonic aircraft to first class and 40-50 percent of regular economy passengers, the assumption being that the airplane would require at least this fare level to assure an economically sound operation. With this limited demand only one market (New York-London) was found to be sufficiently large to support a daily flight. Other markets

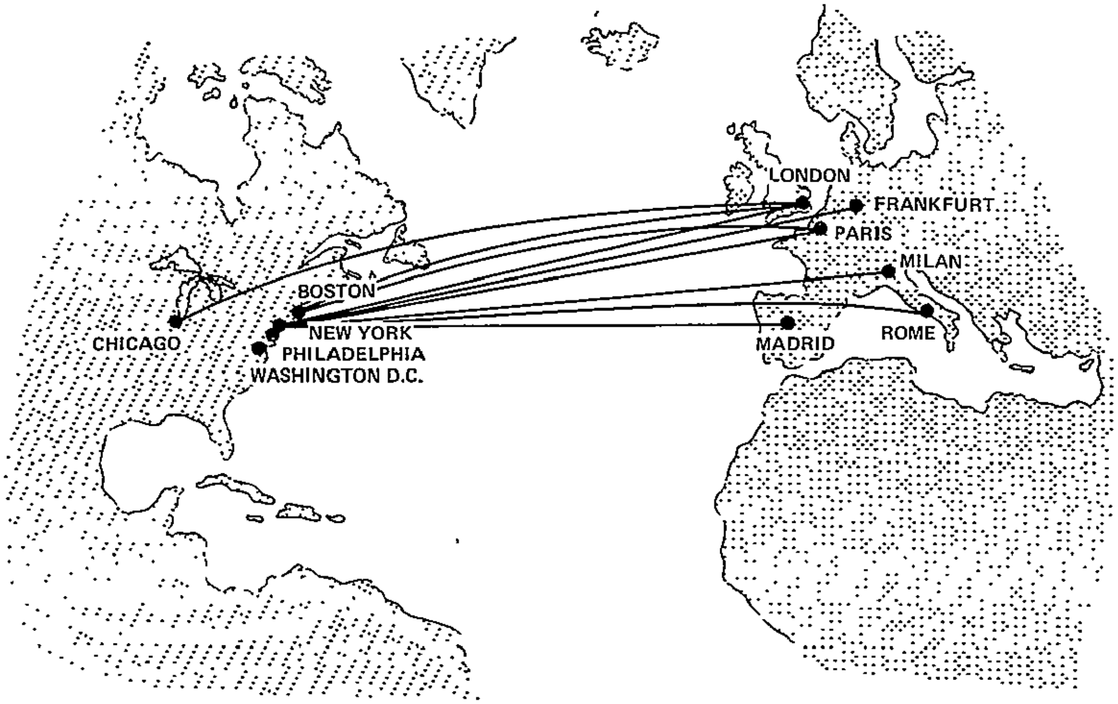


Figure 5. North Atlantic routes

could not be served efficiently. Therefore, it was necessary to postulate that the supersonic aircraft will be capable of serving all classes of traffic at the lower average yields. The weekly passenger demand by city-pair is shown in Table 2.

3.1 Flight Segment Distances and Winds

Segment distances for the subsonic cruise aircraft are great circle distances between the city-pair airports plus one percent for possible operational variations.

For the supersonic cruise aircraft the distances are great circle distances between waypoints selected to preclude supersonic cruise over land masses, plus the distance from the waypoint to origin or destination airport. One percent was added for possible operation variations to obtain the total distance.

Where supersonic cruise aircraft require subsonic departure or arrival legs, this portion of the flight was determined as the distance from the departure airport to the coast line or from the coast line to the destination. The paths selected minimize subsonic flight. For example, the Chicago-London flight overheads New York and then proceeds to London on the same path as a New York to London flight.

TABLE 2. WEEKLY PASSENGER FORECAST FOR 1995
TWA SHARE - EACH DIRECTION

City pair	Airports	No. of pax
New York - Frankfurt	JFK - FRA	3710
- London	- LHR	7840
- Madrid	- MAD	3850
- Milan	- MXP	1890
- Paris	- CDG	3850
- Rome	- FCO	3850
Boston - London	BOS - LHR	2100
- Paris	- CDG	1330
Chicago - London	ORD - LHR	2800
Philadelphia - London	PHL - LHR	1400
Washington - London	IAD - LHR	2100

Tables 3 and 4 summarize the flight segment distances determined for the subsonic and supersonic aircraft routes respectively, and the associated enroute cruise altitude 75 percent annual winds. The wind speeds were taken from Boeing Document D6-15650-1, "Enroute Winds for Supersonic and Subsonic Cruise Altitudes Over World Air Routes." These data are "equivalent" winds which account for higher cruise speeds as the cruise altitude increases.

3.1.1 Operational range requirements. - The most critical segments on the North Atlantic routes with respect to aircraft range requirements are westbound flights, Rome-New York, Milan-New York and London-Chicago, as noted in Table 5. These city-pairs account for about 27 percent of the total passenger miles. The two longest segments, Rome-New York and London-Chicago, account for over 21 percent of the total. This is, of course, a sizeable market and should be served with non-stop flights. Subsonic aircraft operate non-stop routinely today at these ranges. If a supersonic aircraft were incapable of doing so it would increase the trip time of a Mach 2.7 aircraft (FCO-JFK) by 50 percent, or two hours, because an intermediate stop would be required. The speed advantages of supersonic flight are most evident at the longer ranges and, therefore, if a reasonable market exists it should be served by non-stop operation.

The segment revenue statute miles figures used in Table 5 were supplied by the TWA Marketing organization and are the figures (actuals) used by TWA for operations computation purposes. These figures are in very close agreement

TABLE 3. SEGMENT FLIGHT DISTANCES AND WINDS (Subsonic Aircraft)

Segment	Flight Dist. km (n.mi.)	Enroute winds - m/s (knots)(1) 10668m (35 000 ft) Direct	Return
JFK-FRA	6247 (3373)	12 (24)	-25 (-50)
JFK-LHR	5593 (3020)	12 (24)	-26 (-52)
JRK-MAD	5817 (3141)	13 (25)	-25 (-49)
JFK-MXP	6473 (3495)	12 (24)	-25 (-50)
JFK-CDG	5884 (3177)	13 (25)	-26 (-52)
JFK-FCO	6956 (3756)	12 (24)	-24 (-48)
BOS-LHR	5289 (2856)	12 (24)	-26 (-52)
BOS-CDG	5586 (3016)	12 (24)	-26 (-52)
ORD-LHR	6402 (3457)	10 (20)	-23 (-46)
PHL-LHR	5743 (3101)	13 (25)	-26 (-52)
LAD-LHR	5958 (3217)	13 (25)	-26 (-52)

NOTES: (1) (-) Denotes headwind.

TABLE 4. SEGMENT FLIGHT DISTANCE AND WINDS (Supersonic Cruise Aircraft)

Segment	Total Dist. km (n.mi.)	Subsonic(1) Dist. km (n.mi.)	Enroute winds in cruise - m/s (knots)(2)				
			M 1.4 14326m (47,000 ft)	M 2.0 16154m (53 000 ft)	M 2.2 17374m (57 000 ft)	M 2.7 18895m (62 000 ft)	Subsonic 9449m (31 000 ft)
JFK-FRA	6371 (3440)	0/496 (0/268)	11/-21 (21/-42)	7/-13 (14/-26)	6/-12 (11/-23)	5/-11 (10/-21)	2/-24 (3/-47)
JFK-LHR	5776 (3119)	0/130 (0/70)	11/-21 (21/-41)	7/-14 (13/-28)	5/-13 (10/-25)	5/-11 (9/-22)	0 (0)
JFK-MAD	5862 (3165)	0/446 (0/241)	11/-19 (21/-38)	7/-14 (14/-28)	6/-13 (11/-25)	3/-10 (6/-19)	3/-19 (5/-38)
JFK-MXP	6510 (3515)	0/900 (0/486)	11/-20 (21/-39)	7/-14 (14/-28)	6/-13 (11/-25)	5/-11 (10/-21)	1/-22 (2/-43)
JFK-CDG	5938 (3206)	0/339 (0/183)	11/-20 (21/-39)	7/-14 (14/-28)	6/-13 (11/-25)	5/-11 (10/-21)	-2/-22 (-3/-43)
FJK-FCO	6967 (3762)	0/1163 (0/628)	11/-21 (21/-42)	7/-13 (14/-26)	6/-14 (11/-23)	4/-10 (7/-20)	1/-19 (2/-38)
BOS-LHR	5565 (3005)	0/130 (0/70)	10/-23 (19/-45)	7/-14 (13/-28)	6/-13 (11/-26)	4/-11 (8/-22)	0 (0)
BOS-CDG	5732 (3095)	0/339 (0/183)	10/-23 (20/-45)	7/-14 (14/-28)	6/-13 (11/-25)	4/-11 (8/-22)	-2/-22 (-3/-43)
ORD-LHR	6973 (3765)	1261/130 (681/70)	11/-21 (21/-41)	7/-14 (13/-28)	5/-13 (10/-25)	5/-11 (9/-22)	14/-34 (27/-67) (3)
PHL-LHR	5969 (3223)	185/130 (100/70)	11/-20 (21/-39)	7/-14 (14/-28)	6/-13 (11/-25)	5/-11 (10/-21)	5/-20 (10/-40) (3)
LAD-LHR	6173 (3333)	280/130 (151/70)	10/-23 (20/-45)	7/-14 (13/-28)	6/-13 (10/-25)	4/-11 (7/-22)	4/-22 (8/-43) (3)

NOTE: (1) Subsonic departure/arrival.
(2) Winds direct/return (-) denotes headwind.
(3) Subsonic arrival and departure winds (LHR) are zero.

with the subsonic aircraft segment flight distance figures shown in Table 3 if the flight distances are reduced by the one percent added for operational variations.

Table 6 provides the operational range requirements for the six aircraft designs on the most critical North Atlantic segments applicable to the study. These range requirements are for westbound flights and consider the effects of head winds as well as an estimated reduction in specific range for the supersonic cruise aircraft when subsonic departure or arrival legs are involved. For eastbound flights the supersonic aircraft will require between 7223 and 7408 km (3900 and 4000 n.mi.), while the subsonic range requirements are approximately 6667 km (3600 n.mi.).

It is recognized that the supersonic aircraft range requirements are greatly influenced by the need to be able to accommodate relatively long subsonic legs to prevent overland sonic booms. If all-supersonic operation was permitted the range necessary for the Mach 2.7 design would be reduced to about 7038 km (3800 n.mi.) and 7315 km (3950 n.mi.) for Mach 1.4.

3.2 Scheduled Flight Frequency

Flight frequencies were determined by setting desired load factor limits between 58 and 65 percent with absolute limits of 52 and 70 percent. In addition, it was considered desirable to establish frequencies such that each flight operated daily. The objectives were not met in all respects; and in one, the Boston and Paris flight of the Mach 0.82 airplane, the upper limit load factor was exceeded. To reduce the load factor to a more reasonable level would have added to the fleet one airplane operating only one or two days per week; therefore the high load factor was allowed to stand.

Table 7 summarizes the number of round trip flights required per week for each type aircraft to satisfy the noted demand within the assumed load factor limits.

3.3 Block Time Data

Segment block times were determined using the data included as Appendix A of this document provided by Lockheed for each aircraft design speed. The data were adjusted for the effect of 75 percent annual winds at the average cruise altitude for each design.

Block times as calculated using the basic Lockheed data include a constant fifteen minutes of taxi time. Where necessary they were adjusted to actual times with Airline Block-Time Conference (ABC) statistical data, as presented in Table 8. The data, shown in Table 8, are for large three and four engine aircraft.

TABLE 5. NORTH ATLANTIC CITY PAIR PERCENTAGE OF TOTAL PASSENGER MILES

Segment	Revenue distance km (st. miles)	Psgrs. per week	Psgr. distance per week km X10^{-6} (st. miles X10^{-6})	% of total psgr. distance
JFK-FRA	6207 (3858)	3 710	23.02 (14.31)	11.1
JFK-LHR	5556 (3453)	7 840	43.56 (27.07)	21.1
JFK-MAD	5773 (3588)	3 850	22.22 (13.81)	10.8
JFK-MXP	6412 (3985)	1 890	12.12 (7.53)	5.9
JFK-CDG	5849 (3635)	3 850	22.53 (14.00)	10.9
JFK-FCO	6882 (4277)	3 850	26.50 (16.47)	12.8
BOS-LHR	5257 (3267)	2 100	11.04 (6.86)	5.3
BOS-CDG	5551 (3450)	1 330	7.39 (4.59)	3.6
ORD-LHR	6360 (3953)	2 800	17.81 (11.07)	8.6
PHL-LHR	5706 (3546)	1 400	7.98 (4.96)	3.9
IAD-LHR	5899 (3666)	2 100	12.39 (7.70)	6.0
TOTALS		34 720	206.55 (128.37)	100.0

TABLE 6. OPERATIONAL RANGE REQUIREMENTS
(Longest Segments)

Segment	Minimum range - km (nautical miles)					
	M 0.70	M 0.82	M 1.4	M 2.0	M 2.2	M 2.7
LHR-ORD	7223 (3900)	7075 (3820)	7889 (4260)	7797 (4210)	7704 (4160)	7667 (4140)
MXP-JFK	7408 (4000)	7223 (3900)	7186 (3880)	7038 (3800)	7019 (3790)	6982 (3770)
FCO-JFK	7871 (4250)	7593 (4100)	7778 (4200)	7612 (4110)	7575 (4090)	7556 (4080)

TABLE 7. WEEKLY FLIGHT FREQUENCY AS A FUNCTION OF PASSENGER DEMAND AND AIRPLANE CAPACITY

Segment	Passengers per week each direction	Mach 0.70 400 seat a/c		Mach 0.82 246 seat a/c		SCV 290 seat a/c	
		Flts. Per Week	Load Factor %	Flts. Per Week	Load Factor %	Flts. Per Week	Load Factor %
JFK-FRA	3710	14	66	28	54	21	61
JFK-LHR	7840	30	60	49	65	42	64
JFK-MAD	3850	14	69	28	56	21	63
JFK-MXP	1890	7	68	14	55	12	54
JFK-CDG	3850	14	69	28	56	21	63
JFK-FCO	3850	14	69	28	56	21	63
BOS-LHR	2100	8	66	14	61	14	52
BOS-CDG	1330	5	67	7	77	7	66
ORD-LHR	2800	12	58	19	60	14	69
PHL-LHR	1400	6	58	9	63	7	69
IAD-LHR	2100	9	58	14	61	14	52

TABLE 8. TAXI TIMES

	Time - Min.			Time - Min.	
	Out	In		Out	In
Boston (BOS	15	5	New York (JFK)	23	9
Chicago (ORD)	19	11	Paris (CDG)	18	11
Frankfurt (FRA	12	5	Philadelphia (PHL)	15	8
London (LHR)	18	6	Rome (FCO)	18	7
Madrid (MAD)	16	6	Washington (IAD)	10	6
Milan (MXP)	10	5			

Block times for the North Atlantic segments using the various study air aircraft are presented in Table 9.

3.4 Schedule Constraints

The scheduling ground rules employed in the study consider airport curfews, passenger preferential departure and arrival times, aircraft turn and maintenance time requirements, and flight path restrictions for supersonic operation. The scheduling rules applicable to all of the aircraft designs for the North Atlantic operation are summarized as follows:

- No arrivals between 2300 and 0600 local time
- No departures between 2300 and 0900 local time
- Minimum turn time of 1.5 hours
- Aircraft overnight at maintenance station no less than every -
    - Seven round trips for SCV's
    - Five round trips for Mach 0.82 design
    - Four round trips for Mach 0.70 design
- No supersonic flight over land masses
- No subsonic tag-end flights

3.4.1 Airport curfews and flight time preferences. - Many European stations have flight curfews in effect which prohibit takeoffs and landings during the period from approximately 2400 hours to 0600 hours local time. The times vary somewhat between stations by 30 minutes, plus or minus. For example, London does not permit landings from 2330 to 0600 and takeoffs from 2330 to 0630, except Sunday when takeoffs are prohibited to 0800. These restrictions apply absolutely to long range four engine aircraft but permission is granted for smaller aircraft during the period on a quota basis, the total number being limited.

The passenger preference limits of no departures before 0900 and no arrivals after 2300 are seen to be more restrictive than currently imposed curfews. These limits, used in the study for North Atlantic scheduling, are based on past and current experience in operating from the U.S. to Europe. Although the supersonic aircraft may change certain travel habits, e.g., eastbound daylight flights will probably become more popular, there is little reason to believe departures prior to 0900 or arrivals later than 2300 will prove acceptable.

TABLE 9. SCHEDULE BLOCK TIMES (Hours:Minutes)

Segment	Mach 0.70		Mach 0.82		Mach 1.4		Mach 2.0		Mach 2.2		Mach 2.7	
	Direct	Return	Direct	Return	Direct	Return	Direct	Return	Direct	Return	Direct	Return
JFK-FRA	8:28	9:54	7:23	8:09	4:58	5:10	3:56	3:56	3:42	3:41	3:18	3:18
-LHR	7:37	9:04	6:38	7:29	4:28	4:44	3:28	3:33	3:15	3:18	2:52	2:52
-MAD	7:52	9:12	6:52	7:41	4:37	4:51	3:40	3:44	3:28	3:31	3:06	3:05
-MXP	8:41	10:13	7:34	8:23	5:11	5:23	4:12	4:13	3:59	3:59	3:36	3:33
-CDG	8:02	9:29	7:01	7:50	4:44	4:54	3:45	3:45	3:32	3:31	3:09	3:05
-FCO	9:17	10:58	8:05	9:03	5:36	5:55	4:35	4:42	4:21	4:28	3:58	4:01
BOS-LHR	7:06	8:32	6:11	7:04	4:12	4:33	3:15	3:23	3:02	3:10	2:40	2:47
-CDG	7:34	8:59	6:35	7:25	4:31	4:44	3:32	3:35	3:19	3:22	2:57	2:58
ORD-LHR	8:38	10:11	7:29	8:26	5:31	6:05	4:32	4:54	4:19	4:40	3:55	4:16
PHL-LHR	7:40	9:15	6:39	7:40	4:29	4:53	3:29	3:41	3:16	3:26	2:50	3:02
IAD-LHR	7:50	9:34	6:48	7:53	4:35	5:02	3:33	3:48	3:19	3:33	2:54	3:08

3.4.2 Turn time allowances. - The subsonic and supersonic cruise vehicles considered in the study are large aircraft having passenger capacities, fuel loads, and passenger cabin features similar to the large three and four engine aircraft operating today. It is, therefore, considered appropriate to apply current turn time standards to the study aircraft. While improvement in certain procedures involved in turning an aircraft can be hoped for, if not anticipated, by the year 1995, the degree of improvement cannot be determined and therefore none are incorporated in the study.

A standard turn time of 90 minutes has been selected for scheduling all aircraft. This is the approximate time required to turn a B-747, provided the airplanes remains at the gate. A breakdown of the turn time requirements is shown in Figure 6. The fueling time standard shown is for maximum trip fuel for the Mach 2.7 airplane. Other aircraft will require less time, particularly the subsonic aircraft; however, since fueling is not the controlling factor of the turn, the 90 minute standard turn time is conservatively valid in all cases.

It is noted that aircraft maintenance requirements are not specifically indicated in establishing turn times; nevertheless certain routine maintenance is scheduled and completed during the turn, plus pick-ups of any crew write-ups that are of a relatively minor nature. The scheduled turn time maintenance consists of checks and inspections. For example, engine oil is checked and replenished if necessary.

Note, also, that the turn time standard does not consider the possibility of a late arrival; however, turn time available is frequently greater than this standard, allowing time for schedule make-up. Additionally, a modest reduction in some of the turn activities is generally possible when necessary to meet schedule.

3.4.3 Maintenance time allowance. - The maintenance time requirements are a function of the number of flight hours and the number of flight cycles between layover periods at a maintenance station. The number of flight cycles permitted per overnight is related to the airplane's speed, balancing to a degree the flight time and flight cycle effects on maintenance requirements. Thus, as noted in the scheduling ground rules the higher speed supersonic aircraft are limited to seven round trips per routing cycle and the subsonic aircraft to four and five round trips per routing cycle respectively for the Mach 0.70 and Mach 0.82 designs.

The maintenance times proposed for the study are viewed as rough estimates since little is known about the study aircraft, particularly the supersonic cruise vehicles. However, the North Atlantic aircraft routing charts for the Mach 2.7, Mach 1.4 and Mach 0.82 designs were submitted to TWA's Maintenance Planning personnel for comment. It was indicated that the schedules appeared to be satisfactory with respect to available maintenance time. The assessment of the schedules included some degree of optimism for the year 1995, assuming better procedures and techniques will be available and improved maintainability will be designed into the aircraft.

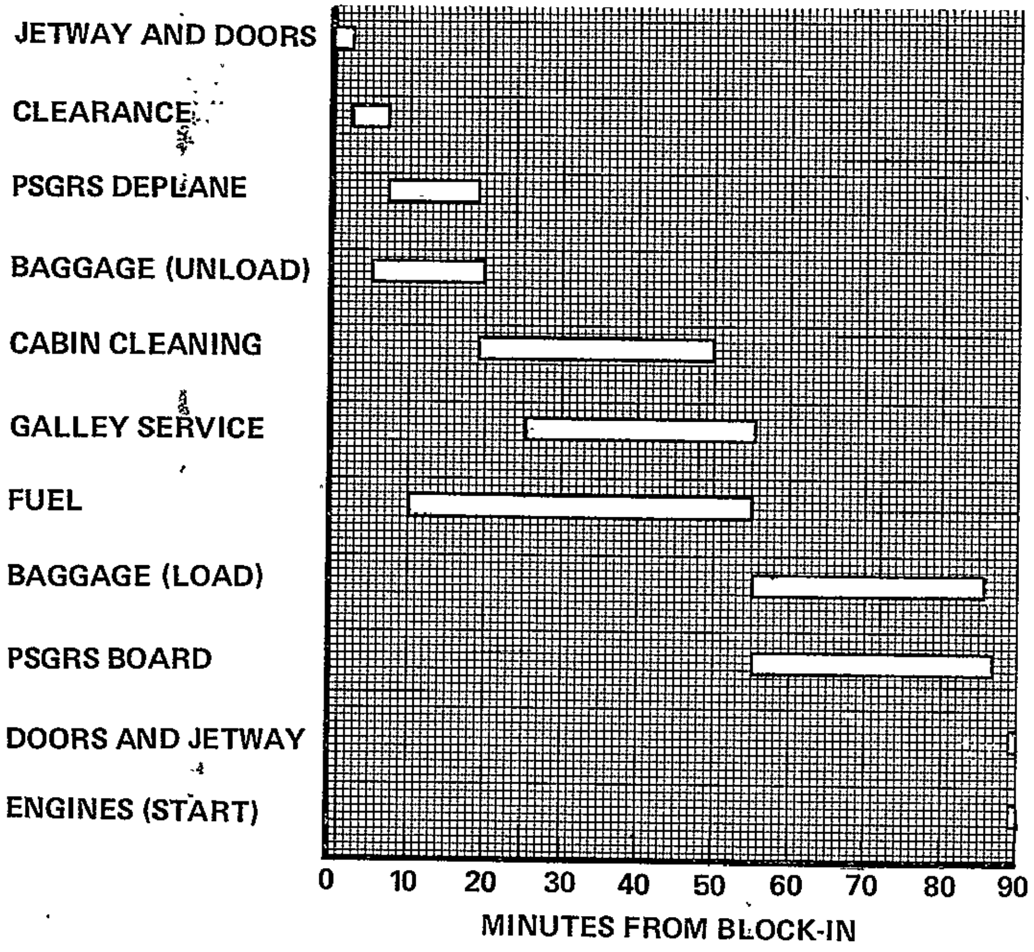


Figure 6. On-gate servicing turn time components

3.5 Schedule and Fleet Requirements Development

Aircraft routing schedules for the North Atlantic routes were developed for each of the six airplane designs using the foregoing input information. A typical aircraft routing schedule is presented in Appendix B of this report. The corresponding passenger schedule and flight crew schedule are shown in Appendix B.

3.5.1 North Atlantic aircraft routing analysis. - Table 10 presents the fleet sizes, flight crew requirements, and required fleet performance corresponding to the North Atlantic route schedules developed during the study.

The subsonic airplanes (Mach 0.70 and Mach 0.82) are scheduled much like today's North Atlantic operation. All but a few flights depart the U.S. in the evening. Morning departures to Europe cannot return without an overnight, and arrival times are generally quite late in the evening. Additionally, a morning departure can be scheduled only at the start of a routing cycle since the airplane does not return in time the next day for another daylight departure.

These airplanes are capable of one round trip per 24 hours, leaving the U.S. in the evening, in most cases, and returning between 1200 and 1800 hours the next day. They, therefore, experience relatively long layover times waiting to depart that evening. This time is frequently sufficient to operate a short domestic segment, e.g., New York-Chicago and return, but this apparent benefit has not been considered in the study. In any event, such additional flights would probably reduce the available time for international service since the accumulated flight cycles and flight time are quite high.

The number of aircraft required to operate the schedules is 24 for the Mach 0.70 design and 40 for the Mach 0.82. The ratio of passenger capacities, 400 to 246, is approximately equal to the fleet size ratio indicating that the speed differential has little influence on the scheduling.

The supersonic cruise aircraft routing charts for North Atlantic operation are identical for the three highest speed aircraft, i.e., the aircraft in each cycle follows the same pattern but with some variance in departure and arrival times necessitated by the speed difference. The chart for the Mach 2.7 airplane was developed initially attempting to optimize fleet size. The Mach 2.2 and Mach 2.0 designs were found to be capable of fitting into the same pattern, maintaining acceptable departure and arrival times. This being so, it seemed apparent that the Mach 2.7 schedule could be reworked and perhaps eliminate one airplane; however, attempts to do so were not successful. Individual round trips could be compressed in many cases by reducing the turn time but scheduling constraints, including the need to space departures to the same destination properly, prevented any reduction in size of the 16 airplane fleet.

TABLE 10. FLEET AND SCHEDULE REQUIREMENTS SUMMARY

Vehicle design cruise speed	Seating capacity	Total fleet size	Daily average block time hours/day/ aircraft	Daily average revenue distance per day per a/c km (st. miles)	Average available turn time hours	Flight crews required
Mach 0.70	400	24	13.99	9 416 (5 852)	3.28	147 (1)
Mach 0.82	246	40	12.76	10 132 (6 297)	4.47	219
Mach 1.4	290	21	13.06	15 691 (9 752)	2.23	133
Mach 2.0	290	16	13.36	20 594 (12 799)	2.12	106
Mach 2.2	290	16	12.57	20 594 (12 799)	2.35	102
Mach 2.7	290	16	11.26	20 594 (12 799)	2.70	92

NOTE: (1) M 0.70 Aircraft requires 57 relief crew members

The Mach 1.4 airplane cannot follow the same pattern as the higher speed designs because of its higher block times. Morning eastbound departures arrive somewhat late in the evening tending to make evening departures more desirable, approaching the characteristics of the subsonic airplane. The airplane routing requires five overnights at stations other than JFK which is the difference in fleet size requirements as compared with the other SCVs. One of these overnights could be eliminated at London but would add another late arrival in New York and would not change the size of the fleet.

The speed of the aircraft influences the departure times available to remain within the arrival time limits. Table 11 shows the time available for four representative eastbound North Atlantic segments. It is of interest to note that essentially the same number of hours a day are available for all aircraft in complying with arrival time limitations; however, the times available for morning versus evening departures vary considerably. The faster airplanes have the greatest amount of time for morning departures and the slower one have the greatest amount for evening departures.

TABLE 11. NORTH ATLANTIC - DEPARTURE TIME AVAILABLE TO COMPLY WITH ARRIVAL CURFEWS (Representative Segments)

Mach No.	Segment	DEPARTURE TIME AVAILABLE TO ARRIVE		Total Time Available (Hrs:Min)
		Before 2300 Hrs.(1) (Hrs:Min.)	After 060 Hrs. (Hrs:Min)	
2.7	JFK-LHR	6:05	0:50	6:55
	JFK-FRA	5:40	1:20	7:00
	JFK-CDG	4:50	2:05	6:55
	JFK-FCO	4:00	3:05	7:05
2.2	JFK-LHR	5:45	1:15	7:00
	JFK-FRA	5:15	1:40	6:55
	JFK-CDG	4:25	2:30	6:55
	JFK-FCO	3:35	3:20	6:55
1.4	JFK-LHR	4:30	2:25	6:55
	JFK-FRA	4:00	2:55	6:55
	JFK-CDG	3:15	3:40	6:55
	JFK-FCO	2:20	4:35	6:55
.82	JFK-LHR	2:20	4:35	6:55
	JFK-FRA	1:35	5:20	6:55
	JFK-CDG	0:55	6:00	6:55
	JFK-FCO	-	7:05	7:05
.70	JFK-LHR	1:25	5:35	7:00
	JFK-FRA	0:30	6:25	7:00
	JFK-CDG	-	7:00	7:00
	JFK-FCO	-	8:15	8:15

NOTES: (1) Reduce available time by 1:30 fro turning flight.
Mach .82 and .70 cannot return from morning departure.

3.5.2 Aircraft productivity versus aircraft cruise speed. - The seating capacity differences between the two subsonic aircraft results in a change of flight frequencies to serve the markets and distorts any comparison attempting to show the effect of speed on productivity. It is apparent that a meaningful comparison requires the same passenger capacity, preferably the same as the supersonic aircraft, to permit a comparison across the speed spectrum. Additional studies were conducted for this purpose and the results are reported in Section 3.6.

During development of the SCV routing schedules, it quickly became evident that the difference in speeds of the Mach 2.0, 2.2 and 2.7 airplanes would not produce a commensurate increase in revenue miles per aircraft. In fact, there is no difference in revenue miles per aircraft. Several things account for this, including the constraints of curfews and passenger preference times and the leveling effect of the subsonic cruise time. A more correlative comparison of speed versus productivity may be made by use of a speed called turn-around block speed. The time that is needed to complete a segment can be measured by adding the turn-around time of 1.5 hours to the block time. When this time is translated into speed for a given segment, the percentage increase for the M 2.2 and M 2.7 airplanes over the M 2.0 is significantly reduced. By reference to Figure 7 these effects are graphically seen. It is this relatively small difference in turn-around block speeds that causes almost equivalent schedules to be developed where the segment lengths are as great as on the North Atlantic.

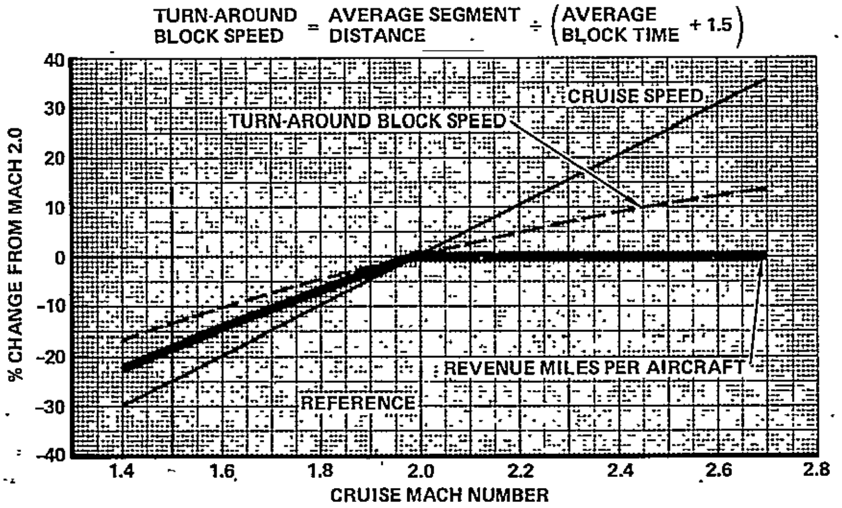


Figure 7. North Atlantic SCV productivity comparison with turn around block speed, Mach 2.0 reference

3.5.3 Impact of SCV subsonic cruise segments. - Every segmant of the North Atlantic SCV schedule requires at least some portion of the flight at subsonic cruise to prevent sonic boom over populated areas. The flight distance in subsonic cruise varies from 48 km (26 n.mi.) to 1226 km (662 n.mi.) with a weighted schedule average of 415 km (224 n.mi.). The total schedule subsonic cruise miles flown per day is 22983 km (12 410 n.mk.), or about seven percent of the total flight distance.

The average increase in block time dur to the subsonic portion of the flight ranges from twenty-two minutes for the Mach 2.7 design to sixteen minutes at Mach 1.4. The most significant increases are on three of the longer segments:

Block Time Increase - Minutes

Segment	M 1.4	M 2.7
ORD-LHR	49	61
JFK-FCO	24	46
JFK-MXP	20	36

While the block time increases are quite high for these segments and account for more than 50 percent of the fleet subsonic cruise time, it is not likely that they affect the productivity of the fleet. An examination of the aircraft routing charts indicates that the number of aircraft required for the schedules could not be reduced, even if the segments were flown supersonically. In some cases, more desirable departure and arrival times might be made available, particularly for the Mach 1.4 design.

3.5.4 SCV flight potential in excess of passenger demand. - Examining the North Atlantic schedules it is noted that in most cases the airplanes return to New York at the end of each cycle with sufficient time for an eastbound departure prior to 2300 hours. This would, however, be simply an extension of the routing cycle which was terminated to accomodate a maintenance layover. The Mach 1.4 design terminates several cycles in the morning but it cannot depart again without an overnight in Europe; and again, this would be extending the routing cycle beyond maintenance limits.

All of the SCVs have two airplane days of ground time due to one of the New York-Milan flights operating five days per week. This time could be scheduled with additional flights if the traffic warrants, adding two round trips per week. However, this may not be the best use of the available time. The airplane now serves as an active spare, capable of backing up a schedule that may be somewhat tight from a maintenance standpoint.

It should be concluded that any significant increase in passenger demand must result in an increase in fleet size. A modest increase in load factor could accommodate some traffic increase but since the load factor, as an average, is quite high, any increase must be quite limited.

3.5.5 Flight crew requirements. - The number of flight crews required to operate each flight schedule was established on the basis of current airline/pilot contractual agreements with respect to flight time and duty time limitations. These agreeements are subject to change when new type flight equipment is introduced, and the introduction of supersonic aircraft will be no exception; however, no attempt is made to define such changes or their possible effects on crew requirements.

The crews required to operate the Mach 0.70, 0.82, 1.4 and 2.7 designs on the North Atlantic were determined by flight schedule input into TWA's Flight Operations Department crew scheduling computer program. The crews for all other schedules were calculated, based on the computer results of these four schedules, considering the block hours and number of aircraft involved and the type of schedule pattern. The number of crews so determined is the number necessary to operate the schedule and does not provide an allowance for vacations, sick leave, training and other nonrevenue flying. Total crew requirements are about 28 percent higher, a factor applicable to all schedules.

In addition to the normal three-man crew, the subsonic airplanes require a relief crew on certain segments. This additional crew member is necessary whenever block time of a nonstop flight exceeds 9.5 hours. The Mach 0.70 aircraft requires the extra man on five North Atlantic flights. The supersonic aircraft, with block times well below the limit are not affected by this requirement.

A typical flight crew schedule is presented in Appendix B. This is a copy of the computer printout for the Mach 2.7 airplane on the North Atlantic routes. An examination of the schedule will reveal a few flight time discrepancies when compared with the aircraft routing charts and block time tables. These discrepancies result from a change in some block times subsequent to submitting the schedule to the computer. The maximum difference is four minutes which does not change the number of crews required.

3.5.6 On-board passenger service. - The meal and beverage service and other amenities provided the passenger on a flight of X hours duration is generally the service that can be provided in X hours. In other words, the service is tailored to the time available. On currently operated long range flights of six to eight hours, a full meal is served plus perhaps a light snack. A movie may be included to help pass the time. Obviously, these services cannot be offered to the same extent aboard the supersonic aircraft. It should be equally obvious that no need exists for such service. With time saving the essence of supersonic flight, the type and amount of on-board passenger service is secondary and is not considered a scheduling factor.

3.6 Additional North Atlantic Route Studies

Two additional side studies were conducted which are reported in the following paragraphs.

TABLE 12. 290 PAX SUBSONIC AIRCRAFT PRODUCTIVITY AND FLEET REQUIREMENTS (Same Flight Frequency as SCVs)

	M 0.70	M 0.82
Total block hours/week	3425	2 885
Total block hours/day	489.3	412.1
No. of aircraft	34	34
Block hours/day/aircraft	14.39	12.12
Rev. dist./day, km (st. miles)	329 497 (204 784)	329 497 (204 784)
Rev. dist./day/aircraft, km (st. miles)	9 691 (6 023)	9 691 (6 023)
Turn Time (average) hr	3.33	4.59
No. of flight crew	214	177
No. of relief crew	83	-

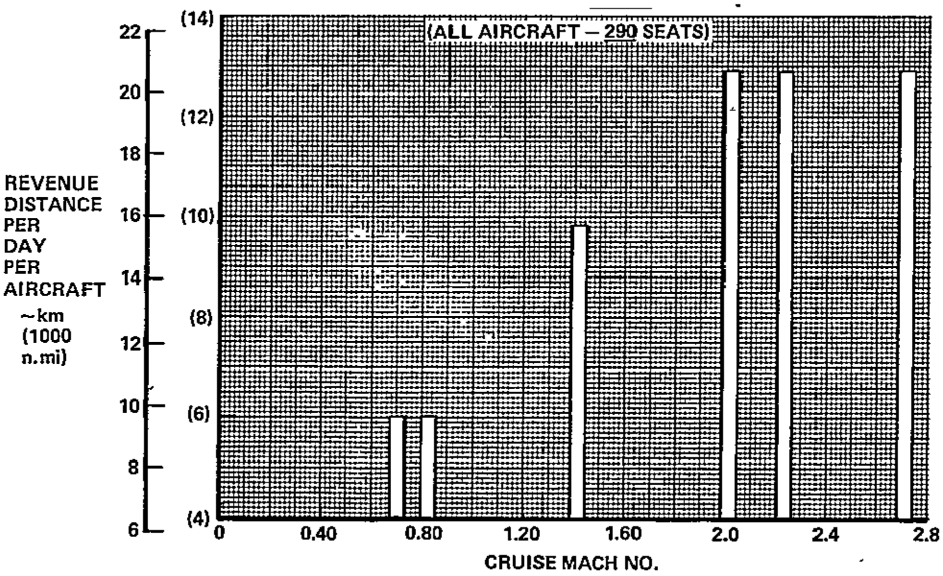


Figure 8. Airplane productivity versus Mach number

3.6.1 Subsonic aircraft fleetsize at SCV seating capacity. - Aircraft routings for the subsonic airplanes were developed using the city-pair flight frequencies of the 290 seat SCVs on the North Atlantic routes. The resulting fleet and aircraft operational capabilities and requirements are shown in Table 12 and a comparison of aircraft productivity is provided in Figure 8. Results indicate that 34 airplanes of both design speeds are required. This is 10 more than the 24 required with the 400 passenger Mach 0.70 design and six less than the 40 required with the 246 passenger Mach 0.82 aircraft. The changes in fleet sizes are closely proportional to the changes in passenger capacity.

The average block time difference (eastbound and westbound) is about 18 percent and it might be expected that some advantage in terms of productivity would accrue to the Mach 0.82 design. However, they are both "one-round-trip" per day airplanes which, for the most part, must be scheduled for night departures eastbound, returning the next morning or early afternoon. Any advantage to the higher speed airplane is lost during the relatively long layover of westbound arriving flights waiting to depart for Europe that evening. Eastbound morning departures of both aircraft must overnight in Europe.

3.6.2 Effect of minimum turn time on fleet size. - The scheduled time to turn an airplane from one flight to another will obviously have a significant effect on its productivity. To quantify the effect, schedules were developed for the three supersonic aircraft on North Atlantic routes imposing different turn time requirements. Turn times of one, two and three hours were investigated and the resulting fleet size compared with the study standard of 90 minutes.

In some cases complete schedules were developed while in others the number of aircraft required for partial schedules of representative segments were extrapolated. The results are shown in Figure 9. It is recognized that the curves of fleet size versus turn time are step functions but since the point at which the step occurs is not readily determined, they are plotted as straight lines.

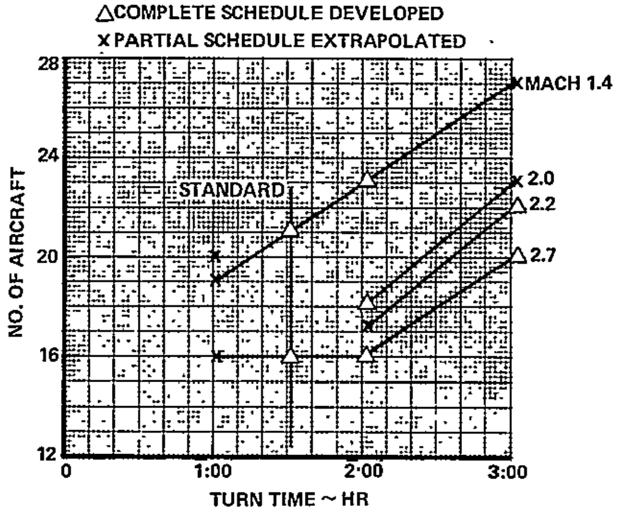


Figure 9. Effect of turn time on fleet size

The chart indicates that the Mach 2.7 design can tolerate at least a two-hour turn time without the need to increase the fleet size; however, a one hour turn does not reduce the fleet from the 16 aircraft required at 90 minutes. The latter would also apply to the Mach 2.0 and 2.2 aircraft and results from the other scheduling constraints such as departure and arrival time limitations being more a factor than turn time. This is not the case with the Mach 1.4 design. A one hour turn time can reduce the fleet size by one, or possibly two aircraft.

The data for a three hour turn are of academic interest only since it is an unreasonable requirement. Two hours, however, are more realistic. It is the standard minimum for most TWA international flights operating today. The chart shows that except for the Mach 2.7 airplane ar additional one to two aircraft are necessary to accommodate a turn time of two hours.

The subsonic airplanes are not shown on the chart. An examination of the routing charts will show that with at least two hours turn time no addition to the fleet is required for either the Mach 0.70 or Mach 0.82 designs. In some instances two hours may appear critical for some turns in Europe, particularly for the Mach 0.70 airplane, but a corrective change in schedule is possible due to the high ground time available in New York and other U.S. cities.

4. TRANSPACIFIC SCHEDULES (TWA)

The city-pairs selected for transpacific schedule development include those major cities that are currently being served by U.S. airlines. The stage lengths are representative of Pacific operation and each market, except one, can support a daily SCV flight. The exception is Guam to Hong Kong where four flights per week adequately serve the market; however, this is a segment operated today as a part of the Honolulu-Hong Kong route, and, therefore, it is included in the schedules.

Figure 10, pictorially shows the selected transpacific routes. The following is a list of the selected city-pairs and their respective airport designations:

Los Angeles	(LAX)	-	Honolulu	(HNL)
San Francisco	(SFO)	-	Honolulu	(HNL)
		-	Tokyo	(TYO)
		-	Anchorage	(ANC)
Honolulu	(HNL)	-	Guam	(GUM)
		-	Hong Kong	(HKG)
		-	Sydney	(SYD)
		-	Tokyo	(TYO)
Guam	(GUM)	-	Hong Kong	(HKG)
Anchorage	(ANC)	-	Tokyo	(TYO)

4.1 Passenger Forecasts for 1995

Scheduled passenger traffic on the transpacific routes was forecast by TWA's Marketing Department for the year 1995. An industry forecast was made for each city pair using 1975 as the base year. Average annual growth rates for the selected markets range from about 2.5 percent for LAX-HNL to 7 percent for SFO-TYO and HNL-SYD. Certain assumptions were made concerning major factors affecting scheduled traffic growth such as an increase in interior U.S.-HNL nonstop service overflying the West Coast and the diversion of scheduled traffic to various types of charters, particularly in the U.S. Mainland-HNL, U.S. Mainland-TYO, and HNL-TYO markets.

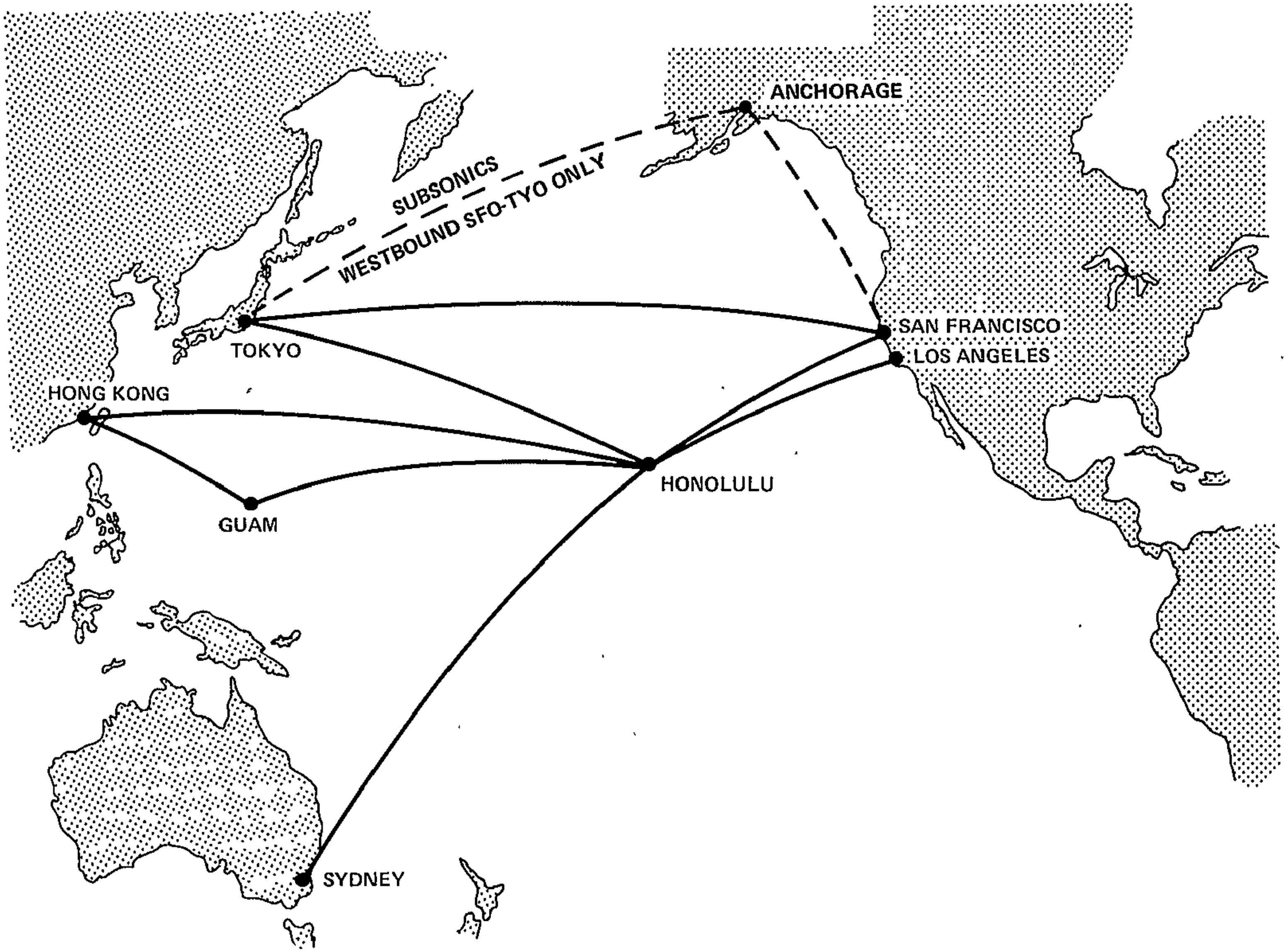


Figure 10. Transpacific routes

Having established the total scheduled passenger demand, a percentage of each market was assumed for the individual airline. The percentage was based on an equal share for each major airline now servicing the market, except for the HNL-HKG segment where 60 percent was assumed for the U.S. carrier. Table 13 shows the passenger demand for each flight segment in the year 1995 as well as the estimated growth factor.

4.2 Flight Segment Distances and Wind

Transpacific segment distances for both subsonic and supersonic cruise aircraft are great circle distances between the city-pair airports plus one percent for possible operational variations. There are no subsonic cruise leg requirements for SCV aircraft.

Tables 14 and 15 summarize the flight distances determined for the subsonic and supersonic aircraft which are identical, and their associated enroute cruise altitude wind speeds (Ref. Section 3.4 and Appendix A).

4.2.1 Operational range requirements. - Segment distances for transpacific operation are considerably greater than for the North Atlantic in spite of the fact that the average segment length is about the same in both cases. As noted in Tables 14 and 15, three segments, SFO-TYO, HNL-HKG, and HNL-SYD are over 8149 km (4400 n. mi.) in length and represent 50 percent of the total Pacific market share in terms of passenger miles as shown in Table 16. The longest segment, HNL-HKG, is 8890 km (4800 n. mi.) which westbound against headwinds is beyond the design range of all of the aircraft designs; however, for the supersonic vehicles it has been assumed that adequate tankage is available to fly the segment at some modest reduction in maximum payload capability. The subsonic airplanes cannot fly this segment westbound nonstop and a fuel stop is scheduled at Guam. A fuel stop is also scheduled for the subsonic aircraft on the westbound SFO-TYO segment, the stop being made at Anchorage, Alaska.

Table 17 shows the operational range requirements for the most critical nonstop Pacific segments. They are westbound flights and include the effect of the associated enroute winds.

4.3 Scheduled Flight Frequency

The conditions for setting flight frequencies of the Pacific schedules were the same as those for the North Atlantic, i.e., load factor limits between 52 percent and 70 percent and, to the degree possible, each flight operating daily.

The frequencies were established to serve individual segment passenger demand and did not specifically consider through traffic, e.g., the number of passengers between HNL and SYD obviously includes some number of passengers

TABLE 13. TRANSPACIFIC PASSENGER DEMAND

(Year 1995)

Segment	Growth factor to year 1995	No. psgrs. - Total mkt.		Assumed market share %	Share per week each direction
		Annual both direc.	Per week each direc.		
LAX-HNL	1.62	261 8000	25 104	20	5019
SFO-HNL	2.13	204 7000	19 629	25	4907
SFO-TYO	3.78	794 000	7 614	40	3045
HNL-GUM	1.83	342 000	3 279	100	3279
HNL-HKG	(1)	185 000	1 774	60	1064
GUM-HKG	2.39	67 000	644	100	644
HNL-SYD	3.78	841 000	8 064	50	4032
HNL-TYO	1.78	2 042 000	19 580	33	6461

NOTE: (1) No base available

TABLE 14. SEGMENT FLIGHT DISTANCES AND WINDS

(Subsonic Aircraft)

Segment	Flight Dist. km (n.mi.)	Enroute winds - M/S (knots) (1) 10668 m (35,0000 ft.)	
		Direct	Return
LAX-HNL	4147 (2239)	-17 (-33)	-7 (13)
SFO-HNL	3893 (2102)	-17 (-33)	-6 (11)
SFO-TYO	8364 (4516)	-27 (-54)	-16 (31)
HNL-GUM	6149 (3320)	-12 (-24)	-2 (3)
HNL-HKG	9001 (4860)	-31 (-62)	-8 (15)
HNL-SYD	8245 (4452)	-12 (-23)	-5 (10)
HNL-TYO	6249 (3374)	-33 (-65)	-14 (28)
GUM-HKG	3415 (1844)	-3 (-5)	-6 (-11)

NOTE: (1) (-) Denotes headwind.

TABLE 15. SEGMENT FLIGHT DISTANCE AND WINDS
(Supersonic Cruise Aircraft)

Segment	Total dist. km (nmi)	Subsonic$^{(1)}$ dist. km (nmi)	Enroute winds in cruise - m/s (knots) (2)				
			M 1.4 14 326m (47 000 ft)	M 2.0 16 154m (53 000 ft)	M 2.2 17 374m (57 000 ft)	M 2.7 18 895m (62 000 ft)	Subsonic 9 449m (31 000 ft)
LAX-HNL	4 147 (2239)	-	(-16/6 (-32/12)	-12/4 (-23/7)	-9/1 (-18/2)	-5/-3 (-10/-6)	-
SFO-HNL	3 893 (2102)	-	-16/6 (-31/11)	-11/4 (-22/7)	-9/1 (-17/2)	-5/-2 (-10/-4)	-
SFO-TYO	8 364 (4516)	-	-24/13 (-47/26)	-18/9 (-36/17)	-16/7 (-31/13)	-13/4 (-25/7)	-
HNL-GUM	6 149 (3320)	-	-11/-1 (-22/-2)	-7/-5 (-13/-9)	-4/-7 (-8/-13)	-1/-9 (-2/-18)	-
HNL-HKG	9 001 (4860)	-	-28/4 (-56/7)	-21/2 (-41/3)	-18/-2 (-36/-4)	-12/-5 (-23/-10)	-
HNL-SYD	8 245 (4452)	-	-11/5 (-21/9)	-8/3 (-15/5)	-6/-1 (-11/-1)	-3/-2 (-6/-3)	-
HNL-TYO	6 249 (3374)	-	-29/11 (-58/22)	-23/6 (-46/12)	-18/4 (-36/7)	-12/-1 (-24/-1)	-
GUM-HKG	3 415 (1844)	-	0/-10 (01-19)	-3/-13 (5/-25)	3/-13 (5/-25)	3/-13 (5/-25)	-

Note: (1) Subsonic departure/arrival.

(2) Winds direct/return (-) denotes headwind.

TABLE 16. TRANSPACIFIC CITY PAIR PERCENTAGE OF TOTAL PASSENGER MILES

Segment	Revenue distance km (st. miles)	Psgrs. per week	Psgr. distance per week km (st. miles x 10^{-6}	% of total psgr. distance
LAX-HNL	4108 (2553)	5 020	20.63 (12.82)	12.2
SFO-HNL	3855 (2396)	4 910	18.92 (11.76)	11.2
SFO-TYO	8285 (5149)	3 050	25.26 (15.70)	14.9
HNL-GUM	6090 (3785)	3 280	19.97 (12.41)	11.8
HNL-HKG	8904 (5534)	1 060	9.48 (5.89)	5.6
HNL-SYD	8167 (5076)	4 030	32.92 (20.46)	19.4
HNL-TYO	6190 (3847)	6 460	39.98 (24.85)	23.6
GUM-HKG	3384 (2103)	640	2.17 (1.35)	1.3
TOTALS		28 450	169.33 (105.24)	100.0

from LAX and SFO. The number was not known since the data was provided only by segment demand. In developing the schedules the number of through flights to SYD and to other cities through HNL was not defined and aircraft routing was optimized on a segment basis. Therefore, such flights do not necessarily operate at the same frequency in all schedules, although the markets are served.

Table 18 summarizes the number of round trip flights required per week for each type aircraft to satisfy the noted demand within the assumed load factor limits.

TABLE 17. TRANSPACIFIC OPERATIONAL RANGE REQUIREMENTS

(Longest Segments)

Segment	M 0.70 km (n.mi.)	M 0.82 km (n.mi.)	M 1.4 km (n.mi.)	M 2.0 km (n.mi.)	M 2.2 km (n.mi.)	M 2.7 km (n.mi.)
SFO-TYO	9 853 (5320)	9 556 (5160)	8 797 (4750)	8 630 (4660)	8 575 (4630)	8 482 (4580)
HNL-HKG	10 590 (5718)	10 386 (5608)	9 590 (5178)	9 312 (5028)	9 219 (4978)	9 127 (4928)
HNL-SYD	8 760 (4730)	8 667 (4680)	8 464 (4570)	8 353 (4510)	8 315 (4490)	8 278 (4470)

TABLE 18. TRANSPACIFIC OPERATION

WEEKLY FLIGHT FREQUENCY AS A FUNCTION OF PASSENGER

DEMAND AND AIRPLANE CAPACITY

		Mach 0.70 400 seat A/C		Mach 0.82 246 seat A/C		SCV 290 seat A/C	
Segment	Passengers per week each direction	Flts. per week	Load factor %	Flts. per week	Load factor %	Flts. per week	Load factor %
LAX-HNL	5019	21	59.8	35	58.3	28	61.8
SFO-HNL	4907	21	58.4	35	57.0	28	60.4
SFO-TYO	3045	14	54.4	21	58.9	18	58.3
HNL-GUM	3276	14	58.5	21	63.4	21	53.7
HNL-HKG	1064	4	66.5	7	61.8	7	52.4
HNL-SYD	4032	17	59.3	28	58.5	21	66.2
HNL-TYO	6461	28	57.7	42	62.5	35	63.7
GUM-HKG	644	3	53.7	4	65.4	4	55.5

4.4 Block Time Data

Segment block times were determined using the data included as Appendix A of this document provided by Lockheed for each aircraft design speed. The data were adjusted for the effect of 75 percent annual winds at the average cruise altitude for each aircraft design. The applicable wind speeds determined are shown in Tables 14 and 15.

Block times as calculated using the basic Lockheed data include a constant of fifteen minutes aircraft taxi time. Where necessary, the taxi times were adjusted to actual times in agreement with the Airline Block-Time Conference (ABC) statistical data presented in Table 19. These data shown in Table 19 are for large three and four engine aircraft.

TABLE 19. TAXI TIMES

	Time - Min.	
	Out	In
Guam (GUM)	13	5
Hong Kong (HKG)	11	6
Honolulu (HNL)	15	6
Los Angeles (LAX)	11	7
San Francisco (SFO)	15	6
Sydney (SYD)	12	6
Tokyo (TYO)	14	6
Anchorage (ANC)	10	5

Block times for the transpacific segments using the various study aircraft were calculated and are presented in Table 20.

4.5 Schedule Constraints

The scheduling ground rules adopted for the transpacific operation are summarized as follows:

- No takeoff or landing time restrictions at Guam or Honolulu for through flights.
- Terminating flight arrivals permitted to 2400 hours

TABLE 20. TRANSPACIFIC SCHEDULE BLOCK TIMES

(Hours:Minutes)

Segment	Mach 0.70		Mach 0.82		Mach 1.4		Mach 2.0		Mach 2.2		Mach 2.7	
	Direct	Return	Direct	Return	Direct	Return	Direct	Return	Direct	Return	Direct	Return
LAX-HNL	6:27	5:52	5:23	5:04	3:22	3:18	2:33	2:36	2:23	2:26	2:06	2.10
HNL-HKG	(1)	11:50	(1)	10:11	*6:56	6:24	*4:57	4:46	*4:34	*4:25	*3:54	*3:48
HNL-GUM	9:11	8:38	7:41	7:20	4:46	4:38	3:32	3:30	3:17	3:16	2:51	2:51
HNL-SYD	12:09	11:07	10:07	9:32	6:12	5:57	4:33	4:27	4:13	4:08	3:36	3:33
HNL-TYO	10:14	8:11	8:21	7:10	5:01	4:36	3:40	3:32	3:23	3:17	2:56	2:53
GUM-HKG	5:05	5:07	4:21	4:23	2:51	2:52	2:13	2:12	2:05	1:57	1:52	1:49
SFO-HNL	6:10	5:33	5:10	4:47	3:15	3:08	2:30	2:28	2:21	2:19	2:04	2:04
SFO-TYO	VIA ANC	10:40	VIA ANC	9:21	6:28	5:58	4:40	4:31	4:19	4:11	3:42	3:37
SFO-ANC	5:30	-	4:35	-								
ANC-TYO	8:15	-	7:08	-								

(1) Beyond range capability.

* Restricted pax payload on this segment.

- Originating flight departures from 0800 hours when necessary to prevent arrival at terminating station after 2400 hours
- No originating flight departures after 2300 hours
- No terminating flight arrivals before 0600 hours
- U.S. West Coast to Honolulu round trip turn time of one hour minimum
- Through time of one hour minimum for flights through Guam and Westbound through Honolulu. Eastbound through Honolulu requires 90 minutes to permit immigration and customs clearance.
- Aircraft overnight at maintenance station no less than every -
    - Seven round trips for SCV's
    - Five round trips for Mach 0.82 design
    - Four round trips for Mach 0.70 design

4.5.1 Airport curfews and flight time preferences. - It is noted that there are some significant differences between these rules and those for the North Atlantic with respect to departure and arrival time limitations. In North Atlantic operation the rules restrict the scheduling process to some degree but reasonable schedules can be developed and acceptable aircraft utilization can be achieved. Applying these same constraints to the Pacific would severaly restrict the schedules, and in at least one case, prevent the aircraft from returning from the Far-East. It was therefore necessary to eliminate the departure and arrival limits at Guam and Honolulu and permit terminating flight arrivals up to 2400 hours at other stations.

The relaxation of the rules for transpacific flights may seem to imply a dual standard; however, the route distances over the Pacific are extremely long and a flight may cross as many as eight time zones from origin to destination. Therefore, it becomes necessary to schedule arrivals and departures at intermediate stations at times somewhat less than desirable. Scheduled flights today transit Guam and Honolulu at early morning hours. No flight curfews are currently in force at these stations but if imposed would severely restrict airline service.

4.5.2 Through flight ground times. - Through flights were not required for the North Atlantic operation; however, they must be considered in the transpacific operation. In may respects there is little difference between the services required for a through flight and one that turns to become another flight. The airplane must be refueled and other essential services provided. Since it is a flight continuation, there are continuing passengers on board who in most instances are not interested in the intermediate station and want to get on with the journey. The airline will, therefore, expedite the required services to minimize through flight ground time.

Through flights of the transpacific schedule pass through Guam and Honolulu. For this study a minimum of one hour has been established for all flights through Guam and west-bound at Honolulu. East-bound flights through Honolulu require additional time to permit clearance of passengers by customs and immigration authorities. An additional thirty minutes is provided for this purpose.

4.6 Schedule and Fleet Requirements Development

Aircraft routing schedules for the transpacific routes were developed for each of the six airplane designs using the foregoing input information. A typical routing schedule is presented in Appendix B of this report.

4.6.1 Transpacific aircraft routing and productivity analysis. - Table 21 presents the fleet sizes, flight crew requirements and required fleet performance corresponding to the transpacific routing schedules developed during the study.

Routing schedules developed for the two subsonic aircraft on the Pacific routes indicate a requirement for 22 Mach 0.70 and 28 Mach 0.82 airplanes.

In terms of seat miles per day per aircraft, the 400 passenger Mach 0.70 airplane generates 31 percent more than the Mach 0.82. On the North Atlantic, however, this percentage is 79 percent. A portion of this improvement of the Mach 0.82 airplane relative to the Mach 0.70, perhaps five percentage points, can be accounted for by the load factor difference between the two aircraft. The remainder is a function of the Pacific route structure which permits higher utilization than could be achieved on the Atlantic. The longer routes allow flights to continue without the lengthy layover associated with Atlantic operation. The Mach 0.70 design benefits to a lesser degree since the reduction of layover time is smaller and its slow cruise speed cannot gain as much advantage of the longer routes.

The aircraft routing charts for transpacific operation of the SCVs were developed independent of one another attempting to optimize fleet size and resulting in four different schedule patterns. As pointed out previously in Section 4.3, flights from LAX/SFO through HNL to cities beyond do not operate at the same frequency in all schedules. In retrospect, it might have been a better approach to establish such frequencies to facilitate schedule comparisons, but failure to do so does not detract from the study objective to determine the effect of speed on productivity.

As shown in Table 21, there is a progressive improvement in productivity with cruise speed. Twelve Mach 2.7 aircraft are required to operate the schedule followed by 13, 14, and 18 for the Mach 2.2, 2.0, and 1.4 designs respectively. The productivity ratios, using Mach 2.7 as a base are 1.00, 0.92, 0.86, and 0.67 respectively.

TABLE 21. TRANSPACIFIC FLEET AND SCHEDULE REQUIREMENTS SUMMARY

Vehicle design cruise speed	Seating capacity	Total fleet size	Daily average block time hours/day/ aircraft	Daily average revenue distance per day per a/c km (st. miles)	Average available turn time hours	Flight crews required
Mach 0.70	400	22	13.94	9 450 (5 873)	2.32	182 (1)
Mach 0.82	246	28	14.66	11 705 (7 275)	2.31	230 (2)
Mach 1.4	290	18	11.86	15 303 (9 510)	2.22	137
Mach 2.0	290	14	11.44	19 675 (12 228)	2.21	105
Mach 2.2	290	13	11.47	21 189 (13 169)	2.02	100
Mach 2.7	290	12	10.82	22 954 (14 266)	2.25	87

NOTE: (1) M 0.70 Aircraft requires 102 relief crew members

(2) M 0.82 Aircraft requires 82 relief crew members

A comparison of the fleet and schedule requirements summaries for the Transpacific and North Atlantic (Tables 21 and 10) shows a substantial increase in unit revenue miles per day for the Mach 2.7 airplane, a small increase for the Mach 2.2 and a small reduction for the lower speed aircraft. The improvements in productivity can be attributed to the elimination of subsonic cruise segments, including the added flight mileage for such segments. The faster aircraft will, of course, benefit to a greater degree than the slower ones. To a lesser degree, the productivity changes result from the longer Pacific segments such as SFO-TYO, HNL-SYD and HNL-HKG which make up about 38 percent of the total scheduled mileage. The change in productivity with cruise speed on the Pacific routes would seem to indicate that if all the North Atlantic segments could be flown supersonically a similar change would result; however, this is not apparent on inspection of the routing charts.

As previously explained in Section 3.6, a more correlative comparison of speed versus productivity may be made by use of a speed called turn-around block speed instead of cruise speed. The time that is needed to complete a segment can be measured by adding the turn-around time of 1.5 hours to the block time. When this time is translated into speed for a given segment, the percentage increase for the Mach 2.2 and 2.7 airplanes over the Mach 2.0 airplane is significantly reduced. Figure 11 graphically presents a productivity comparison of supersonic aircraft in the transpacific operation in the various speed terms. It is noted that almost perfect correlation is achieved between the turn-around block speed and productivity (revenue miles per day per aircraft). It is also noted that slightly larger percent changes in turn-around block speed occur for the transpacific compared to the North Atlantic; this is probably due to the absence of subsonic cruise segments which have a levelling effect on the North Atlantic schedules.

Figure 12 graphically presents a comparison of productivity for the six study aircraft in the transpacific operation. The comparison utilizes the revenue-passenger-miles basis in this case due to the differentials in subsonic aircraft seating capacities.

4.6.2 Impact of SCV subsonic cruise segments.

- With respect to the effect of subsonic cruise segments, the average segment flight speed for the Mach 2.7 design on Pacific flights is about 11 percent higher than the North Atlantic average segment speed. This reduces to 4 percent for the Mach 1.4 aircraft and is solely attributed to the subsonic cruise requirement for the North Atlantic operation.

4.6.3 SCV flight potential in excess of passenger demand.

- In Section 3.6, regarding this subject for the North Atlantic operation, it was concluded that any significant increase in passenger demand must result in an increase in fleet size. A modest increase in load factor could accommodate some traffic increase but since the load factor, as an average is quite high, any increase must be quite limited. A review of the transpacific schedules reveals a similar situation, except for a few days idle airplane time at San Francisco which could be used for growth in the SFO to TYO or HNL markets or extra sections or to back up schedules.

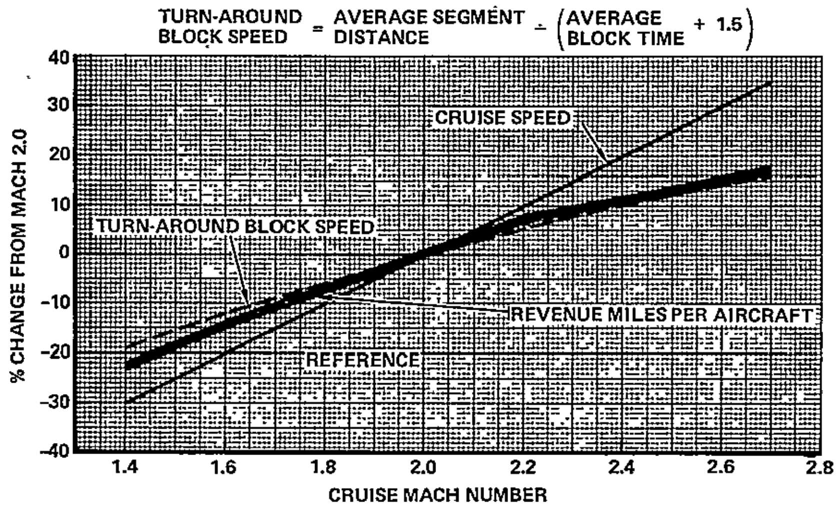


Figure 11. Transpacific ACV productivity comparison with turn-around block speed, Mach 2 reference

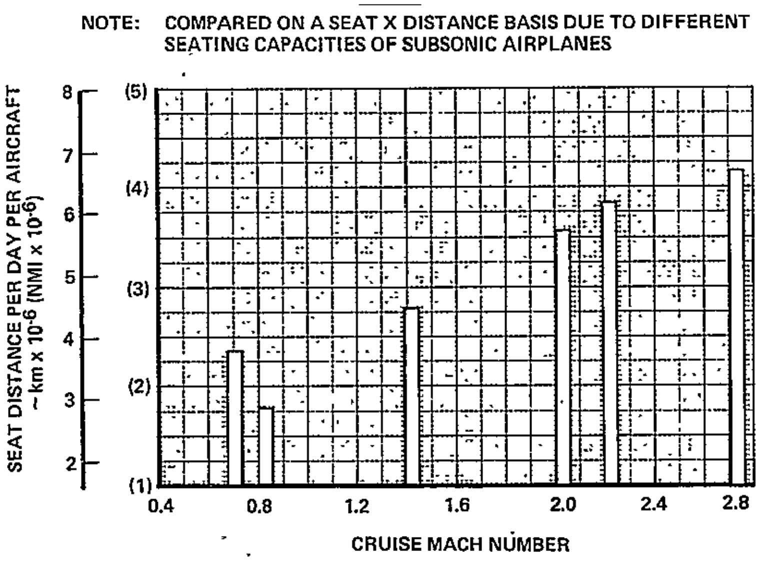


Figure 12. Transpacific airplane productivity versus Mach number

4.6.4 Flight crew requirements. - Flight crew requirements for the transpacific schedules were developed in the same manner as those for the North-Atlantic schedules (see Section 3.6). The number or crews so determined is the number necessary to operate the schedule and does not provide an allowance for vacations, sick leave, training, and other nonrevenue flying. Total crew requirements are about 28 percent higher, a factor applicable to all schedules.

In addition to the normal three-man crew, the subsonic airplanes require a relief crew on certain segments. This additional crew member is necessary whenever block time of a non-stop flight exceeds 9.5 hours. The Mach 0.70 and Mach 0.82 aircraft require the extra man on seven and five transpacific flights respectively. Block times for the supersonic aircraft are well below the 9.5 hour limit and therefore, the supersonic aircraft flights are not affected by this requirement.

4.7 Effect of Turn Time on Fleet Size

The effects of turn time on fleet size for the transpacific operation were determined for two hour turns and compared with the standard time of 90 minutes. Complete schedules were developed for all but the Mach 2.0 design which will follow the trend of the Mach 2.2 airplane.

In developing the schedules for two hour turns the minimum through-times at Guam and Honolulu remain the same as for the standard schedules, i.e., one hour, except 90 minutes eastbound through Honolulu.

The results of the investigation are shown in Figure 13. They are similar to those for the North Atlantic for the SCV schedules except for the Mach 2.7 design which requires an additional airplane at two hours turn time, whereas no increase was required on the Atlantic. The two subsonic airplanes were also investigated and results show no increase in fleet size for the Mach 0.82 airplane but the Mach 0.70 requires two additional aircraft. Unlike the North Atlantic routing patterns there are no long layovers for the subsonic airplanes. A high percentage of the turns approach the minimum time, particularly for the Mach 0.70 design for which the two hour turn is more critical.

No schedules were developed for a one hour or three hour turn time. The three hour requirement is, of course, unrealistic but as a matter of interest an inspection of the routing charts indicates it would create an almost impossible scheduling situation for the slower speed airplanes. A one hour turn, also somewhat unrealistic as routine, would no doubt reduce the fleet size for the subsonic and Mach 1.4 aircraft by perhaps one unit. The higher speed designs, particularly Mach 2.7, would not benefit in terms of fleet size since a one airplane reduction is a relatively high percent of the fleet.

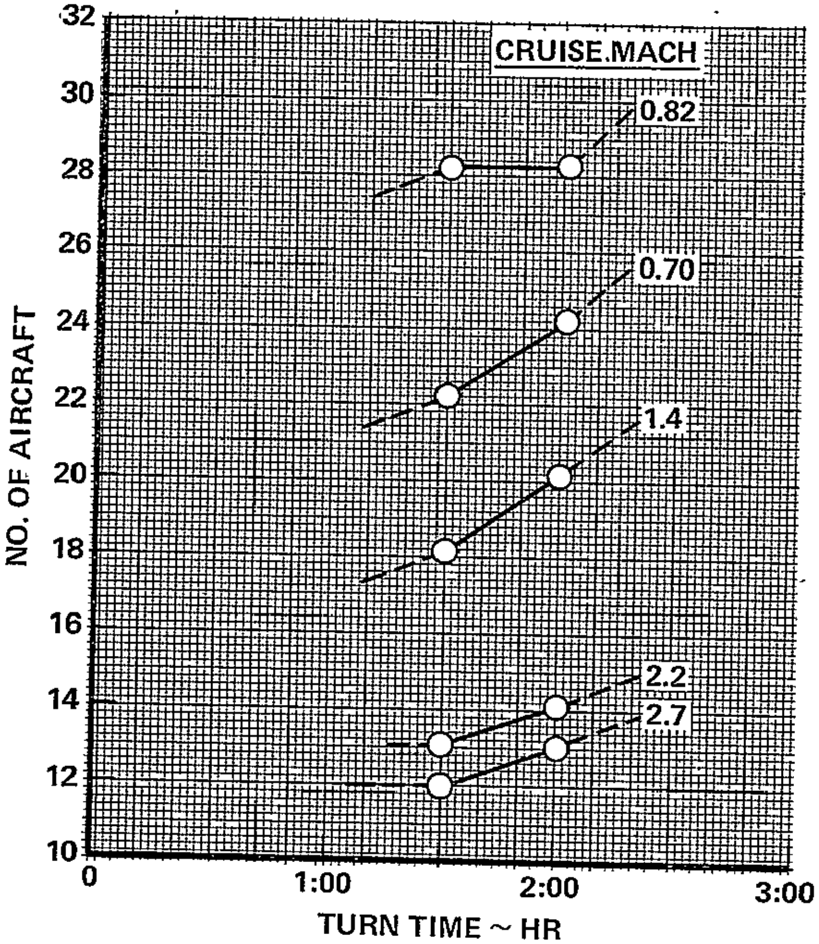


Figure 13. Trans-Pacific effect of turntime on fleet size

5. NORTH-SOUTH AMERICA (BRANIFF)

The city-pair selections for the North-South America routes were selected from Braniff International's current route structure and are ones that require at least two hours block time for the Mach 2.7 aircraft. The present Braniff route structure includes several international segments of less than 2778 km (1500 n.mi.); however, these segments were not included in the city-pairs selected for this study because there is little likelihood they would be included in a future supersonic transport route structure. The city-pairs and corresponding airports listed below are pictorially shown in Figure 14.

	City Pair	Airports
New York	- Panama City, Panama	JKF - TUM
	- Bogata, Columbia	- BOG
	- Guayaquil, Ecuador	- GYE
	- Lima, Peru	- LIM
	- Santiago, Chile	- SCL
	- Buenos Aires, Argentina	- EZE
Miami	- Guayaquil	MIA - GYE
	- Lima	- LIM
	- Santiago	- SCL
	- Buenos Aires	- EZE
Los Angeles	- Bogata	LAX - BOG
	- Lima	- LIM

5.1 Passenger Forecasts for 1995

Unlike domestic United States passenger traffic data, most information sources on international passenger traffic are inadequate. Among the variety of sources available, the information are often incomplete or inconsistent. For this reason, the 1975 base passenger traffic data used by Braniff are from the Immigration and Naturalization Service (INS) 1975 Annual Report.

The INS data are the most adequate information source of total passenger traffic flow between U.S. gateways and the South America market. Using this data, a total market assessment was made for passenger travel between U.S. ports and those South American countries that Braniff International holds non-stop route authority. In most cases traffic enters South American countries only through Braniff-served cities. The results of this assessment and the 1995 passenger forecasts are shown in Table 22.

The 1975 to 1995 passenger traffic projections are based on average annual growth rates obtained from the Air Transport Association report "International Air Travel Industry Passenger Demand Forecast — U.S. Related Traffic." The overall average for the selected city-pairs is approximately 8 percent. Braniff assumes 50 percent share of the total market.

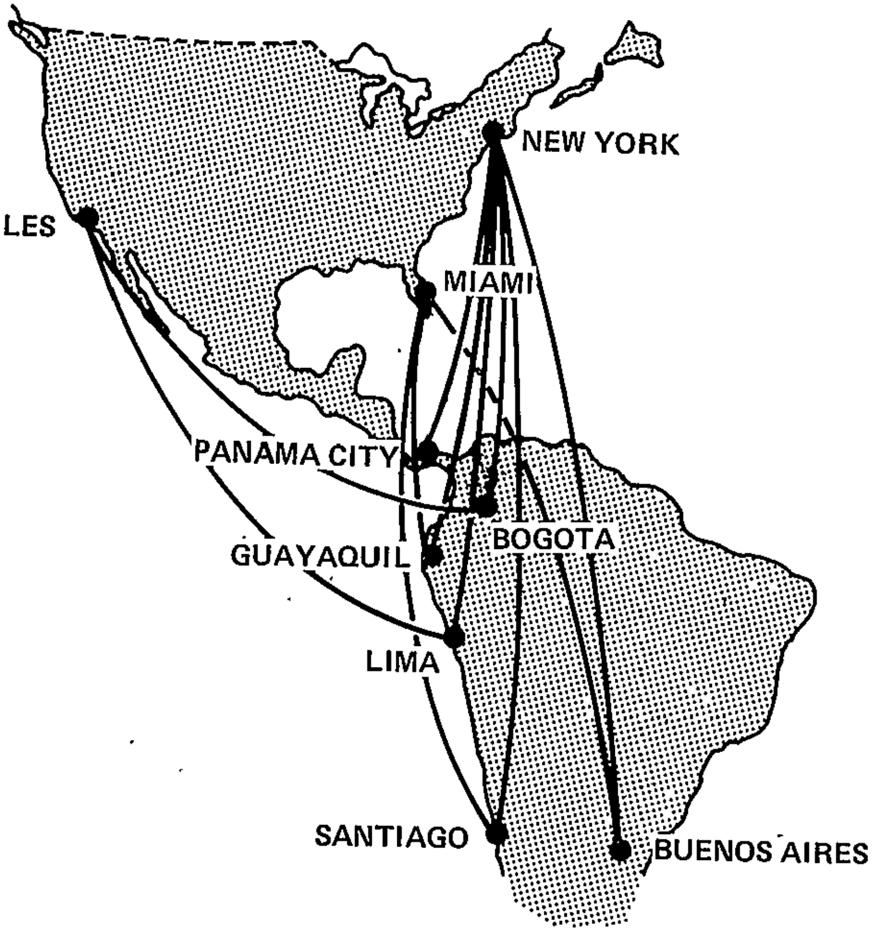


Figure 14. North-South America routes

Miami is currently the main U.S. gateway for South America as reflected by the INS data; however, the final destination of many of the Miami passengers is actually New York. The introduction of more attractive direct service between New York and South America would undoubtedly shift many passengers away from one-stop Miami service to nonstop New York service. The 1995 passenger forecast data allow for this shift by assuming that 40 percent of the present day Miami traffic will fly directly to New York by 1995.

5.2 Flight Distances and Winds

The flight segment distances and wind data for the subsonic aircraft shown in Table 23 are the same as those currently used by Braniff. The corresponding data for the SCV's shown in Table 24 are based on flight paths that avoid supersonic flight over inhabited land areas assuming a sonic boom path of 50 miles. For purposes of this study, uninhabited areas are defined as areas having less than three inhabitants per square mile. Some of the supersonic tracks pass over such sparsely populated areas.

There are no tolerances applied to the distance data for operational or navigational errors. The winds are from Boeing's published worldwide annual winds with a75 percent reliability as referenced in section 3.2.

5.3 Scheduled Flight Frequency

Scheduled flight frequencies were set to achieve 60 to 70 percent load factors for the projected passenger demand. Daily service is provided between most city-pairs. The number of weekly round trip flights for each type of aircraft are listed in Table 25.

5.4 Block Time Data

Segment block time data for the different speed aircraft were determined using the data in Appendix A and are listed in Table 26. In addition to the 10-minutes departure and 5 minutes arrival taxi time allowances included in the Appendix A data, another 5-minutes were added for arrivals and departures at U.S. airports. South American airports are generally uncongested and thus do not require additional time allowances.

TABLE 22. NORTH-SOUTH AMERICA WEEKLY PASSENGER FORECAST FOR 1995 BRANIFF SHARE - EACH DIRECTION

Segment	1975 Industry actual	1995 Total annual forecast	Braniff's weekly share each way
JFK-TUM	18 091	333 195	3150
-BOG	59 351	583 890	5600
-GYE	16 125	218 140	2100
-LIM	32 561	243 862	2350
-SCL	13 716	83 334	800
-EZE	75 293	351 016	3360
MIA-GYE	100 853	327 212	3150
-LIM	98 210	365 793	3500
-SCL	30 972	125 002	1190
-EZE	54 258	252 951	2450
LAX-BOG	23 321	108 723	1050
-LIM	37 128	173 091	1680

TABLE 23. SEGMENT FLIGHT DISTANCES AND WINDS (Subsonic Aircraft)

Segment	Flight distance km (n.mi.)	Enroute Wings - m/s (knots)(1) 10 058 (33 000 ft)	
		Direct	Return
JFK-TUM	3650 (1971)	-8 (-15)	-3 (-6)
-BOG	4104 (2216)	-7 (-11)	-4 (-8)
-GYE	4924 (2659)	-6 (-12)	-3 (-5)
-LIM	6010 (3245)	-4 (-8)	-3 (-6)
-SCL	8427 (4550)	-2 (-4)	-5 (-10)
-EZE	8730 (4714)	-2 (-3)	-6 (-11)
MIA-GYE	3200 (1728)	-4 (-7)	-4 (-7)
-LIM	4334 (2340)	-2 (-4)	-4 (-8)
-SCL	6817 (3681)	-1 (-1)	-6 (-12)
-EZE	7288 (3935)	1 (+1)	-7 (-14)
LAX-BOG	5737 (3098)	-1 (-1)	-12 (-24)
-LIM	6843 (3695)	0 (0)	-8 (-15)

NOTE: (1) (-) Denotes headwind

TABLE 24. SEGMENT FLIGHT DISTANCE AND WINDS
(Supersonic Cruise Aircraft)

Segment	Total dist. ~km (n.mi.)	Subsonic[(1)] dist. ~km (n.mi.)	Enroute winds in cruise – m/s (knots)[(2)]				
			M 1.4 14 326 m (47 000 ft)	M 2.0 16 154 m (53 000 ft)	M 2.2 17 374 m (57 000 ft)	M 2.7 18 898 m (62 000 ft)	Subsonic 9 449 m (31 000 ft)
JFK–TUM	3732 (2015)	0/0 (0/0)	-7/-3 (-13/-6)	-4/-3 (-8/-5)	-4/-3 (-8/-5)	-3/-3 (-6/-5)	0/0 (0/0)
-BOG	4145 (2238)	0/324 (0/175)	-5/-3 (-9/-6)	-3/-3 (-6/-6)	-3/-3 (-6/-5)	-3/-3 (-5/-5)	-5/-4 (-10/-7)
-GYE	4980 (2689)	0/341 (0/184)	-5/-3 (-10/-5)	-3/-3 (-6/-5)	-3/-3 (-6/-5)	-3/-3 (-5/-5)	-6/-3 (-11/-5)
-LIM	6288 (3395)	0/0 (0/0)	-3/-3 (-6/-6)	-2/-2 (-4/-4)	-2/-2 (-4/-4)	-2/-2 (-3/-3)	0/0 (0/0)
-SCL	8754 (4727)	0/250 (0/135)	-2/-5 (-3/-9)	-1/-3 (-2/-6)	-1/-3 (-2/-6)	-2/-3 (-3/-5)	-2/-5 (-4/-9)
-EZE	8890 (4800)	0/939 (0/507)	-1/-3 (-2/-5)	-1/-1 (-2/-2)	-2/-1 (-3/-2)	-2/-1 (-4/-1)	-2/-5 (-3/-10)
MIA-GYE	3582 (1934)	0/341 (0/184)	-3/-4 (-6/-7)	-2/-4 (-4/-7)	-2/-3 (-4/-6)	-3/-3 (-5/-6)	-3/-4 (-6/-7)
-LIM	4889 (2640)	0/0 (0/0)	-2/-4 (-3/-8)	-2/-4 (-3/-7)	-2/-3 (-3/-6)	-2/-3 (-4/-6)	0/0 (0/0)
-SCL	7356 (3972)	0/250 (0/135)	0/-6 (0/-11)	-1/-4 (-1/-8)	-1/-4 (-1/-7)	-2/-3 (-3/-5)	-1/-6 (-1/-11)
-EZE	8041 (4342)	0/939 (0/507	-1/-7 (-1/-13)	0/-5 (0/-9)	-1/-4 (-1/-8)	-2/-3 (-3/-5)	-1/-7 (-1/-13)
LAX-BOG	6223 (3360)	0/370 (0/200)	-1/-12 (-2/-23)	-3/-9 (-5/-17	-5/-8 (9/-15)	-6/-5 (-11/10)	-1/-12 (-2/-23)
-LIM	6843 (3695)	0/0 (0/0)	-1/-7 (-1/-14)	-2/-5 (-3/10)	-3/-4 (-5/-8)	-4/-3 (-8/-6)	0/0 (0/0)

NOTES: (1) Subsonic departure/arrival.

(2) Winds direct/return (-) denotes headwind.

TABLE 25. WEEKLY FLIGHT FREQUENCY AS A FUNCTION OF PASSENGER DEMAND AND AIRPLANE CAPACITY

Segment	Passengers per week each direction	Mach 0.70 400 seat A/C		Mach 0.82 246 seat A/C		SCV 290 seat A/C	
		Flts. per week	Load factor %	Flts. per week	Load factor %	Flts. per week	Load factor %
JFK-TUM	3150	12	66	20	64	17	64
-BOG	5600	21	67	35	65	30	64
-GYE	2100	8	66	13	66	11	66
-LIM	2350	9	65	14	68	12	68
-SCL	800	3	67	5	65	5	55
-EZE	3360	12	70	21	65	18	64
MIA-GYE	3150	12	66	20	64	17	64
-LIM	3500	13	67	21	68	18	67
-SCL	1190	5	60	7	69	6	68
-EZE	2450	9	68	14	71	12	70
LAX-BOG	1050	4	66	7	61	6	60
-LIM	1680	6	70	10	68	9	64

TABLE 26. SCHEDULE BLOCK TIMES - SOUTH AMERICA
(Hours:Minutes)

Segment	Mach 0.70		Mach 0.82		1.4 Mach		2.0 Mach		2.2 Mach		2.7 Mach	
	Direct	Return	Direct	Return	Direct	Return	Direct	Return	Direct	Return	Direct	Return
JFK-TUM	5:32	5:25	4:45	4:40	3:04	3:03	2:24	2:23	2:15	2:15	2:00	2:00
-BOG	6:07	6:04	5:13	5:11	3:25	3:26	2:42	2:44	2:34	2:35	2:18	2:19
-GYE	7:14	7:08	6:07	6:04	4:00	3:59	3:07	3:08	2:56	2:57	2:36	2:37
-LIM	8:38	8:36	7:20	7:19	4:47	4:47	3:36	3:36	3:21	3:21	2:54	2:54
-SCL	11:49	11:59	10:01	10:07	6:28	6:30	4:50	4:51	4:30	4:31	3:53	3:54
-EZE	12:04	12:25	10:05	10:17	6:46	6:48	5:16	5:18	4:57	4:58	4:23	4:24
MIA-GYE	4:50	4:50	4:11	4:11	3:02	3:03	2:27	2:28	2:19	2:21	2:06	2:08
-LIM	6:18	6:22	5:25	5:26	3:50	3:51	2:56	2:56	2:45	2:45	2:24	2:24
-SCL	9:35	9:49	8:10	8:13	5:30	5:35	4:10	4:12	3:53	3:55	3:23	3:24
-EZE	10:08	10:32	8:38	8:52	6:11	6:17	4:51	4:54	4:34	4:37	4:04	4:06
LAX-BOG	8:08	8:37	6:56	7:12	4:48	4:55	3:42	3:46	3:29	3:31	3:04	3:05
-LIM	9:36	9:55	8:10	8:22	5:07	5:12	3:51	3:52	3:35	3:36	3:06	3:06

5.5 Schedule Constraints

A summary of ground rules applicable to schedule development are presented below:

- No U.S. departures between 2300 and 0900
- No U.S. arrivals between 2300 and 0600
- Minimum turn time of 1 hour and 30 minutes
- No subsonic tag-end flights
- Maintenance base at JFK or LAX.

5.5.1 Airport curfews and flight time preferences. — Existing curfews at U.S. airports were observed, but no curfew constraints were applied to operations at South American airports. The South American airports in this study are located in sparsely populated areas and have no pressure from local citizens for curfews or noise restrictions.

In most South American countries, late night departures for North American destinations are preferred. Such departures allow the passengers to have their usual late evening dinner with sufficient time to board an airplane scheduled for early morning arrival in North America.

5.5.2 Turn time allowance. — The conditions which cause the establishment of a 1.5 hour minimum turn time are passenger unloading, passenger cabin cleaning, and passenger loading. For routine operations, 1.5 hours is a reasonable minimum for a 290 passenger airplane. Less time would be taken for unusual circumstances such as when making up for lost time.

5.5.3 Maintenance time allowance. — The maintenance times were allotted to JFK during the curfew hours. The maintenance cycles were not analyzed due to unfamiliarity with the SCV; however, Braniff maintenance authorities reviewed the routing schedules and concluded there was ample maintenance time available.

5.6 Schedule and Fleet Requirements Development

Based on the foregoing scheduling demands, aircraft routing schedules were developed for each of the six design cruise speed aircraft.

A summary of productivity and utilizations data from these schedules are presented in Table 27.

5.6.1 Aircraft productivity versus aircraft cruise speed. — A comparison of the SCV productivity to the turn-around block speed is shown in Figure 15.

TABLE 27. NORTH — SOUTH AMERICA SCHEDULE SUMMARY

Vehicle design cruise speed	Seating capacity	Total fleet size	Daily average block time hours/ day/ aircraft	Daily average rev. distance per day per a/c km (st. miles)	Flight crews required	Average available turn time hours
Mach 0.70	400	22	13.6	17 613 (10 946)	174	-
Mach 0.82	246	35	12.3	11 071 (6 881)	245	-
Mach 1.4	290	20	10.2	12 040 (7 483)	118	2.5
Mach 2.0	290	16	9.9	15 050 (9 354)	92	1.7
Mach 2.2	290	14	10.6	17 202 (10 691)	87	2.0
Mach 2.7	290	14	9.4	17 202 (10 691)	76	2.3

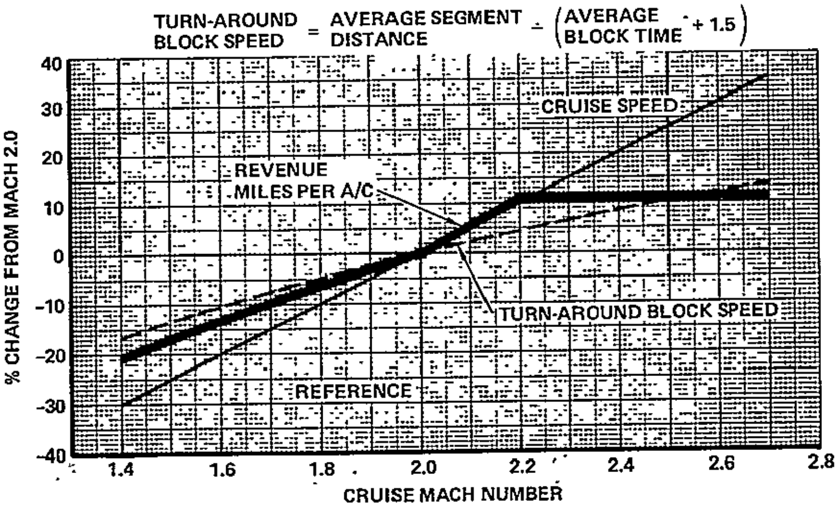


Figure 15. North - South America SCV productivity comparison with turn-around block speed, Mach 2 reference

6. COMBINED ROUTE STUDIES

The combined route studies investigate the potential for improving SCV fleet productivity by combining the SCV fleet operations of two airlines. Presumably, a combined fleet operation will increase the number of scheduling options available, permitting the circumvention of the marketing condition constraints attendant to single airline route operation. The main thrust of this investigation is to determine if scheduling constraints have greater effect on aircraft of certain cruise speed.

One of the keys to high aircraft productivity obviously is to route individual aircraft with minimal scheduling constraints. Aircraft routing schedules for the individual-route-systems are sometimes constrained by curfews, or more frequently, by the lack of passengers. An aircraft that could make two flights a day but is scheduled for only one is an example of such a constraint. Such an aircraft might be paired with one in a similar situation on another airline. Ideally, the scheduling commitments of two aircraft could be met by one thereby doubling productivity.

Because of the relatively high aircraft utilizations achieved generally on the individual route schedules, it was decided to do the combination schedules as a combined airline, rather than two different airlines sharing equipment or routes. By this means, the maximum productivity was antiticipated. TWA developed routing schedules for the Mach 1.4 and 2.7 aircraft and Braniff developed schedules for the Mach 2.0 and 2.2 aircraft.

6.1 Scheduled Flight Frequency

The city-pairs and routing data are the same for the combined routes as for the individual route systems shown in Sections 3, 4, and 5. The Mach 1.4 and 2.7 aircraft flight frequencies for both the North Atlantic and Trans-Pacific segments were changed in a few cases to bring load factors more in line with the system average. These changes result in a reduction of two flights per week between North Atlantic city-pairs and one per week for the transpacific. There were no changes in North-South America service. These minor changes in total flights would have no effect on the fleet size requirements of the original schedules.

6.2 Scheduling Constraints

The scheduling constraints for the combined schedules are the same as those used for the individual schedules, i.e., for the North Atlantic, trans-pacific, and North-South America routes.

The combined schedules assume that a single airline operates the routes and the 1.5 hour minimum turn time applies. On an interchange basis the minimum turn time would have to be increased to at least two hours and perhaps two-and-one-half hours if the aircraft were moved another gate area. Additional time might also be needed for changing passenger cabin and galley items to those of the operating airline.

The routing schedules were developed to allow six to eight hours maintenance-time-allowance per 14 flights with the maintenance base at JFK or LAX.

6.3 Schedule and Fleet Requirements Development

Two aircraft routing schedules were developed per SCV aircraft: (1) North Atlantic flights were combined with those from New York to South America, and (2) transpacific flights with those from Los Angeles to South America. Generally, the Miami to South America routings were left intact except for some minor adjustments in Braniff's Mach 1.4 schedules which routed aircraft from Miami to South America, and then to Los Angeles.

Summaries of the combined schedule results are provided in Table 28 to 31.

6.3.1 Mach 1.4 SCV Routing Analysis. - Combining the routes with the Mach 1.4 aircraft results in a reduction in fleet size of four aircraft from the sum total of the separate fleets. The North Atlantic/South America fleet reduction is two aircraft; the transpacific and Miami/South America, one each.

The utilization of this airplane from Los Angeles and New York to South America is quite low providing time for additional flights when combined with the other routings. It was possible to serve all the Los Angeles/South America segments with the transpacific fleet of 18 aircraft. This also reduced the Miami fleet by one aircraft since all but one LAX-LIM flight per week had been served by the Miami fleet.

6.3.2 Mach 2.0 and Mach 2.2 SCV Routing Analysis. - The Mach 2.0 and Mach 2.2 combined route schedules have a fleet size reduction of one each compared to the corresponding total fleet size requirements for the individual-routes.

6.3.3 Mach 2.7 SCV Routing Analysis. - No reduction in fleet size, as compared with the sum of separate schedules, was realized with the Mach 2.7 airplane. Daily aircraft utilization, except for Miami-South America, is reasonably high and little time is available for improvement. The Miami-South America utilization is relatively low and thought was given to turning flights to South America from JFK back to Miami to improve the utilization and perhaps save one aircraft. The scheduled frequencies did not permit this with any degree of efficiency.

TABLE 28. COMPARISON BETWEEN COMBINED AND SEPARATE SCHEDULES RESULTS FOR MACH 1.4 AIRCRAFT

	Separate schedules	Combined schedules			
	Totals and averages (Note 1)	Totals and averages (Note 2)	N. Atl and S. America operated from JFK	Pacific and S. America from LAX	Miami to S. America (Note 3)
Block hours/day	692.2	688.5	389.3	233.7	65.5
No. of aircraft	59	55	31	18	6
Utilization (hrs/day/aircraft)	11.73	12.52	12.56	12.98	10.92
Scheduled revenue distance/day km	845 745	840 749	468 145	300 355	72 249
(S. miles)	(525 634)	(522 529)	(290 954)	(186 672)	(44 903)
Revenue distance/day/aircraft km	14 355	15 287	15 102	16 687	12 042
(S. miles)	(8909)	(9501)	(9386)	(10 371)	(7484)

Note 1 See Tables 32 and 33 for breakdown

Note 2 Difference in mileage and block hours totals due to refinement in TWA schedules to bring some load factors more in line with the study averages.

Note 3 Same as Braniff in separate schedules

TABLE 29. COMPARISON BETWEEN COMBINED AND SEPARATE SCHEDULES RESULTS FOR MACH 2.0 AIRCRAFT

	Separate schedules	Combined schedules		
	Totals and averages (Note 1)	Totals and averages	N. Atl and S. America (Note 2)	Pacific and S. America from LAX
Block hours/day	532.5	532.5	355.7	176.8
No. of aircraft	46	45	31	14
Utilization (hrs/day/aircraft	11.58	11.83	11.47	12.63
Scheduled revenue distance/day km	845 745	845 745	543 483	302 262
(S. miles)	(525 634)	(525 634)	(377 777)	(187 857)
Revenue distance/day/aircraft km	18 386	18 795	17 532	21 590
(S. miles)	(11 427)	(11 681)	(10 896)	(13 418)

Note 1 See Tables 32 and 33 for breakdown

Note 2 Includes operations from JFK and MIA

TABLE 30. COMPARISON BETWEEN COMBINED AND SEPARATE SCHEDULES RESULTS FOR MACH 2.2 AIRCRAFT

	Separate schedules	Combined schedules		
	Totals and averages (Note 1)	Totals and averages	N. Atl and S. America (Note 2)	Pacific and S. America from LAX
Block hours/day	499.2	499.2	334.8	164.3
No. of aircraft	43	42	28	14
Utilization (hrs/day/aircraft)	11.61	11.88	11.96	11.74
Scheduled revenue distance/day km	845 745	845 745	543 483	302 262
(S. miles)	(525 634)	(525 634)	(337 777)	(187 857)
Revenue distance/day/aircraft km	19 668	20 137	19 409	21 590
(S. miles)	(12 224)	(12 515)	(12 063)	(13 418)

Note 1 See Tables 32 and 33 for breakdown

Note 2 Includes operations from JFK and MIA

TABLE 31. COMPARISON BETWEEN COMBINED AND SEPARATE SCHEDULES RESULTS FOR MACH 2.7 AIRCRAFT

	Separate schedules	Combined schedules			
	Totals and averages (Note 1)	Totals and averages (Note 2)	N. Atl and S. America operated from JFK	Pacific and S. America from LAX	Miami to S. America (Note 3)
Block hours/day	441.5	441.5	255.9	143.2	42.5
No. of aircraft	42	42	24	13	5
Utilization (hrs/day/aircraft)	10.51	10.52	10.66	11.01	8.49
Scheduled revenue distance/day km	845 745	840 749	468 145	300 355	72 249
(S. miles)	(525 634)	(522 529)	(290 954)	(186 672)	(44 903)
Revenue distance/day/aircraft km	20 137	20 018	19 506	23 104	14 450
(S. miles)	(12 515)	(12 441)	(12 123)	(14 359)	(8981)

Note 1 See Tables 32 and 33 for breakdown

Note 2 Difference in mileage and block hours totals due to refinement in TWA schedules to bring some load factors more in line with the study averages.

Note 3 Same as Braniff in separate schedules

6.3.4 Combined Routes Versus Individual Routes. - Aircraft productivities and utilizations versus cruise speed for the combined-routes and individual-routes are shown in Figures 16 and 17.

The averages of the two combined-routes shows considerable productivity improvement over the average of the three individual-route systems except for the Mach 2.7 aircraft. The small deficiency in the Mach 2.7 productivity for the combined average is due to the reduction in flights described previously. The productivity improvement for the three lower speed SCV's over the individual-route average is due to improved aircraft utilizations between North American and South American city-pairs. This is illustrated in Figure 17 by the 20 percent higher aircraft utilizations of the combined average as compared to those for the individual North-South America routes. These comparisons also illustrate that combining routes has a detrimental impact on both the North Atlantic and transpacific productivities. Hence, the results of this investigation show that though expanded routing may be beneficial to certian constricted routings, it is detrimental to routings that are generally unconstricted.

If the combined routes were scheduled on the basis of shared equipment requiring gate changes, it is doubtful that any productivity improvement could have been generated. Moving aircraft from the gate of one airline to that of another would increase turn-time by at least one hour raising the minimum turn-time for such instances to two-and-one-half hours. This would likely nullify the modest productivity gains achieved in this study; however, gate changes are not necessarily a part of sharing aircraft between two airlines. Braniff presently has a shared equipment arrangement with another airline with no gate changes during a stop. Aircraft leaving Braniff routes use Braniff gates and aircraft returning use the other airline's gates. Although modest productivity gains are achieved with this shared-equipment agreement, the main advantage is that it allows Braniff to offer one-stop (no plane change) service to a city outside of its route system and vice-versa for the other airline.

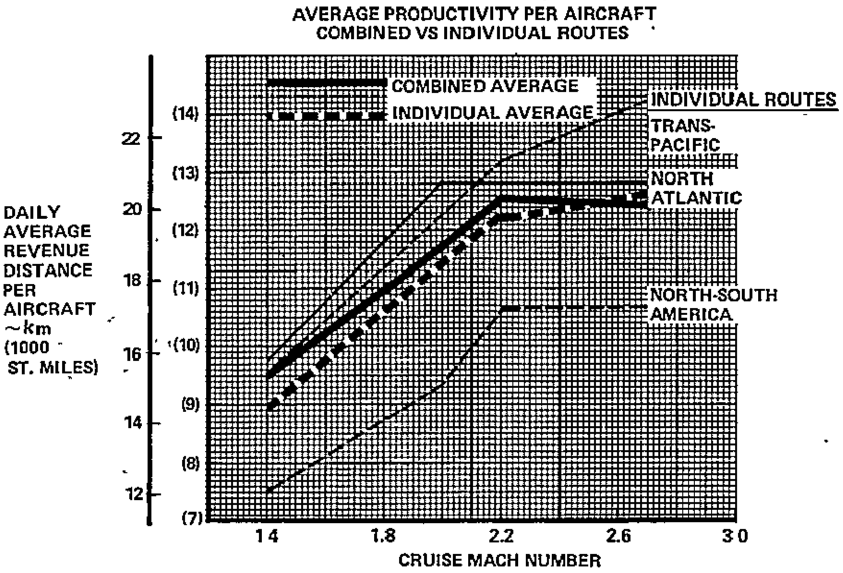


Figure 16. - Average productivity per aircraft combined versus individual routes.

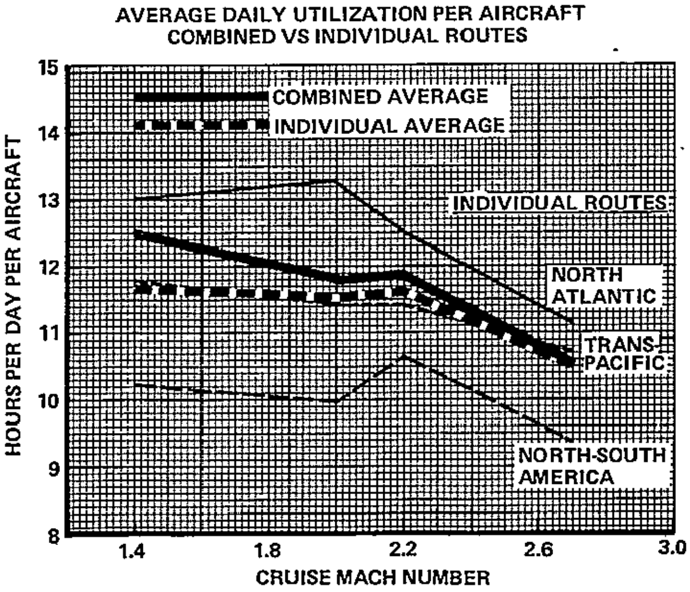


Figure 17. - Average daily utilization per aircraft combined versus individual routes.

7. STUDY RESULTS AND CONCLUSIONS

The three individual route studies reveal some interesting similarities and contrasts when their results are compared to one another. This section provides such comparisons which in addition to the findings presented in the preceding sections form the basis for the study conclusions.

7.1 Schedule Summaries

Valid productivity comparisons between the subsonic aircraft and between the subsonic and supersonic aircraft were not possible in the individual route studies because of the seating capacity differences. The seating capacity differences result in flight frequency differences which distort any comparison attempting to show the effect of speed on productivity for these aircraft. Additional schedules were therefore developed by TWA for the subsonic aircraft scheduled to the SCV flight frequencies.

These schedules were developed for the North Atlantic and transpacific routes with the North Atlantic results reported in Section 3.6. For both the North Atlantic and transpacific schedules, the changes in fleet size are closely proportional to changes in seating capacity. On the basis of this proportionality, the subsonic aircraft fleet sizes for the North-South America studies were adjusted to the 290 passenger seating capacity. Thus, the subsonic aircraft schedule results reported in this section are based on the same seating capacity as the SCV's.

A summarization of schedule requirements for each of the individual route systems including totals and averages for the overall system are listed in Table 32. These passenger demands, flight frequencies, and route distance summaries are the conditions for which the aircraft routing schedules were developed.

A summary of the productivities and utilizations derived from the routing schedules is shown in Table 33.

7.2 Individual Route Comparisons

Generally, the three individual route systems show productivity improvement possibilities for increasing cruise speed up to a speed of Mach 2.0. Above this speed, as illustrated in Figure 18, the possibilities for further productivity improvement with further speed increases differs between the three individual route systems. There are several differences between the route systems that would account for their differing productivity-to-speed relationships above Mach 2.0. Before examining these possibilities, it should be noted that contrary to the chart there is very little productivity improvement potential for speeds above Mach 2.7 on the transpacific. For illustration purposes, the data shown in Figure 18 are plotted as straight line variations

TABLE 32. SUMMARY OF SCHEDULING REQUIREMENTS - PASSENGERS, DISTANCES, AND BLOCK HOURS

	North Atlantic	Transpacific	North-South America	Overall Totals or Averages
No. of City Pairs	11	8	12	31 (Total)
1995 Weekly pax each way - single airline	34 720	28 448	30 380	93 548 (Total)
Req'd round trips per week (flights)	194 (388)	162 (324)	161 (322)	517 (1034) (Total)
Average load factor per flight	62%	61%	65%	62% (Avg)
Weekly route distance - subsonics - km (n.mi.)	2 315 970 (1 250 524)	1 945 356 (1 050 408)	1 735 039 (936 846)	5 996 091 (3 237 630) (Total)
Weekly route distance - SCV's - km (n.mi.)	2 384 950 (1 287 770)	1 945 356 (1 050 408)	1 820 638 (983 066)	6 150 944 (3 321 244) (Total)
Average segment distance - sub - km (n.mi.)	5 969 (3 223)	6 004 (3 242)	5 387 (2 909)	5 799 (3 131) (Avg)
Average segment distance - SCV - km (n.mi.)	6 147 (3 319)	6 004 (3 242)	5 654 (3 053)	5 949 (3 212) (Avg)
Avg SCV subsonic cruise distance - km (n.mi.)	415 (224)	0	278 (150)	237 (128) (Avg)
Weekly revenue distance - km (statute miles)	2 306 482 (1 433 488)	1 928 000 (1 198 260)	1 685 756 (1 047 704)	5 920 238 (3 679 452) (Total)

Cruise Mach No.	North Atlantic Total Daily Block Hours	North Atlantic Avg. Block Hours/Flight	Transpacific Total Daily Block Hours	Transpacific Avg. Block Hours/Flight	North-South America Total Daily Block Hours	North-South America Avg. Block Hours/Flight	Overall Total Daily Block Hours	Overall Avg. Block Hours/Flight
0.70	439.4	8.83	409.7	8.85	358.3	7.79	1 257.4	8.51
0.82	412.4	7.44	343.4	7.42	304.1	6.61	1 059.9	7.17
1.4	274.4	4.95	213.4	4.61	204.2	4.44	699.2	4.68
2.0	213.9	3.86	160.1	3.46	158.5	3.44	532.5	3.59
2.2	201.2	3.63	149.0	3.22	149.0	3.24	499.2	3.38
2.7	180.1	3.22	129.1	2.79	131.6	2.86	441.5	2.97

TABLE 33. SUMMARY OF SCHEDULING RESULTS - FLEET SIZE, UTILIZATIONS, PRODUCTIVITIES, AND OTHER DATA - 290 SEATS

	North Atlantic			Trans-Pacific			North-South America			Overall Totals or Averages		
Cruise Mach no.	Fleet size	Daily utilization per A/C hours	Daily revenue distance per A/C (km st. miles)	Fleet size	Daily utilization per A/C hours	Daily revenue distance per A/C (km st. miles)	Fleet size	Daily utilization per A/C hours	Daily revenue distance per A/C (km st. miles)	Total fleet size	Daily utilization per A/C hours	Daily revenue distance per A/C (km st. miles)
0.70	34	14.34	9 691 (6 023)	29	14.12	9 498 (5 903)	31	11.56	7 768 (4 828)	94	13.40	8 998 (5 592)
0.82	34	12.13	9 691 (6 023)	24	14.31	11 477 (7 133)	30	10.14	8 027 (4 989)	88	12.04	9 611 (5 973)
1.4	21	13.06	15 691 (9 752)	18	11.85	15 303 (9 511)	20	10.21	12 040 (7 483)	59	11.73	14 335 (9 909)
2.0	16	13.36	20 594 (12 799)	14	11.44	19 675 (12 228)	16	9.91	15 050 (9 354)	46	11.58	18 384 (11 427)
2.2	16	12.57	20 594 (12 799)	13	11.46	21 189 (13 169)	14	10.64	17 202 (10 691)	43	11.61	19 668 (12 224)
2.7	16	11.17	20 594 (12 799)	12	10.76	22 954 (14 266)	14	9.40	17 202 (10 691)	42	10.51	20 137 (12 515)
Cruise Mach no.	Flights per day per A/C	Flight crews required	Average available turn-time hours	Flights per day per A/C	Flight crews required	Average available turn-time hours	Flights per day per A/C	Flight crews required	Average available turn-time hours	Flights per day per A/C	Total flight crews required	Overall average available turn time hours
0.70	1.63	214	3.33	1.59	176	2.43	1.48	245	-	1.57	635	-
0.82	1.63	177	4.59	1.93	147	2.54	1.53	210	-	1.68	534	-
1.4	2.64	133	2.23	2.57	137	2.22	2.30	118	2.5	2.50	388	2.31
2.0	3.46	106	2.12	3.31	105	2.21	2.88	92	1.7	3.21	303	2.02
2.2	3.46	102	2.35	3.56	100	2.02	3.29	87	2.0	3.43	289	2.14
2.7	3.46	92	2.70	3.86	87	2.25	3.29	76	2.3	3.52	255	2.43

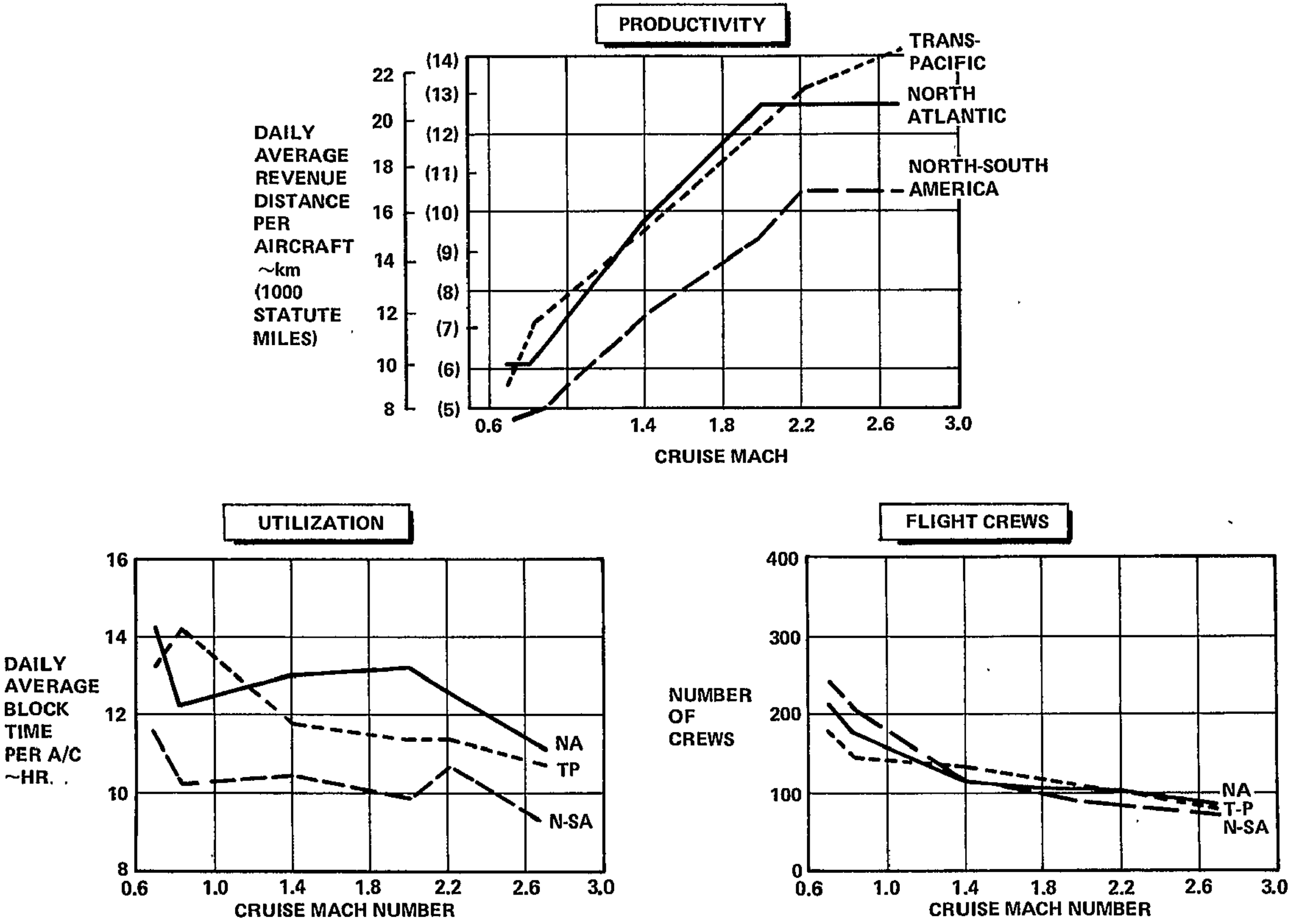


Figure 18. Individual route study results - 290 seats

between the six cruise speed points covered in the study, but the actual variations are step functions. The chart therefore should not be interpreted as showing a productivity improvement potential for small speed changes. Additional transpacific schedules were developed for Mach 2.7 block times reduced 30 minutes (corresponds to approximately Mach 3.0) and no productivity gains were achieved. Thus, at some speed all three route systems exhibit a flattening-out of the productivity-to-speed relationship. These productivity-to-speed plateaus occur at approximately Mach 2.7 for the transpacific, at approximately Mach 2.2. for the North-South America routes, and at approximately Mach 2.0 for the North Atlantic.

Impact of route segment distances - The most significant difference between the three route systems are their route segment distances. Both the transpacific and North-South America route systems include segments that are substantially longer and shorter than those of the North Atlantic although the weighted averages as listed in Table 32 are approximately the same. However, the long distance city-pairs of the transpacific and North-South America route systems coupled with their lower subsonic cruise requirements results in supersonic cruise distances that average nearly 1852 km (1000 n.mi.) longer than the longest North Atlantic distances. These longer supersonic cruise distances allow the Mach 2.7 aircraft to generate significantly greater time savings over a Mach 2.0 aircraft as shown below.

BLOCK TIME COMPARISON BETWEEN THE MACH 2.0 AND MACH 2.7 AIRCRAFT
FOR THE LONGEST SEGMENTS OF EACH ROUTE SYSTEM

	North Atlantic	Trans-Pacific	No./So. America
Total segment distance, km (n.mi.)	6371-6973 (3440-3765)	8245-9001 (4452-4860)	6843-8890 (3695-4800)
Supersonic cruise distance, km (n.mi.)	5186-5556 (2800-3000)	7964-8519 (4300-4600)	6482-8149 (3500-4400)
Percent of total distance	38%	39%	45%
Avg. Block Time, M 2.0	4:22	4:35	4:45
M 2.7	3:47	3:39	3:55
ΔTime, M 2.0 to M 2.7	:35	:56	:50

The above block time differences take on greater significance when it is considered that for productivity purposes, it is the cumulative time savings that count. For three flights, the total time savings for Mach 2.7 over

Mach 2.0 on the North Atlantic is one hour and forty-five minutes compared to two hours and forty-eight minutes for the transpacific. At the completion of three flights, the Mach 2.7 transpacific aircraft will obvously be in a better position for a fourth flight than its North Atlantic counterpart.

The reference in previous sections to the turn-around block speed were to demonstrate the limited impact cruise speed has on block time. Another illustration of this limitation is that shown in Figure 19. It is seen here that as speed is increased, speeds are eventually reached whereby further speed increases do not generate significant time savings. Extending the distance only extends the speed for which significant time savings are possible. Thus, the limitations against improving productivity by increasing cruise speed as demonstrated by each of the route systems studied is not so much a scheduling limitation as the limitation that exists for any speed-distance relationship. Since the vast majority of the major international routes would have supersonic cruise distances between 3704 and 9160 km (2000 and 5000 n.mi.), the productivity improvement potential for supersonic cruise speeds are limited to the speeds that apply to these distances. A chart was devised as shown in Figure 20 based on the speed-distance productivity limitations of the three route systems: Mach 2.0 for 5186 to 5556 km (2800 to 3000 n.mi.); Mach 2.2 for 6482 to 8149 km (3500 to 4000 n.mi.); Mach 2.7 for 7964 to 8519 km (4300 to 4600 n.mi.). The resulting chart designates the approximate minimum cruise speeds for maximum productivity as a function of the supersonic cruise distances of the longest 40% of the total route segments. The bandwidth designated "dependent on scheduling factors" represents 30 minutes reduction in block time from the lower speed to the higher speed. The scheduling perturbations with turn-time show that 30-minutes may or may not affect productivity.

With regard to the impact of segment distance on the subsonic aircraft, Figure 19 illustrates the fact that relatively small speed changes in the subsonic regime cause quite large differences in block time and these differences increase as distance increases. However, the block time requirements for most international subsonic flights are large making it difficult to squeeze in another flight and thereby improve productivity as discussed in Section 3. Nevertheless, the longer distances and headwinds for westbound flights for the transpacific cause two hour block time differences between the Mach 0.7 and 0.82 aircraft. This time saving is converted into a significant productivity may have a significant impact on productivity in the subsonic regime at relatively smaller speed differences.

Although scheduling is very much a factor in achieving the fullest productivity attainable for any speed aircraft, longer cruise distance obviously favors the productivity improvement potential of higher cruise speeds. However, there are not many markets with segments as long as those of the transpacific. Approximately 85 percent of the passenger demand for this study were

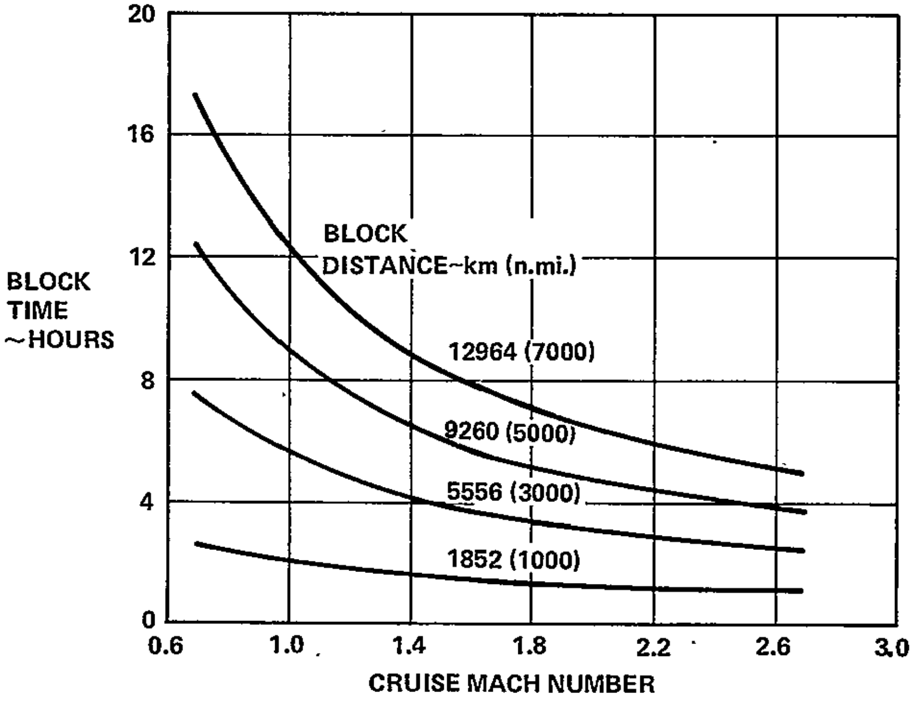


Figure 19. Effect of cruise speed on block time for a range of block distances

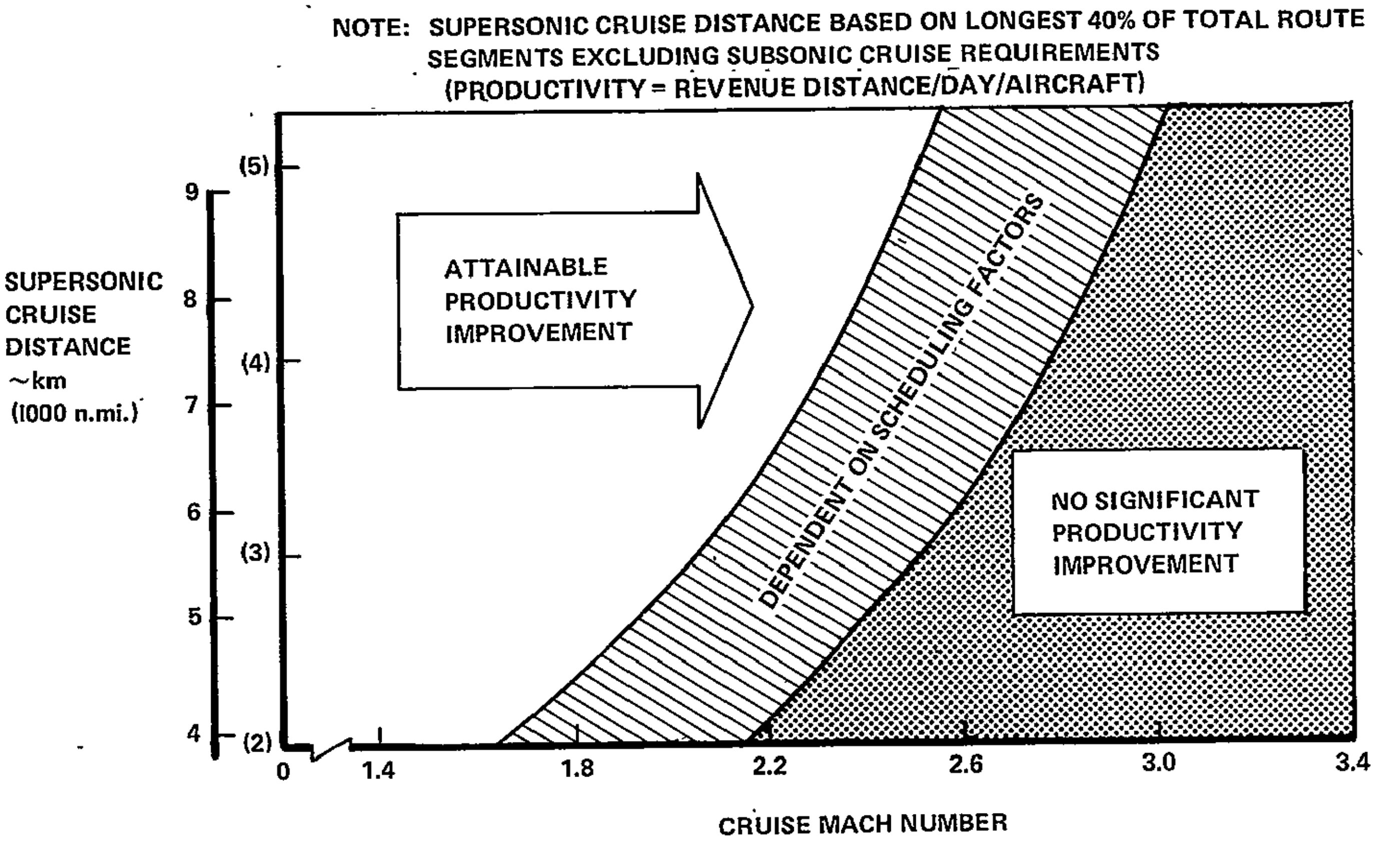


Figure 20. Productivity Improvement Potential of Cruise Speed as a Function of Supersonic Cruise Distance

for city-pairs having segment distances less than 7408 km (4000 n.mi.) as shown in Figure 21. For a given market, it is not feasible to select only the longest distance city-pairs. Generally, the bulk of the scheduling requirements are for shorter distance flights, 3704 to 5556 km (2000 to 3000 n.mi.) which tends to diminish the impact of speed on productivity. This study reflects a reasonable mix between short and long distances flights and this mix compares well with that for present day long-haul transports as shown in Figure 22. If anything, the study probably favors longer segment lengths. In any event, it can reasonably be concluded that cruise speed is an effective means for improving aircraft productivity, but the maximum speed for which significant productivity gains are possible is primarily a function of the route system cruise distances. Productivity improvement is achieved to Mach 2.0 for route systems comprised substantially of cruise distances of between 4630 km (2500 n.mi.) and 5556 km (3000 n.mi.). Significant productivity gains for speeds higher than Mach 2.0 requires that a substantial part of the route system consist of flights with supersonic cruise distances in excess of 5556 km (3000 n.mi.) with higher speeds favoring the longer distances.

Aircraft utilization and flight cycles. - The generally higher SCV utilization levels for the North Atlantic over the other route systems are evident in the comparisons shown in Figure 18. Utilization levels of 12 to 13 hours are considered high for even a subsonic, long haul transport which may attain such levels with one or two flights. For an SCV, several flights are needed requiring operational times of 18 to 19 hours which is about a maximum if sufficient time is allowed for maintenance purposes. The operational time is the total block hours plus the total amount of turn time. Since the time savings generated by increased speed are usually not sufficient to cover the time needed for another flight, another flight usually increases operational time as illustrated in Figure 23. This implies that a limit on the available operational time imposes a limitation on daily utilization. Most differences in operational time among the three route systems are due to differences in utilization; i.e., differnces in total block time. The total daily turn-time requirements are roughly the same. Thus, assuming a maximum operational time of 17 to 18 hours and total daily turn-time requirements of 5 hours, then 12 to 13 hours' daily utilization is a practical upper limit for an SCV. Actually, operationsl times of 17 to 18 hours must be considered somewhat optimistic considering that 16 hours is high for a present day fleet average.

Impact of scheduling constraints. - The transpacific and North-South America markets have less stringent airport curfew limitations and more liberal passenger preferential departure and arrival times than the North Atlantic. For the transpacific, flights are scheduled through Guam and Honolulu during early morning hours with a one hour minimum through time. The North-South America schedules include late night departures which are not permitted on the North Atlantic because of curfew restrictions. However, the impact of more stringent conditions are apparently not critical to North Atlantic scheduling since the utilization levels for the North Atlantic as previously pointed out are about as high as can be expected.

- 1995 FORECAST PASSENGER DEMAND FOR A SINGLE MAJOR AIRLINE ON THE NORTH ATLANTIC, TRANSPACIFIC, AND NORTH-SOUTH AMERICA ROUTE SYSTEMS

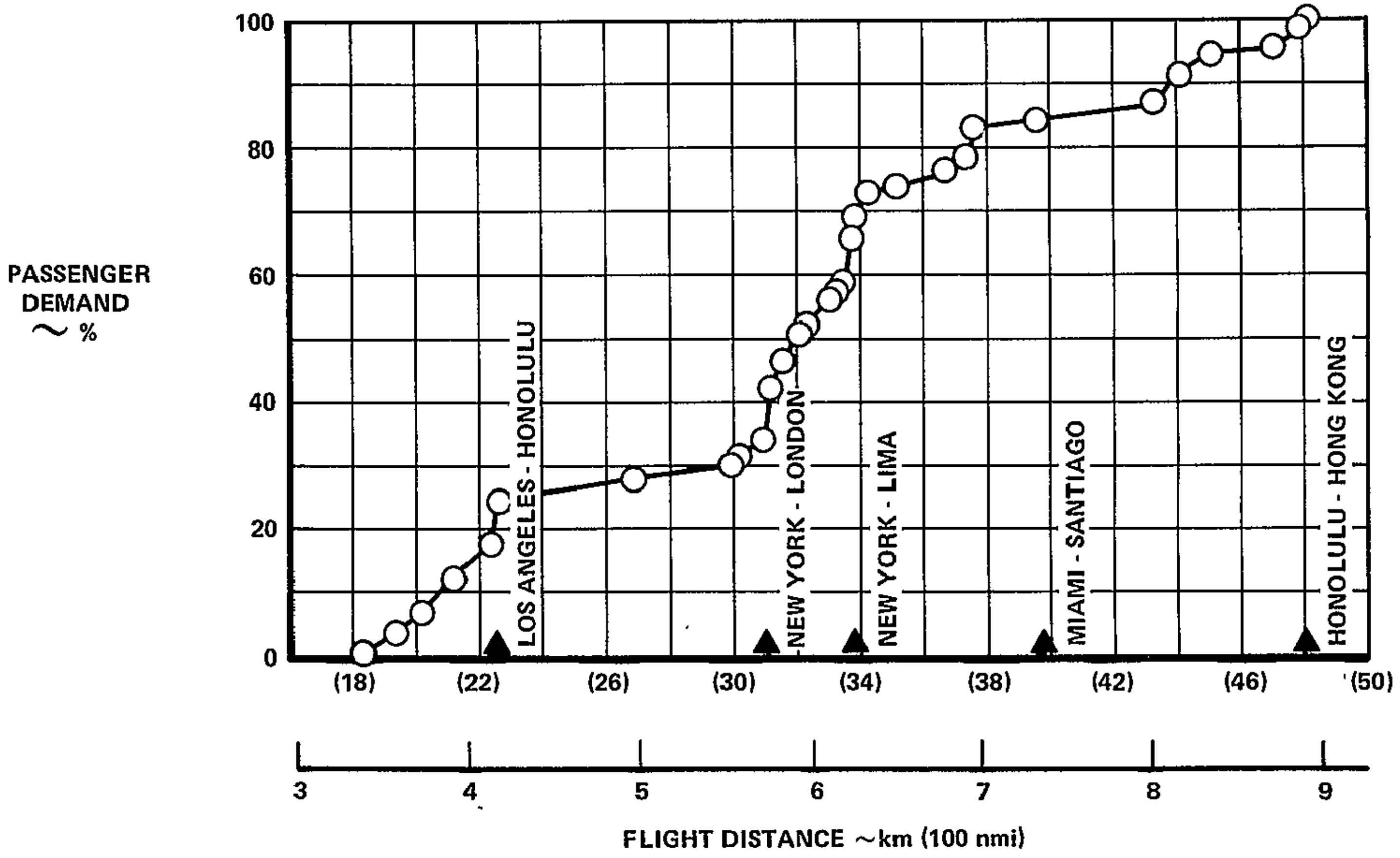


Figure 21. Zero Wind Range Requirements as a Function of Passenger Demand

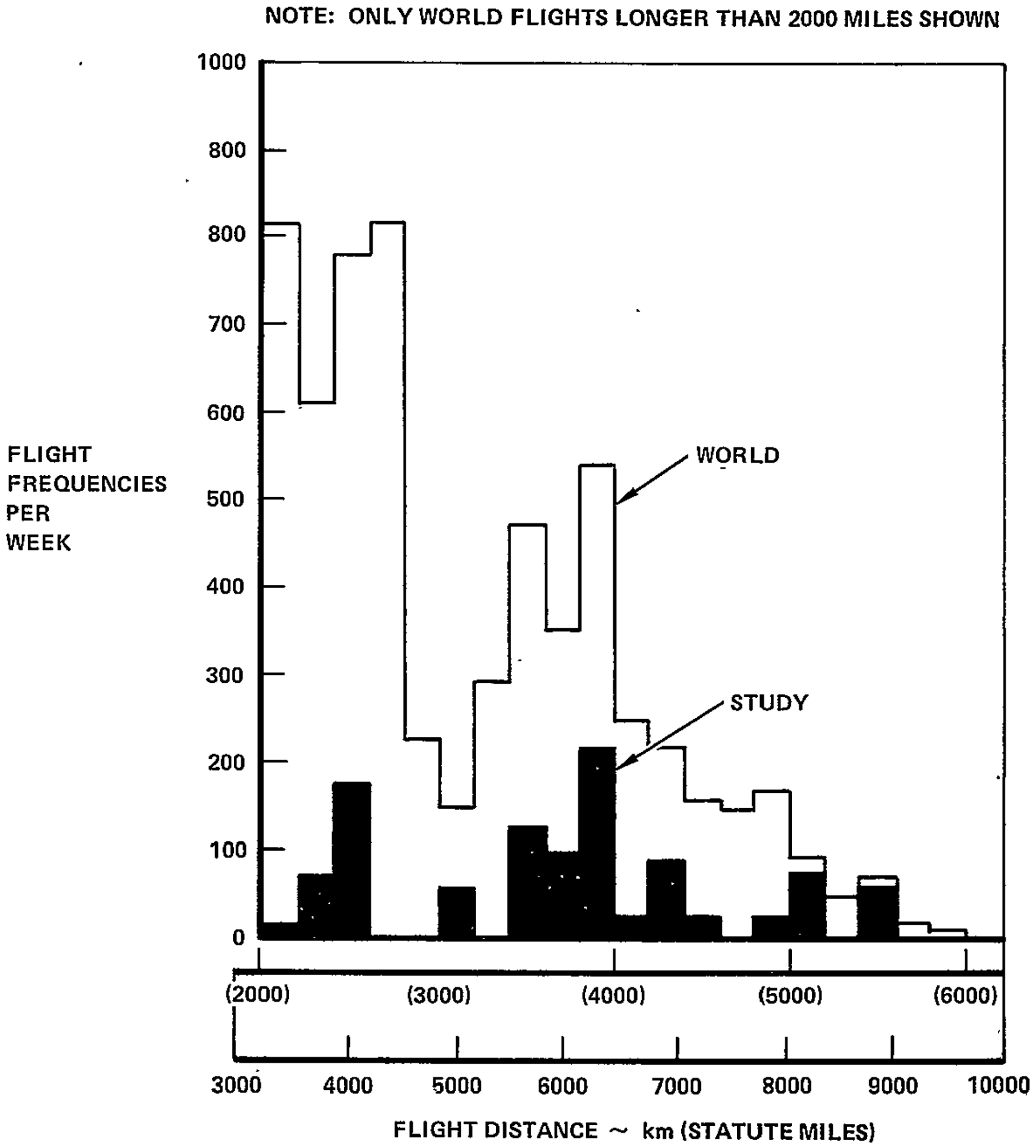


Figure 22. Flight Frequencies and Distances of the Study Compared to World Averages for Long Range Aircraft

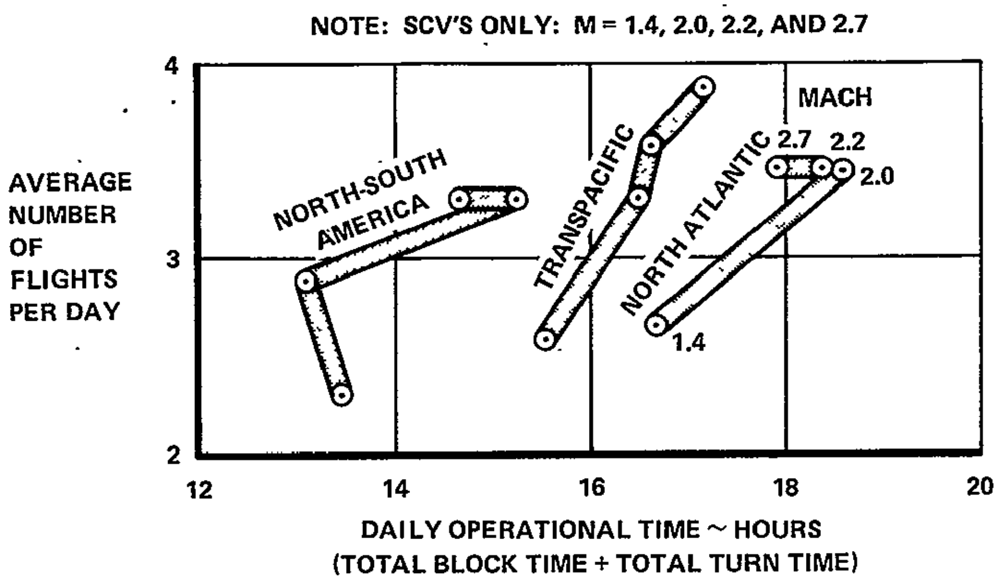


Figure 23. Comparison of Operational Time and Flight Frequencies for the Three Route Systems

Generally, the impact of scheduling constraints are greater on the Mach 1.4 and Mach 2.0 aircraft than the higher speed SCV's. This would be expected since these aircraft usually have less surplus time between flights. The turn-time perturbation studies reveal that the Mach 1.4 and Mach 2.0 aircraft productivity levels are more likely to be affected by either increases or decreases in turn-time. Also, the combined routes studies show that the two lower speed SCV's were most improved by increased scheduling options obtained from combining routes.

Impact of subsonic cruise distance - The transpacific is the only route system that does not require the supersonic aircraft to cruise subsonically to avoid sonic boom on populated areas. For the North Atlantic, the average SCV subsonic cruise distance is 415 km (224 n.mi.) and for the North-South America routes it is 278 km (150 n.mi). However, examination of the North Atlantic schedules as discussed in Section 3.0 indicates that elimination of the subsonic cruise requirement would not improve the productivity levels of the Mach 2.2 or Mach 2.7 aircraft over the Mach 2.0 aircraft. Actually, elimination of the longest subsonic cruise segment of the study, the Chicago to U.S. East coast segment which is 1261 km (681 m.mi), reduces the Mach 2.0 aircraft block time by almost as much as that for Mach 2.7; i.e., 38 minutes compared to 47 minutes. Therefore, all-supersonic flight benefits the Mach 2.0 and Mach 2.2 aircraft to almost the same degree as the Mach 2.7 aircraft.

For all SCV's, subsonic cruise increases the block time requirements. The average North Atlantic flight is 25 minutes longer because of the subsonic cruise requirements. This, in fact, accounts for much of the difference in utilization levels between the North Atlantic and the other route systems. The higher utilization levels and possibly less efficient fuel mileage for an SCV in subsonic cruise indicate important economic implications for subsonic cruise requirements. As shown in the study, SCV's in actual service will be required to cruise subsonically an average of 185 km (100 n.mi) to 370 km (200 n.mi).

7.3 Overall System Comparisons

Many of the discontinuities characteristics of the individual route systems disappear when averaged for the overall system. The overall productivity-to-speed relationship shown in Figure 24 reflects the fleet size requirements, passenger demands, and total route distances of the individual routes in proportion to the totals for the overall system. Thus, the North Atlantic being the largest route system has the greatest impact on the overall averages. Since neither the North Atlantic nor the North-South America route systems show productivity improvement potential for the Mach 2.7 aircraft, the productivity-to-speed relationship for the overall system likewise shows little potential for speeds higher than Mach 2.2. Actually, a true weighted average based on total market differences between the three route systems would likely increase the impact of the North Atlantic on the overall averages. This is because the route systems of this study are for single airlines and the North-Atlantic route system represents a smaller proportion of its total market than do the others. In any event, the three individual route systems possess sufficient market diversity so that the overall productivity-to-speed relationship shown in Figure 24 is probably representative of the productivity improvement potential for cruise speed for most international route systems.

7.4 Study Conclusions

Based on the foregoing commentaries and results from other sections of this report, the following is a summary of the study conclusions:

1. Increasing cruise speed is an effective means for improving aircraft productivity, but the maximum speed for which significant productivity gains are possible is primarily a function of the route system cruise distances. A chart was devised illustrating the productivity improvement potential of cruise speed as a function of the route system cruise distances (Figure 20).

2. Productivity improvement is achieved to a speed of Mach 2.0 for route systems comprised substantially of cruise distances of 4630 km

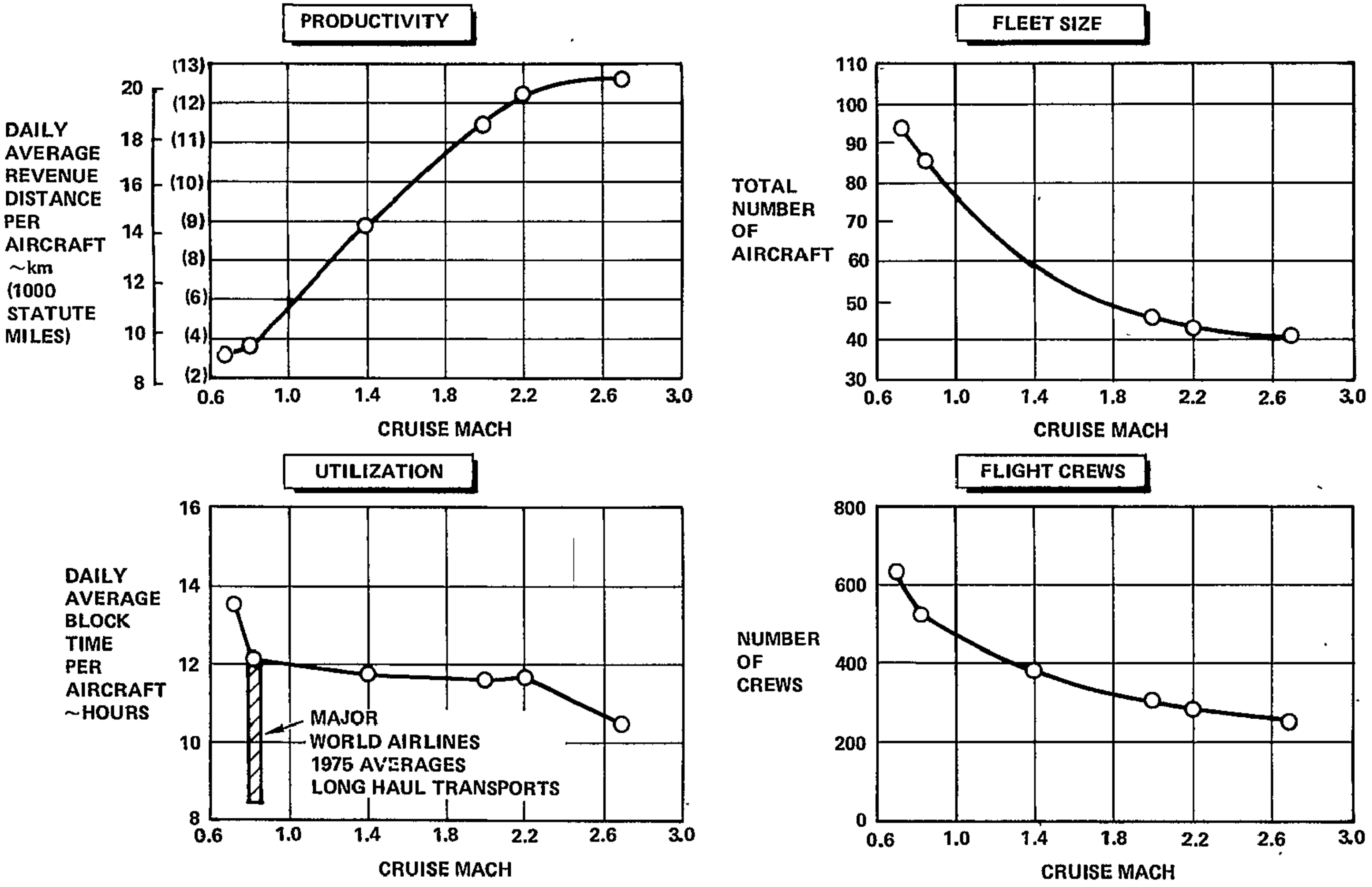


Figure 24. Overall study results - 290 seats

(2500 n.mi) to 5556 km (3000 n.mi). Productivity gains for speeds higher than Mach 2.0 requires that a substantial part of the route structure have cruise distance longer than 5556 km (3000 n.mi).

3. A Mach 0.7 aircraft is significantly less productive than a Mach 0.82 aircraft when operating at distances in excess of 6482 km (3500 n.mi.).

4. Removal of the subsonic cruise requirements for the SCV's that are necessary to prevent sonic booms on populated areas would not improve the productivity levels of the Mach 2.7 and Mach 2.2 aircraft on the North Atlantic route system nor the Mach 2.7 aircraft on the North-South America system.

5. Supersonic aircraft in actual service will be required to cruise subsonically an average of 185 to 370 km (100 to 200 n.mi.).

6. Based on purely intercontinental flights, utilization levels that are high by today's standards were achieved for each of the different speed aircraft. A utilization of 12 to 13 hours per day is a practical maximum for an SCV with 11-12 hours a realistic upper limit.

7. Generally, the aircraft were fully utilized as long-haul transports so that attempts to increase utilization with short distance flights would reduce scheduled maintenance time allowances.

8. Passenger preferential departure and arrival times are more constrictive than airport curfews.

9. Departure and arrival time limitations were found to have about the same impact on each of the different speed aircraft. Departure and arrival time limitations for eastbound North Atlantic flights have the same impact on each of the different speed aircraft in terms of total departure time available during each day. West-bound they are more restrictive for the slower speed subsonic aircraft with respect to evening departures. For transpacific westbound operation the higher speed aircraft are less affected by the restrictions. Time available for eastbound departures is generally greater for the slower speed aircraft.

10. Decreasing the minimum allowable turn-time by 30 minutes from the study standard of 1.5 hours generally improves productivity for the Mach 0.7, 0.82, and 1.4 aircraft but has no effect on the productivity levels of the Mach 2.0, 2.2, and 2.7 aircraft.

11. Increasing turn-time by 30 minutes generally decreases productivity for all speeds except for the Mach 2.7 aircraft on the North Atlantic.

12. The lower block time requirements of a higher speed aircraft allows for more flexible scheduling.

13. Combining routes results in a slight productivity improvement for the Mach 1.4, 2.0, and 2.2 aircraft over the average of the three individual route systems by raising the comparatively low North-South America unit productivities and lowering those of the North Atlantic and transpacific.

14. Combined routes on an equipment interchange basis may not generate the productivity gain obtained in this study because of possible greater turn-time required in some instances.

15. Flight crew requirements become progressively less with increasing speed. Since crew pay generally increases with aircraft speed and weight this apparent economic advantage is questionable.

16. A Mach 0.7 aircraft on the transpacific system requires a large number of relief crews due to its long block time requirements.

In addition to the above conclusions, the study indicates that because long range segments benefit most from supersonic flight speeds, the SCV should be a long range aircraft; i.e., 7408 km (4000 n.mi.) to 9160 km (5000 n.mi.). For the North Atlantic, the range requirement is approximately 7780 km (4200 n.mi.) and for the transpacific it is approximately 9075 km (4900 n.mi.).

Another observation is that the SCV must be economically competitive with contemporary subsonic aircraft to assure adequate markets in support of its operation.

APPENDIX A

AIRCRAFT BLOCK TIME RELATIONSHIP

This appendix provides the method and information for computing block time as a function of distance for the study aircraft. Block time is the time required for an aircraft to travel from the gate or ramp of its departure point to the gate or ramp of its destination.

The study block time data includes provision for making wind corrections. The wind speeds applied should be 75 percent of the annual wind speed values for the average cruise altitudes shown in Table A-1.

A.1 Study Aircraft

The study aircraft listed in Table A-1 are identified by six different cruise speeds: two subsonic and four supersonic. These aircraft are preliminary design concepts except for the Mach 0.82 design which is a derivative of an in-service, wide-bodied transport.

A.2 Flight Profiles

Block time data are based on the flight profiles shown in Figure A-1 for the subsonic aircraft and Figure A-4 for the SCV's. These profiles include departure time allowances of 10 minutes for taxi-out and hold, and 2 minutes for takoff and climb to 457 meters (1500 feet). Destination time allowances are 3 minutes for hold at 457 meters (1500 feet), 3 minutes for final approach and landing, and 5 minutes for taxi-in.

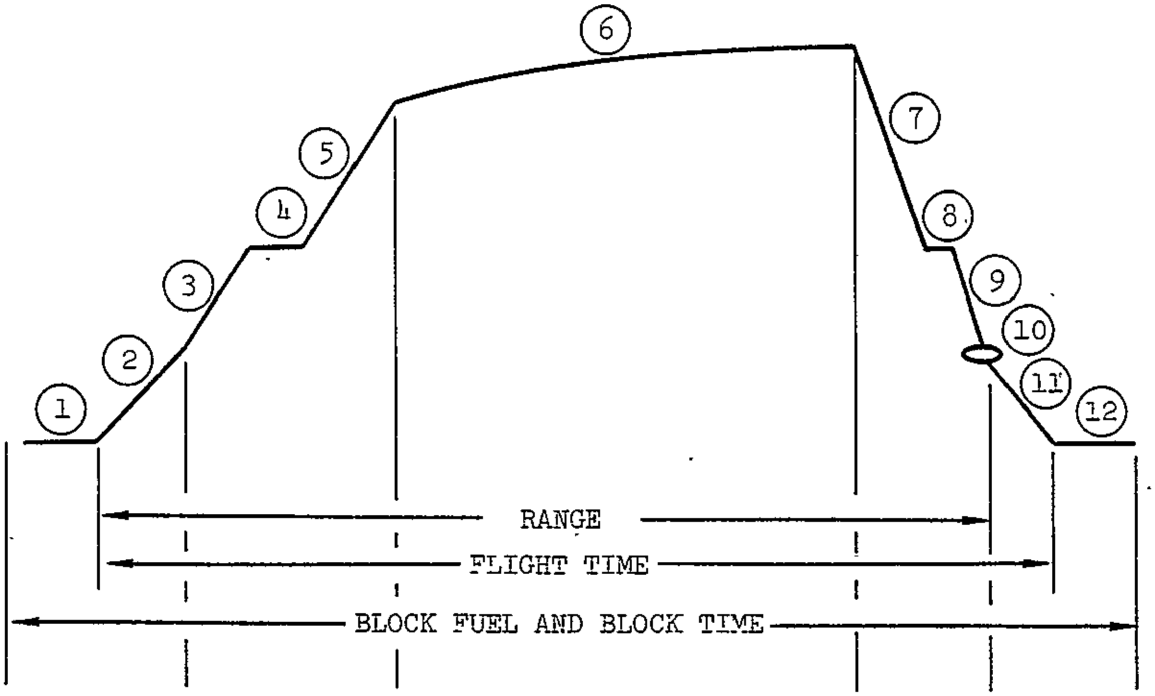
A.3 Block Time Data

Subsonic transport block times are presented as a function of range in Figures A-1 and A-2. An example for using these charts is shown in Figure A-3.

The SCV block time data shown in Figures A-4 to A-9 allow for the inclusion of additional subsonic distance on the departure or arrival end of the flight. This feature requires separate accounting for the subsonic climb and descent distance and times (Figures A-4 and A-5) and subsonic cruise time (Figure A-6). These data also include separate accounting for the supersonic climb distance and time (Figure A-7) which enables keeping track separately of supersonic cruise time (Figures A-8 and A-9). Supersonic cruise time is the time that would be available for inflight meal service. An example for using these charts is provided in Figure A-10.

TABLE A-1. STUDY AIRCRAFT

Cruise Mach No.	Type of Vehicle	Design Range km (n.mi.)	Seating Capacity	Average Cruise Altitude m (ft)
0.70	Low Energy Transport	8890 (4800)	400	10 668 (35 000)
0.82	Current Widebody	8890 (4800)	246	10 668 (35 000)
1.40	SCV Concept	8890 (4800)	290	14 326 (47 000)
2.0	SCV Concept	8890 (4800)	290	16 764 (55 000)
2.2	SCV Concept	8890 (4800)	290	17 374 (57 000)
2.7	SCV Concept	8890 (4800)	290	18 898 (62 000)



1. START, TAXI, GROUND HOLD	10 min	0 n.mi.
2. TAKE OFF TO 457 m (1500 ft)	2 min	0 n.mi.
3. CLIMB TO 3048 m (10 000 ft)		
4. ACCELERATE TO CLIMB SPEED		
5. CLIMB AT CONSTANT CAS/MACH SPEED SCHEDULE		
6. CRUISE AT OPTIMUM CRUISE ALTITUDE		
7. DESCENT TO 3048 m (10 000 ft)		
8. DECELERATE		
9. DESCENT TO 457 m (1500 ft)		
10. HOLD AT 457 m (1500 ft)	3 min	0 n.mi.
11. APPROACH AND LAND	3 min	0 n.mi.
12. TAXI, STOP, AND SHUTDOWN	5 min	0 n.mi.

RESERVES: 10% OF FLIGHT TIME AT FUEL FLOW FOR END CRUISE WT
MISSED APPROACH, CLIMB TO 3048 m (10 000 ft)
370 km (200 n. mi) CRUISE TO ALTERNATE
30 MIN LOITER AT 457 m (1500 ft)
APPROACH AND LAND

Figure A-1. Subsonic vehicle flight profile

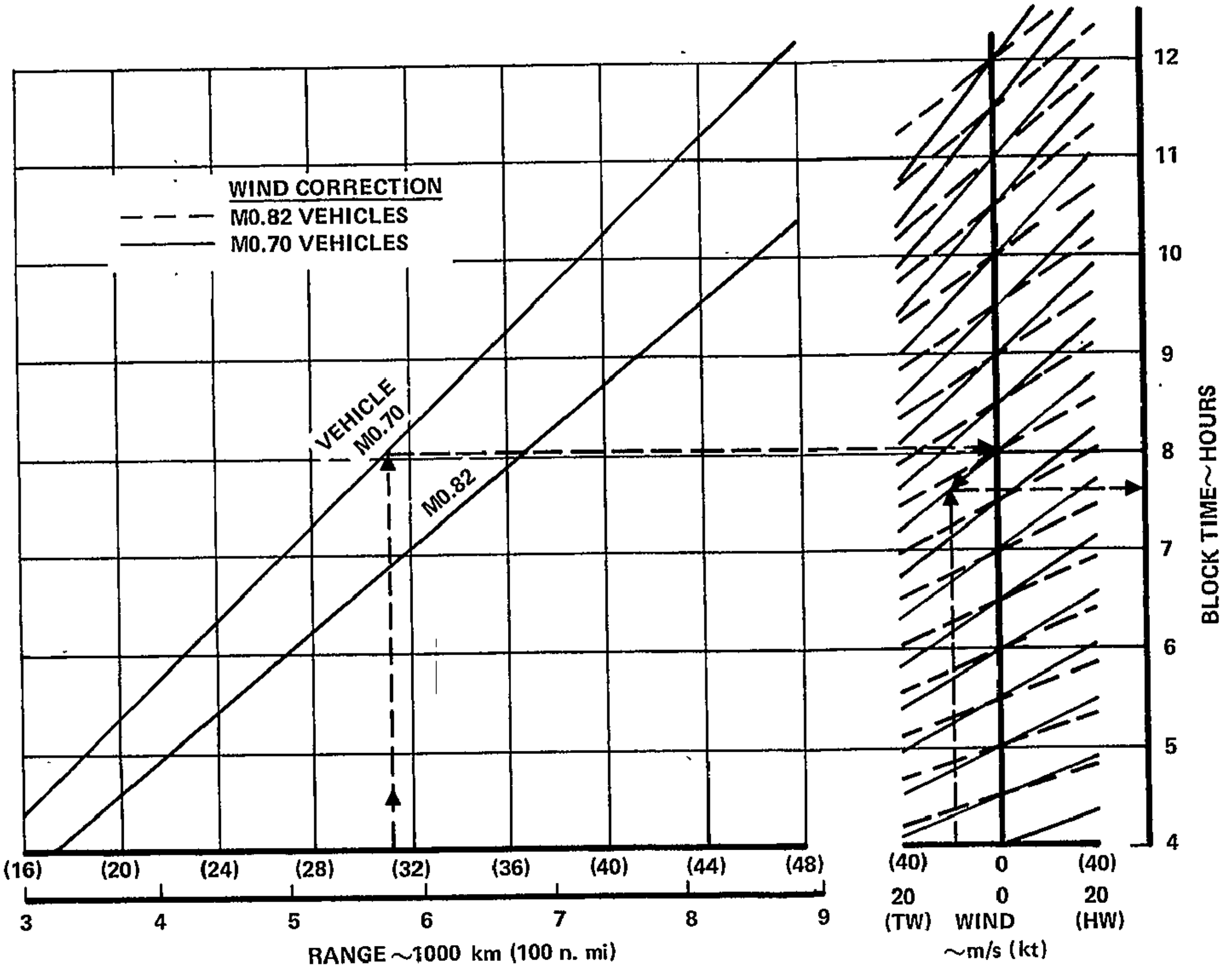
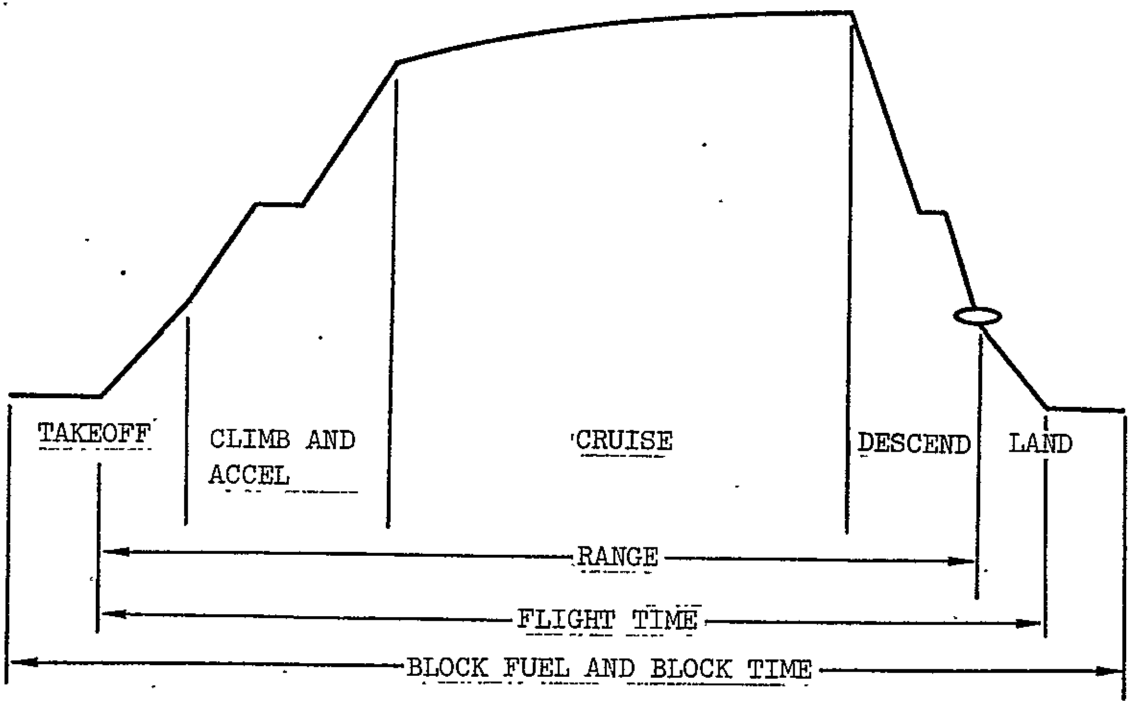


Figure A-2. Subsonic vehicles block time ISA + 8°C cruise at 8839 to 11 278 meters (29 000 to 37 000 ft)



VEHICLE TYPE MACH 0.7

CITY PAIR PHILADELPHIA (PHL) TO LONDON (LHR)

RANGE . . . . 5743 km 3101 n.mi.

WIND 75% ANNUAL CRUISE ALTITUDE 13 m/s 25 (TW) kt

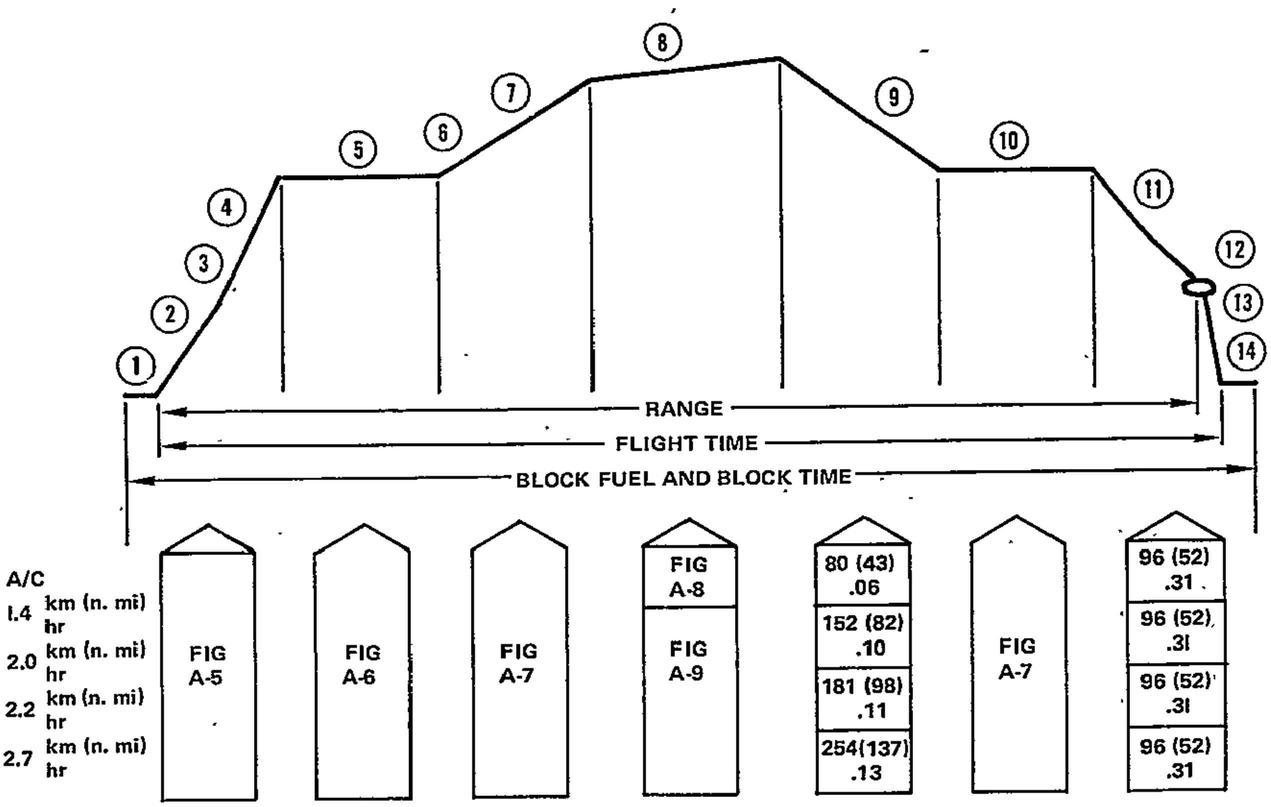
AIRLINE/AIRPORT PECULIARS { DEPART .13 hr / ARRIV 0 hr } TOTAL .13 hr

BLOCK TIME . . . . 7.53 hr FIG. A-2

TOTAL BLOCK TIME 7.66 hr

7:40

Figure A-3. Example subsonic vehicle block-time build-up



1. Start, taxi, ground hold — 10 min — 0 km (0 n.mi.) — Included in Fig. A-5
2. Takeoff to 457 m (1500 ft) — 2 min — 0 km (0 n.mi.)
3. Accelerate and climb to 3048 m (10 000 ft)
4. Climb at constant EAS to 9449 m (31 000 ft)
5. Optional subsonic cruise-departure 9449 m (31 000 ft), M0.92
6. Climb at constant EAS to 13 411 m (44 000 ft)
7. Climb/accel to cruise Mach, initial cruise alt
8. Cruise at optimum supersonic cruise altitude
9. Decelerate and descend to 9449 m (31 000 ft) M0.92
10. Optional subsonic cruise-arrival 9449 m (31 000 ft) M0.92
11. Decelerate and descent to 457 m (1500 ft) — 8 min — 96 km (52 n.mi.)
12. Hold at 457 m (1500 ft) — 3 min — 0 km (0 n.mi.)
13. Approach and land — 3 min — 0 km (0 n.mi.)
14. Taxi, stop, and shutdown — 5 min — 0 km (0 n.mi.)

Reserves: 5% block fuel
Missed approach, climb to 9449 m (31 000 ft) subsonic
Cruise, descent to 4572 m (15 000 ft) (Total distance 482 km (260 n.mi.)
30 minute loiter at 4572 m (15 000 ft)

Figure A-4. Supersonic vehicle flight profile

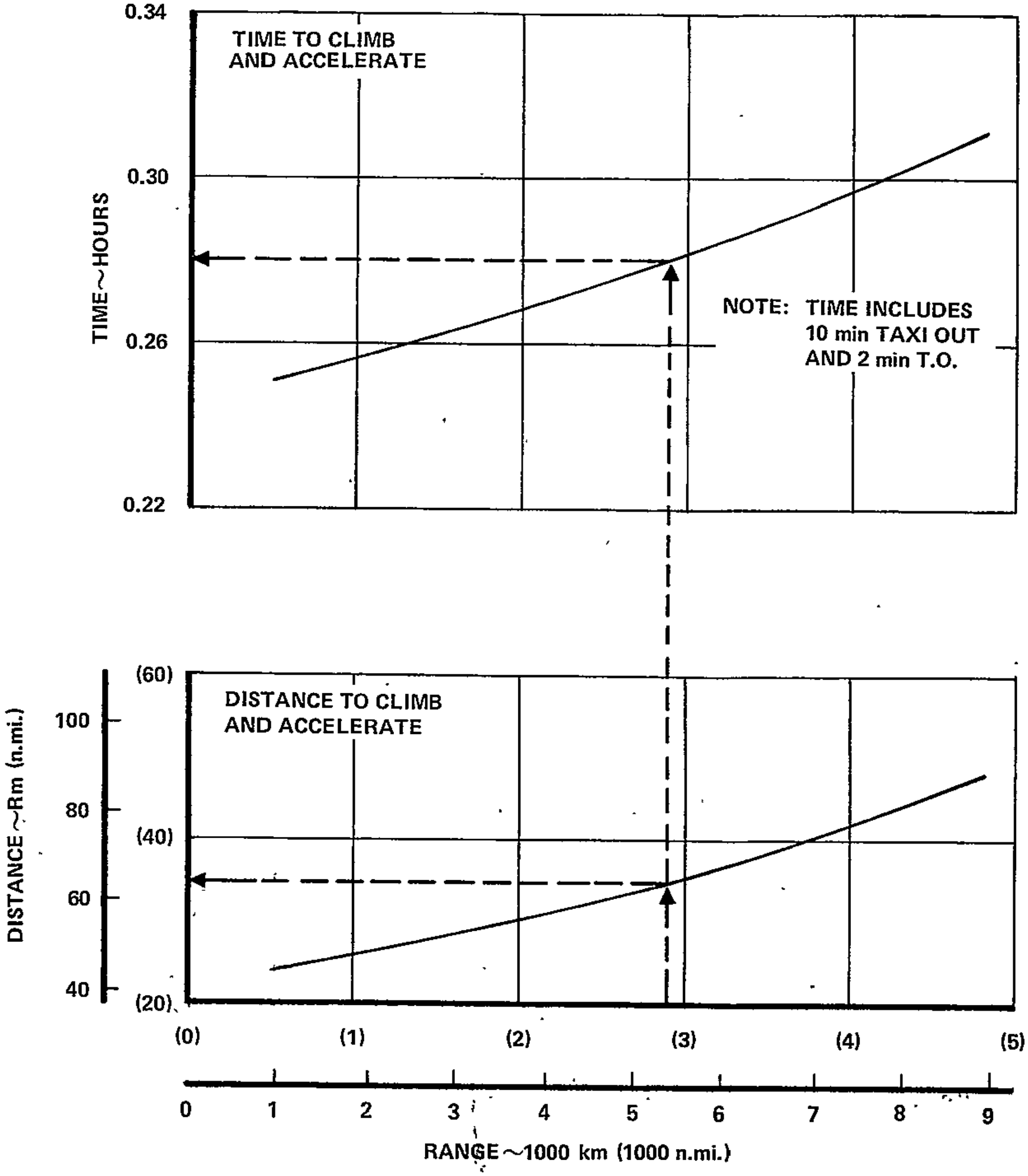


Figure A-5. Supersonic vehicles subsonic climb and acceleration distance and time ISA + 8°C taxi, takeoff to 457 m (1500 ft), climb to 9449 m (31 000 ft), M0.92

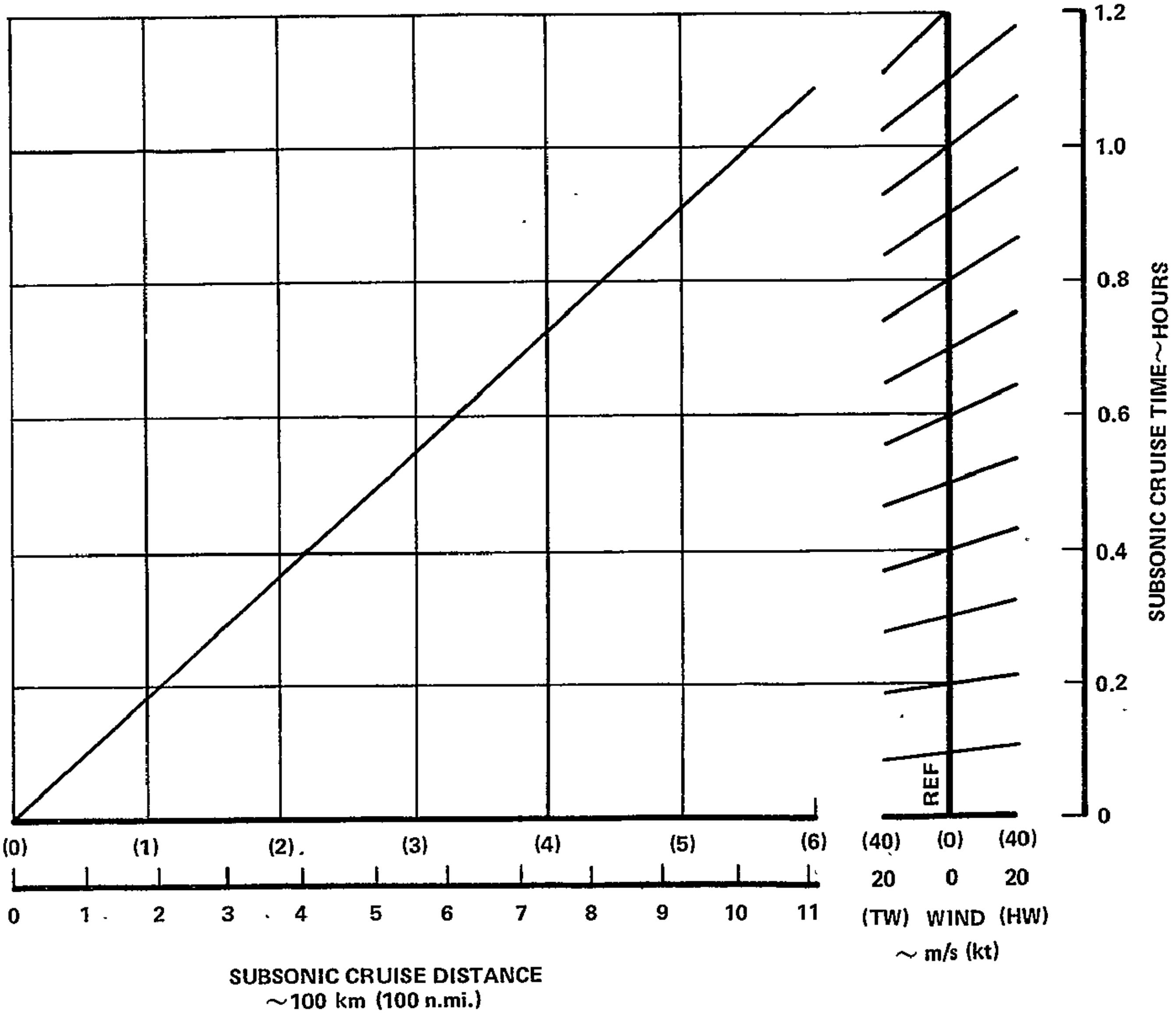


Figure A-6. Supersonic vehicle subsonic cruise time ISA + 8°C M0.92 cruise at 9449 m (31 000 ft)

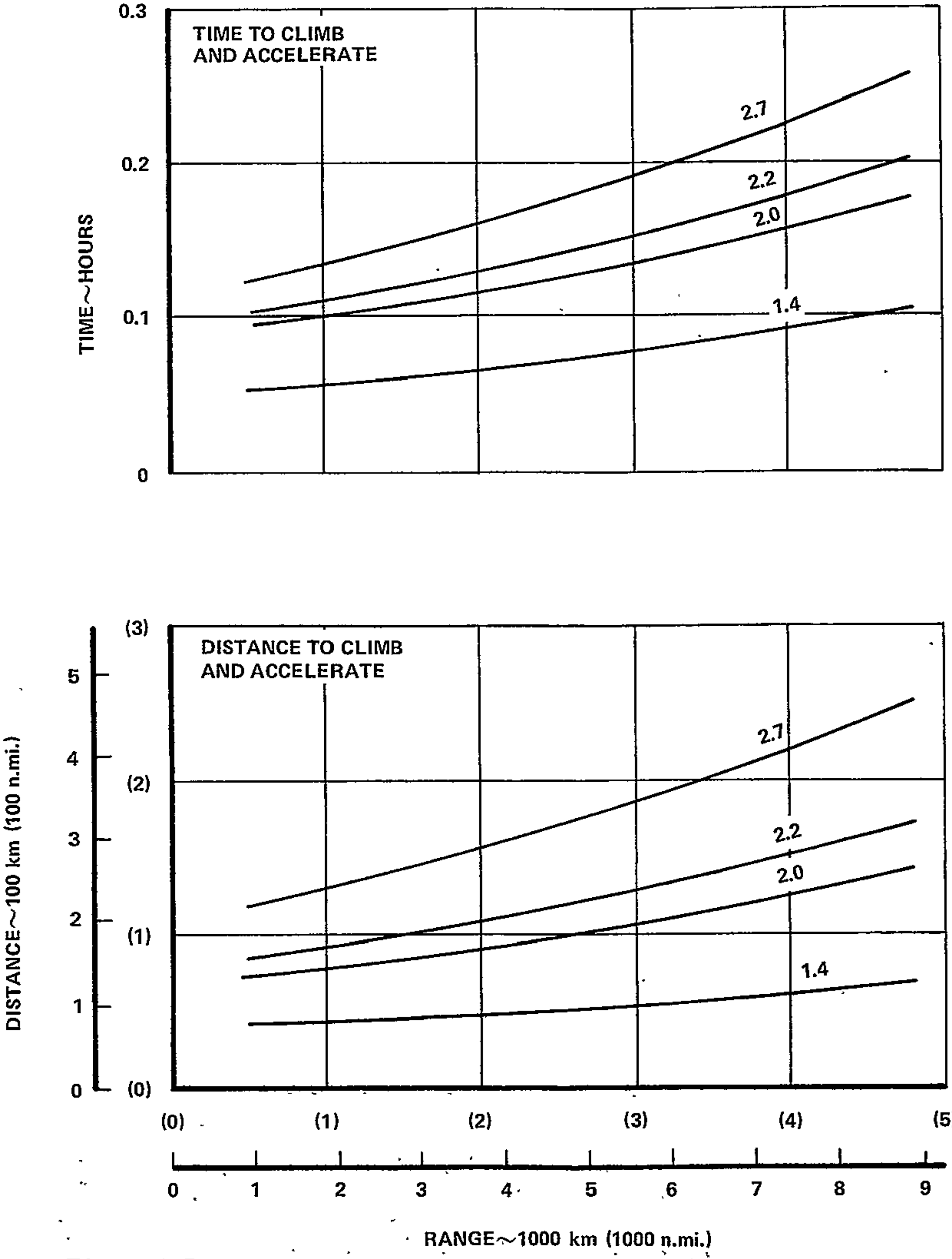


Figure A-7. Supersonic vehicles supersonic climb and acceleration ISA + 8°C from 9449 m (31 000 ft) to initial cruise altitude from M0.92 to cruise mach number

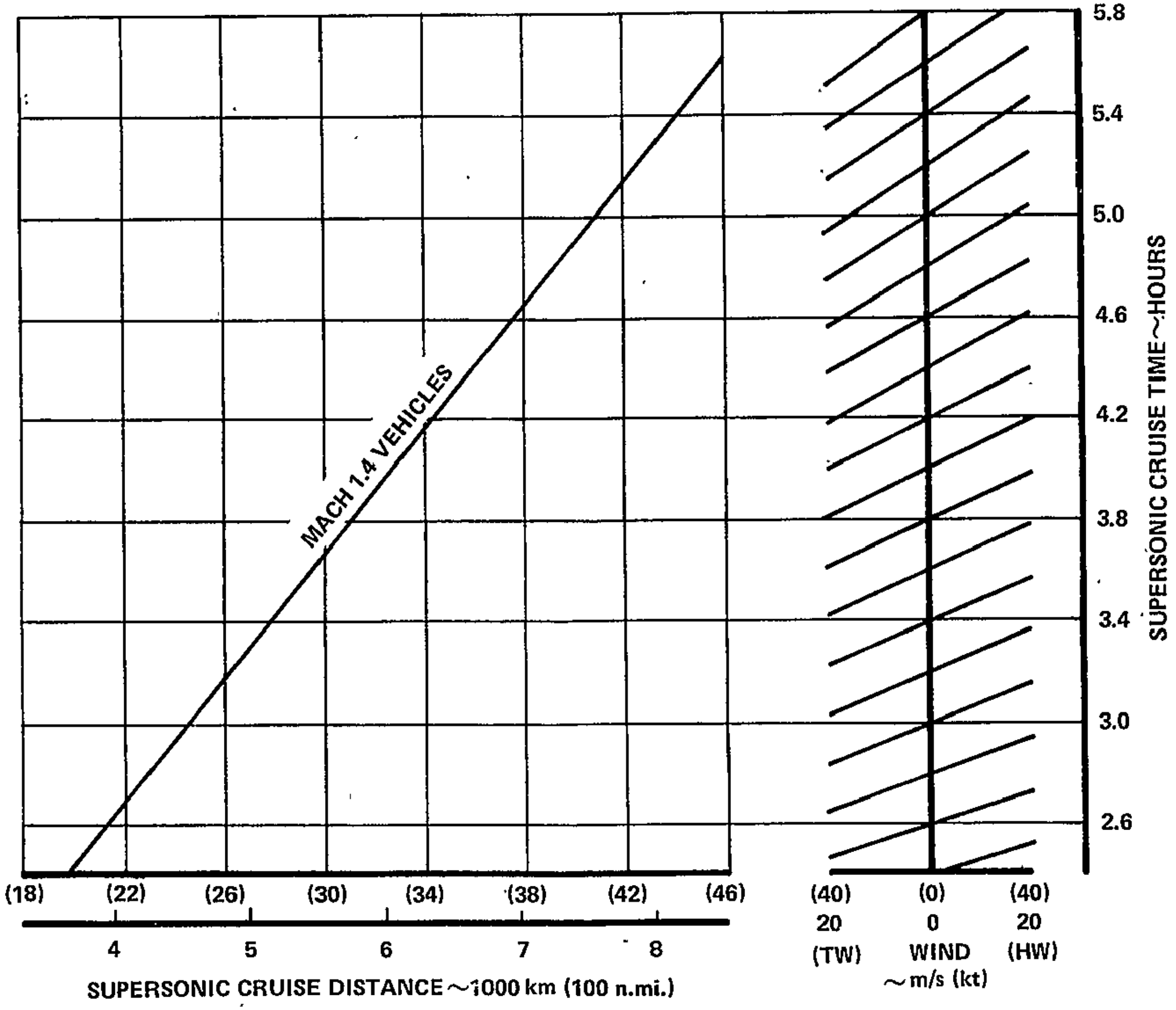


Figure A-8. M1.4 vehicle supersonic cruise time-medium to long range ISA + 8°C cruise at 13 716 to 14 935 meters (45 000 to 49 000 ft)

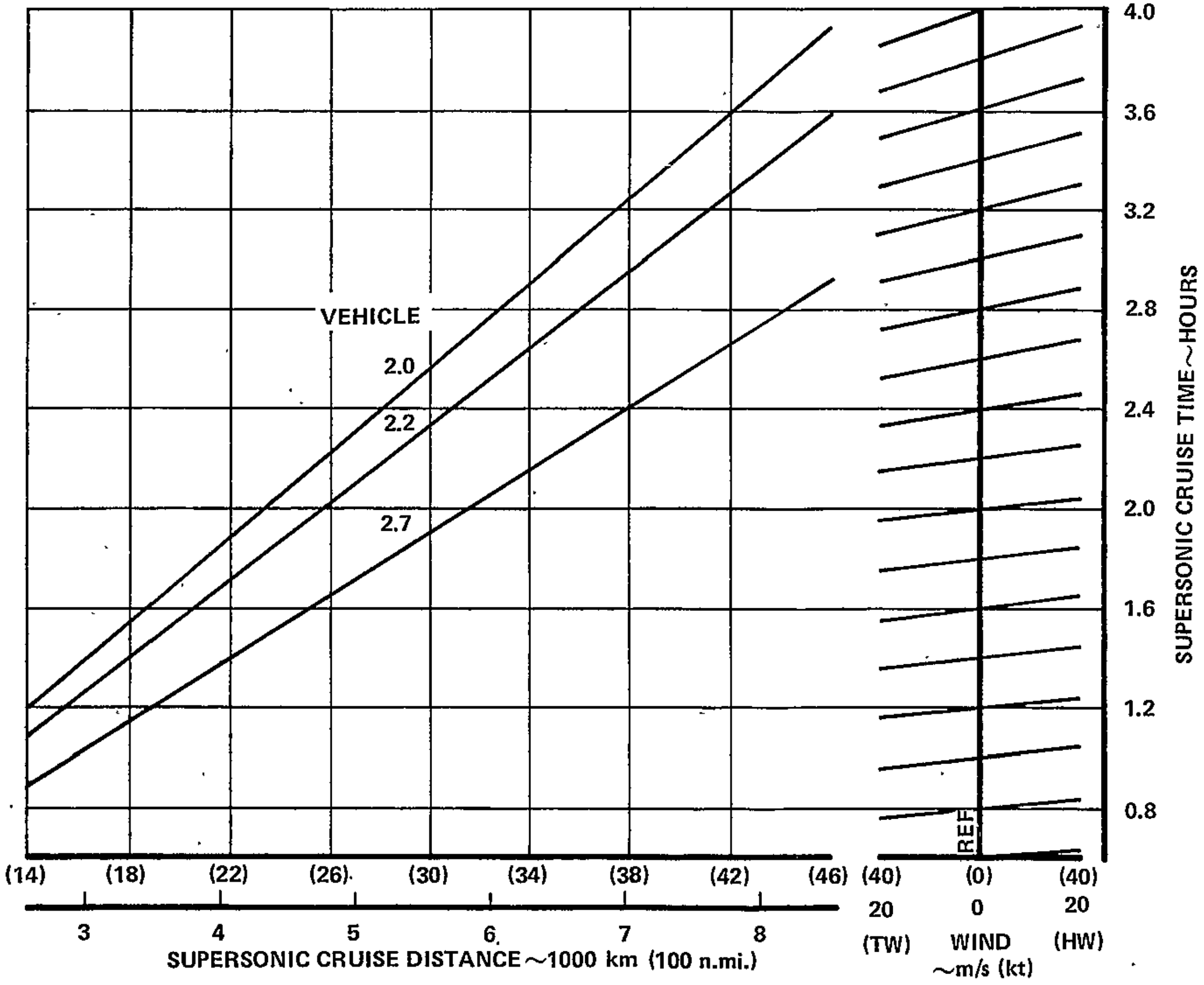
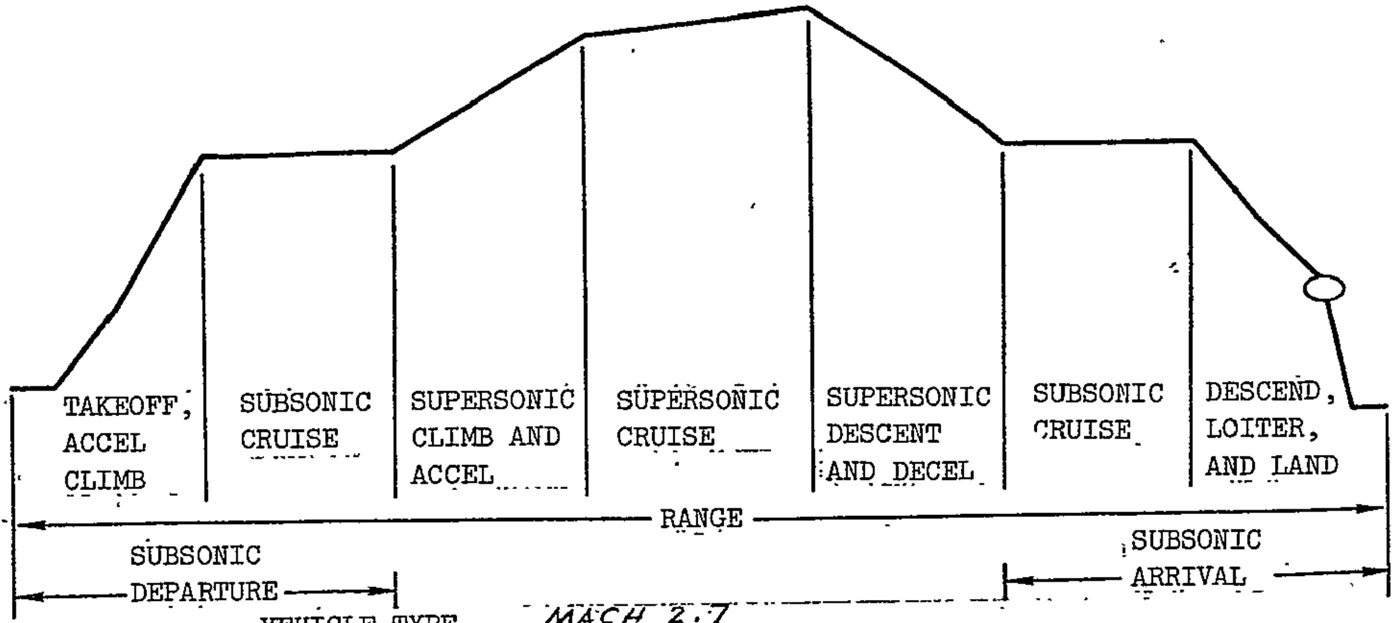


Figure A-9. Supersonic vehicles supersonic cruise time-medium to long range ISA 8°C cruise at 6154 to 19 812 meters (53 000 to 65 000 ft)



VEHICLE TYPE MACH 2.7

CITY PAIR NEW YORK (JFK) TO ROME (FCO)

RANGE . . . . 6967 (3762) km(NM)

REQUIRED SUBSONIC DISTANCE DEPARTURE 0 km(NM)

REQUIRED SUBSONIC DISTANCE ARRIVAL 1163 (628) km(NM)

WINDS 75% ANNUAL @ 18900 m 62000 ft 4 m/s 7 (TW) kt (SUPERSONIC)

WINDS 75% ANNUAL @ 9449 m 31000 ft 1 m/s 2 (TW) kt (SUBSONIC)

AIRLINE/AIRPORT PECULIARS DEPART .21 HR, ARRIV .06 HR, TOTAL .27 HR

SEGMENT	DISTANCE km	DISTANCE NM	TIME HR
TAKEOFF/ACCEL/CLIMB	74	40	.294
SUBSONIC DEPART = 0	0	0	0
SUPERSONIC CLIMB/ACCEL	391	211	.216
SUPERSONIC DESCENT/DECEL	254	137	.130
SUBSONIC ARRIV = 1163 − 96 (628 − 52)	1067	576	1.040
DESCEND, LOITER/LAND	96	52	.310
SUB TOTALS	1882	1016	1.99
SUPERSONIC CRUISE =	5085	2746	1.73
TOTALS	6967	3762	3.72
TOTAL PECULIARS			.27
BLOCK TIME			3.99

Figure A-10. Example supersonic block time build-up

APPENDIX B

TYPICAL
ROUTING SCHEDULES
PASSENGER SCHEDULES
FLIGHT CREW SCHEDULES

AIRCRAFT ROUTING SCHEDULE

SCHEDULE: NORTH ATLANTIC

MACH NO. 2.7

CYCLE NO. 1
NO. OF A/C 4

CODE	CITY \ FLIGHT NO.	2	1	4	3	6	5	8	7	10	9	12	11	14	13
ORD	CHICAGO				0746	0930					1816	2130			
BOS	BOSTON		1715	2245					0730	1000					
PHL	PHILADELPHIA														
IAD	WASHINGTON														
JFK	NEW YORK	0900					1852	2300					0737	0930	1748
LHR	LONDON	1652	1930	0625	0930	1925	2100	0652	0945	1740	2000	0725	0945		
CDG	PARIS														
FRA	FRANKFORT													1748	1930
MAD	MADRID														
MXP	MILAN														
FCO	ROME														

AIRCRAFT ROUTING SCHEDULE

SCHEDULE: NORTH ATLANTIC

MACH NO. 2.7

CYCLE NO. 2
NO. OF A/C 4

CODE	CITY \ FLIGHT NO.	16	15	18	17	20	19	22	21	24	23	26	25	28	27
ORD	CHICAGO														
BOS	BOSTON				0728	0900									
PHL	PHILADELPHIA														
IAD	WASHINGTON														
JFK	NEW YORK	0930	1805	2230			1650	2015	0731	0930	1931	2200	0718	0915	1735
LHR	LONDON														
CDG	PARIS	1839	2100	0739	1030	1757	1945								
FRA	FRANKFORT											0618	0900		
MAD	MADRID													1821	2030
MXP	MILAN														
FCO	ROME							0613	0930	1928	2130				

AIRCRAFT ROUTING SCHEDULE

SCHEDULE: NORTH ATLANTIC

MACH NO. 2.7

CYCLE NO. 3
NO. OF A/C 4

CODE	CITY / FLIGHT NO.	30	29	32	31	34	33	36	35	38	37	40	39	42	41
ORD	CHICAGO														
BOS	BOSTON							↓							
PHL	PHILADELPHIA	↓					1828	2215		↓		↓			↑
IAD	WASHINGTON			↓		↓			0738	0930	1838	2230		↓	
JFK	NEW YORK	1000	1848	2130	0733	1000							0852	1100	1952
LHR	LONDON	X TU X TH				1752	2030	0605	0930	1724	2030	0624	1100	1852	2200
							↑		↑		↑		↑		↑
CDG	PARIS														
FRA	FRANKFORT														
MAD	MADRID														
			X TU X TH												
MXP	MILAN	1936	2115	0707	1000										
FCO	ROME		↑		↑										

AIRCRAFT ROUTING SCHEDULE

SCHEDULE: NORTH ATLANTIC

MACH NO. 2.7

CYCLE NO. 4

NO. OF A/C 4

CODE	CITY \ FLIGHT NO.	44	43	46	45	48	47	50	49	52	51	54	53	56	55
ORD	CHICAGO														
BOS	BOSTON														
PHL	PHILADELPHIA														↑
IAD	WASHINGTON	↓		↓		↓		↓		↓		↓		↓	
JFK	NEW YORK	1200	2052	2230	0805	1100	1948	2200	1001	1145	1935	2215	1022	1200	1950
LHR	LONDON	1952	2300									0607	1230		
			↑										↑		
CDG	PARIS									2054	2230				
FRA	FRANKFORT					1918	2130				↑				
MAD	MADRID			0736	1100		↑							2106	2245
					↑										↑
MXP	MILAN														
FCO	ROME							0758	1200						
									↑						

PASSENGER SCHEDULE

MACH NO. 2.7
SCHEDULE NORTH ATLANTIC

EASTBOUND

FLT. NO.		6	12	10	4	36	38	40	2	34	42
CODE / FREQ.		DAILY	DAILY	DAILY	DAILY	DAILY	DAILY	DAILY	DAILY	DAILY	DAILY
ORD	AR										
	LV	0930	2130								
BOS	AR										
	LV			1000	2245						
PHL	AR										
	LV					2215					
IAD ●	AR										
	LV						0930	2230			
JFK	AR										
	LV								0900	1000	1100
LHR	AR	1925	0725	1740	0625	0605	1724	0624	1652	1752	1852
	LV										
ODG	AR										
	LV										
FRA	AR										
	LV										
MAD	AR										
	LV										
MIL	AR										
	LV										
FCO	AR										
	LV										

PASSENGER SCHEDULE

EASTBOUND

MACH NO. 2.7
SCHEDULE NORTH ATLANTIC

FLT. NO.		44	54	8	20	16	52	18	14	48	26
CODE	FREQ.	DAILY	DAILY	DAILY	DAILY	DAILY	DAILY	DAILY	DAILY	DAILY	DAILY
ORD	AR										
	LV										
BOS	AR										
	LV				0900						
PHL	AR				↓						
	LV				↓						
IAD	AR				↓						
	LV				↓						
JFK	AR				↓						
	LV	1200	2215	2300	↓	0930	1145	2230	0930	1100	2220
		↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
LHR	AR	1952	0607	0652	↓	↓	↓	↓	↓	↓	↓
	LV				↓	↓	↓	↓	↓	↓	↓
CDG	AR				1757	1839	2054	0739	↓	↓	↓
	LV								↓	↓	↓
FRA	AR								1748	1918	0618
	LV										
MAD	AR										
	LV										
MIL	AR										
	LV										
FCO	AR										
	LV										

PASSENGER SCHEDULE

EASTBOUND

MACH NO. 2.7
SCHEDULE NORTH ATLANTIC

FLT. NO.		28	56	46	30	32	24	22	50		
CODE \ FREQ.		DAILY	DAILY	DAILY	X TUE X THU	DAILY	DAILY	DAILY	DAILY		
ORD	AR										
	LV										
BOS	AR										
	LV										
PHL	AR										
	LV										
IAD	AR										
	LV										
JFK	AR										
	LV	0915	1200	2230	1000	2130	0930	2015	2200		
LHR	AR										
	LV										
CDG	AR										
	LV										
FRA	AR										
	LV										
MAD	AR	1821	2106	0736							
	LV										
MIL	AR				1936	0707					
	LV										
FCO	AR						1928	0613	0758		
	LV										

PASSENGER SCHEDULE

WESTBOUND

MACH NO. 2.7
SCHEDULE NORTH ATLANTIC

FLT. NO.		21	49	23	31	29	45	27	55		
FREQ. CODE		DAILY	DAILY	DAILY	DAILY	X TUE X THU	DAILY	DAILY	DAILY		
FCO	AR										
	LV	0930	1200	2130							
MIL	AR										
	LV				1000	2115					
MAD	AR										
	LV						1100	2030	2245		
FRA	AR										
	LV										
CDG	AR										
	LV										
LHR	AR										
	LV										
JFK	AR	0731	1001	1931	0733	1848	0805	1735	1950		
	LV										
IAD	AR										
	LV										
PHL	AR										
	LV										
BOS	AR										
	LV										
ORD	AR										
	LV										

PASSENGER SCHEDULE

WESTBOUND

MACH NO. 2.7
SCHEDULE NORTH ATLANTIC

FLT. NO.		25	13	47	17	19	15	51	11	39	53
CODE / FREQ.		DAILY	DAILY	DAILY	DAILY	DAILY	DAILY	DAILY	DAILY	DAILY	DAILY
FCO	AR										
	LV										
MIL	AR										
	LV										
MAD	AR										
	LV										
FRA	AR										
	LV	0900	1930	2130							
CDG	AR										
	LV				1030	1945	2100	2230			
LHR	AR										
	LV								0945	1100	1230
		↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
JFK	AR	0718	1748	1948	↓	1650	1805	1935	0737	0852	1022
	LV										
IAD	AR				↓						
	LV										
PHL	AR				↓						
	LV										
BOS	AR				0728						
	LV										
ORD	AR										
	LV										

PASSENGER SCHEDULE

WESTBOUND

MACH NO. 2.7
SCHEDULE NORTH ATLANTIC

FLT. NO.		5	41	43	35	27	33	7	1	3	9
CODE	FREQ.	DAILY	DAILY	DAILY	DAILY	DAILY	DAILY	DAILY	DAILY	DAILY	DAILY
FCO	AR										
	LV										
MIL	AR										
	LV										
MAD	AR										
	LV										
FRA	AR										
	LV										
CDG	AR										
	LV										
LHR	AR										
	LV	2100	2200	2300	0930	2030	2030	0945	1930	0930	2000
		↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
JFK	AR	1852	1952	2052							
	LV										
IAD	AR				0738	1838					
	LV										
PHL	AR						1828				
	LV										
BOS	AR							0730	1715		
	LV										
ORD	AR									0746	1816
	LV										

TYPICAL FLIGHT CREW SCHEDULE
& PAY HOURS
MACH 2.7 - NORTH ATLANTIC

SEGMENT	FLIGHT PAIRING	GMT SCHEDULE TIME	FLIGHT TIME	ROUTE FLIGHT TIME	DUTY HOURS	LAYOVER (TRIP)	DUTY CREDIT	TRIP CREDIT	PAY HOURS
JFK-LHR	2	1400-1652	2:52			2:38			
LHR-BOS	1	1930-2215	2:45		11:00	29:30	:01		
BOS-LHR	4	0345-0625	2:40			3:05			
LHR-ORD	3	0930-1346	4:16		11:46	25:44			
ORD-LHR	6	1530-1929	3:59			1:31			
LHR-JFK	5	2100-2356	2:56	19:28	10:11	(84:56)		4:47	24:16
JFK-LHR	8	0400-0652	2:52			2:53			
LHR-BOS	7	0945-1230	2:45		11:15	26:30	:09		
BOS-LHR	10	1500-1740	2:40			2:20			
LHR-ORD	9	2000-0016	4:16		11:01	27:14			
ORD-LHR	12	0330-0729	3:59			2:16			
LHR-JFK	11	0945-1241	2:56	19:28	10:56	(83:41)		4:18	23:55
JFK-FRA	14	1430-1748	3:18			1:42			
FRA-JFK	13	1930-2248	3:18	6:36	11:03	(11:18)			6:36
JFK-CDG	16	1430-1739	3:09			2:21			
CDG-JFK	15	2000-2309	3:09	6:18	11:24	(11:39)			6:18
JFK-CDG	18	0330-0639	3:09			2:51			
CDG-BOS	17	0930-1228	2:58		11:43	25:32			
BOS-CDG	20	1400-1657	2:57			1:48			
CDG-JFK	19	1845-2154	3:09	12:13	9:39	(45:24)		:45	12:58
JFK-FCO	22	0115-0513	3:58		6:43	27:17	:02		
FCO-JFK	21	0830-1235	4:05	8:03	5:50	(38:20)		2:52	10:57
JFK-FCO	24	1430-1828	3:58		6:43	26:02	:02		
FCO-JFK	23	2030-0035	4:05	8:03	5:50	(37:05)		2:31	10:36
JFK-FRA	26	0230-0548	3:18			2:42			
FRA-JFK	25	0830-1148	3:18	6:36	12:03	(12:18)			6:36
JFK-MAD	28	1415-1721	3:06			2:09			
MAD-JFK	27	1930-2239	3:09	6:15	11:09	(11:24)			6:15
(1) JFK-MXP	30	1500-1836	3:36			1:39			
MXP-JFK	29	2015-2352	3:37	7:13	11:37	(11:52)			7:13
JFK-MXP	32	0230-0607	3:37		6:22	26:53	:23		
MXP-JFK	31	0900-1237	3:37	7:14	5:22	(37:07)	:23	2:36	10:36

(1) All flights daily except F30/29 operates five days per week only.

TYPICAL FLIGHT CREW SCHEDULE & PAY HOURS
MACH 2.7 - NORTH ATLANTIC
(Continued)

SEGMENT	FLIGHT PAIRING	GMT SCHEDULE TIME	FLIGHT TIME	ROUTE FLIGHT TIME	DUTY HOURS	LAYOVER (TRIP)	DUTY CREDIT	TRIP CREDIT	PAY HOURS
JFK-LHR	34	1500-1752	2:52			2:38			
LHR-PHL	33	2030-2332	3:02		11:17	27:43			
PHL-LHR	36	0315-0609	2:54			3:21			
LHR-IAD	35	0930-1238	3:08		11:08	25:52			
IAD-LHR	38	1430-1728	2:58		4:43	17:32	1:02		
LHR-JFK	39	1100-1356	2:56	17:50	4:41	(97:56)	1:04	8:03	27:59
JFK-LHR	42	1600-1852	2:52			1:38			
LHR-IAD	37	2030-2338	3:08		10:23	27:52			
IAD-LHR	40	0330-0628	2:58		4:43	15:32	1:02		
LHR-JFK	41	2200-0056	2:56	11:54	4:41	(59:56)	1:04	3:07	17:07
JFK-LHR	44	1700-1952	2:52			3:08			
LHR-JFK	43	2300-0156	2:56	5:48	11:41	(11:56)	:11		5:59
JFK-MAD	46	0330-0636	3:06			3:24			
MAD-JFK	45	1000-1309	3:09	6:15	12:24	(12:39)	:07		6:22
JFK-FRA	48	1600-1918	3:18			1:42			
FRA-JFK	47	2100-0018	3:18	6:36	11:03	(11:18)			6:36
JFK-FCO	50	0300-0658	3:58		6:43	28:02	:02		
FCO-JFK	49	1100-1505	4:05	8:03	5:50	(39:05)		3:05	11:10
JFK-CDG	52	1645-1954	3:09			1:36			
CDG-JFK	51	2130-0039	3:09	6:18	10:39	(10:54)			6:18
JFK-LHR	54	0315-0607	2:52		5:37	30:23	1:08		
LHR-JFK	53	1230-1526	2:56	5:48	4:41	(39:11)	1:04	3:12	11:12
JFK-MAD	56	1700-2006	3:06			1:39			
MAD-JFK	55	2145-0054	3:09	6:15	10:39	(10:54)			6:15

Flight Hours/Month (30 Days) - 5409:16
Pay Hours/Month - 6699:16
No. of Crews @ 73 Pay Hours/Month - 91.77
Penalty Hours/Month - 1290:00
Crew Penalty - % of Flight Hours - 23.84