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COMMERCIAL AIRPLANE DIVISION

STUDY OF AIRCRAFT IN INTRAURBAN TRANSPORTATION SYSTEMS

SAN FRANCISCO BAY AREA

INTERIM REVIEW

DECEMBER 1970

NASA CONTRACT NAS 2-5969

FOR

ADVANCED CONCEPTS AND MISSIONS DIVISION
OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

THE BOEING COMPANY

RENTON, WASHINGTON

Contents

INTRAURBAN
STUDY OBJECTIVES

- DEFINE TECHNICAL, ECONOMIC AND OPERATIONAL CHARACTERISTICS OF AN INTRAURBAN SYSTEM
- DETERMINE SENSITIVITY OF SYSTEM TO CHANGES IN AIRCRAFT DESIGN AND OPERATIONAL CHARACTERISTICS
- IDENTIFY KEY AREAS FOR ADDITIONAL RESEARCH

NASA GROUND RULES

- STUDY AREA — SAN FRANCISCO BAY AREA

- TIME PERIOD — NEAR TERM (1975)
  FAR TERM (1985)

- VEHICLES — ROTOR VTOL
  NON ROTOR VTOL
  POWERED STOL
  SHORT FIELD CONVENTIONAL

INTRAURBAN STUDY APPROACH

- ESTABLISH TRAVEL DEMAND FOR THE SAN FRANCISCO BAY AREA
- LOCATE TERMINALS AND LAYOUT ROUTE SYSTEMS
- CONFIGURE VTOL AND STOL AIRCRAFT FOR 1975 USING TODAY'S TECHNOLOGY AND FOR 1985 USING ADVANCED TECHNOLOGY ESTABLISHED FOR THAT TIME PERIOD
- ESTIMATE DIRECT AND INDIRECT OPERATING COSTS ON A COMPONENT-BY-COMPONENT OR BUILDING BLOCK ANALYSIS OF BOTH THE AIRCRAFT AND THE TRANSPORTATION SYSTEM
- EVALUATE THESE AIRCRAFT FOR RELATIVE SUITABILITY ON A SYSTEM WIDE BASIS USING A TRANSPORTATION NETWORK MODEL THAT PERFORMS THE FOLLOWING FUNCTIONS AND ALLOWS AN ANALYSIS OF THE COMPLEX INTERACTION BETWEEN FUNCTIONS.
    - MODE SPLIT ANALYSIS
    - DETAIL SCHEDULE BUILDUP
    - OPERATING COSTS SUMMED PER FLIGHT
    - ECONOMIC EVALUATION

Summary

Major Intraurban System Characteristics

Revenue Passengers
Revenue Departures } greater than a large domestic trunk

Revenue Passenger Miles - less than 5% of a large domestic trunk

Revenue - less than 5% of a large domestic trunk

Terminals - less than one third of a large domestic trunk

Airplanes - less than one fourth of a large domestic trunk

SUMMARY

CONFIGURATION — TECHNOLOGY
DESIGN PHILOSOPHY AND ASSUMPTIONS

- INITIAL ASSUMPTION THAT SYSTEM COSTS WILL BE SENSITIVE TO TURN AROUND TIME
- MINIMIZE INGRESS—EGRESS TIMES
- SEMI-AUTOMATIC REFUELING SYSTEM
- CONTAINERIZED BAGGAGE WITH CONTAINERS LOCATED LATERALLY ACROSS BODY
- CONTINUOUSLY OPERATED ENGINES
- AIRPLANE CONFIGURATIONS AND SYSTEMS TO BE KEPT AS SIMPLE AS POSSIBLE
    - CONSTANT BODY SECTIONS
    - IDENTICAL DOORS
    - CONSTANT CHORD WING AND HORIZONTAL TAIL
    - SEMI-RETRACTING LANDING GEAR
    - SEMI-PRESSURIZED (1.0 P.S.I.)

AUGMENTOR WING STOL
1985 TECHNOLOGY
95 PASSENGERS

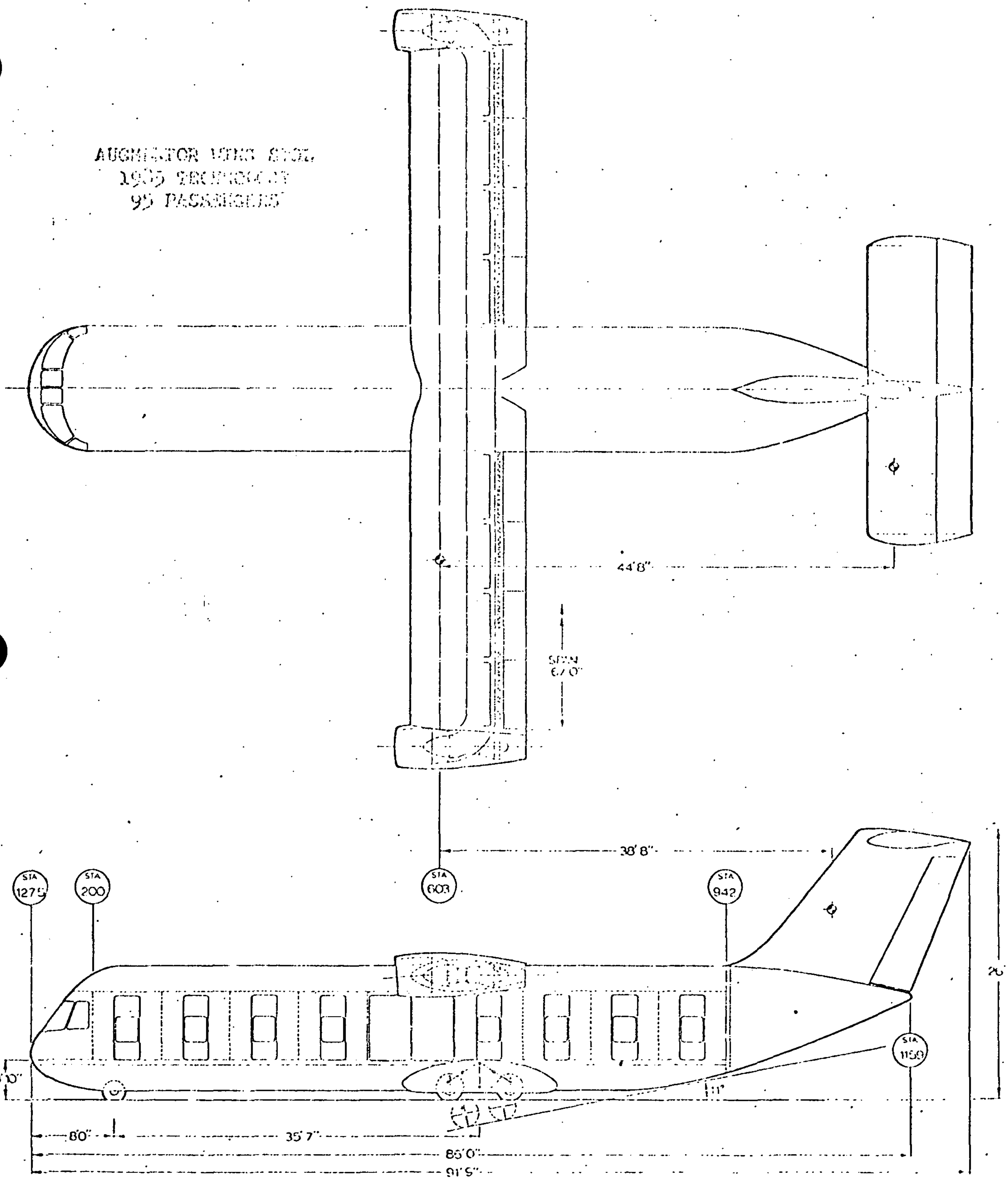

Fig. 6-31

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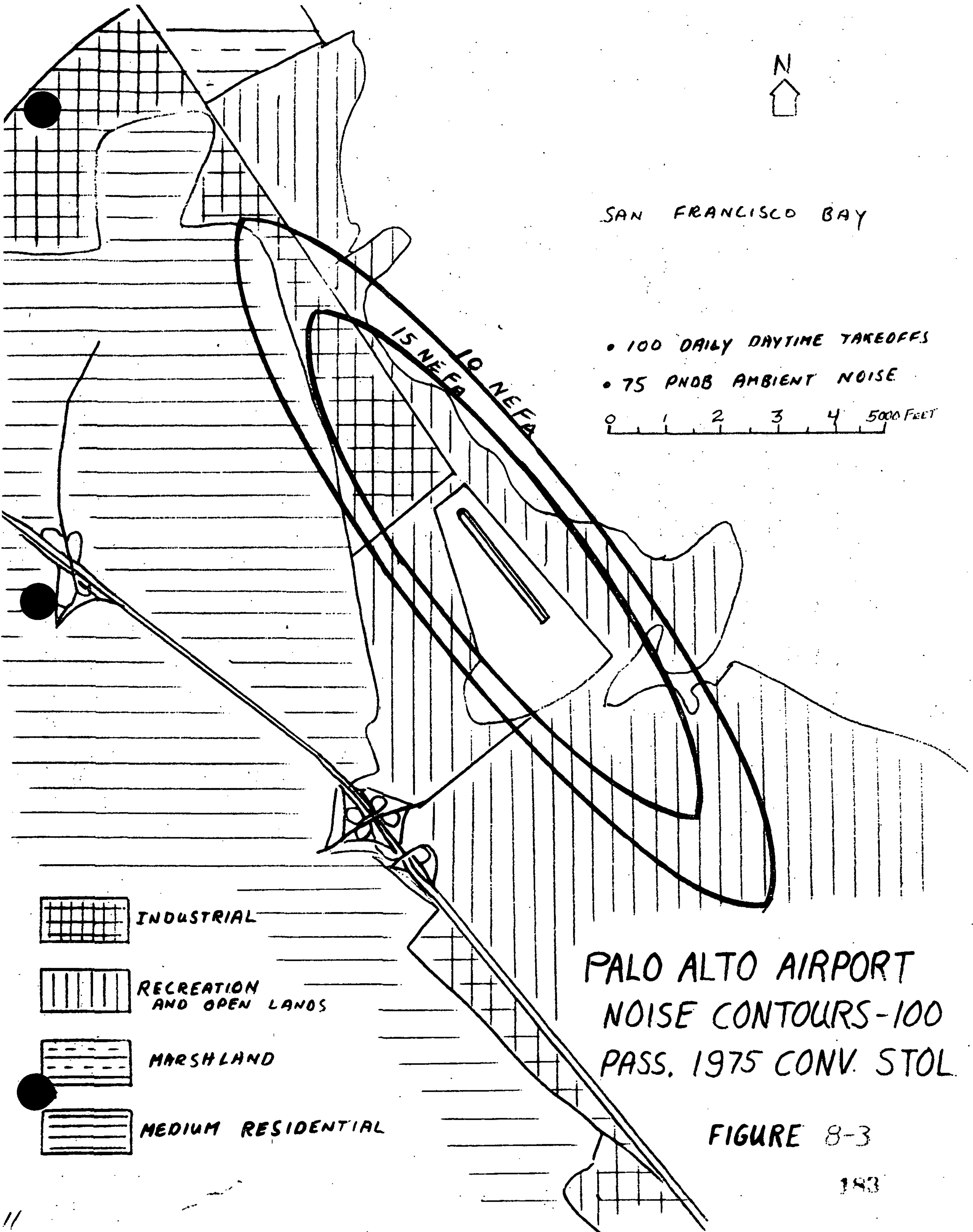
I. NOISE ANALYSIS

- NOISE EXPOSURE FORECAST

  EFFECT OF:
  - AMBIENT NOISE
  - FLIGHT FREQUENCY
  - MIXED OPERATIONS

- NOISE CRITERIA



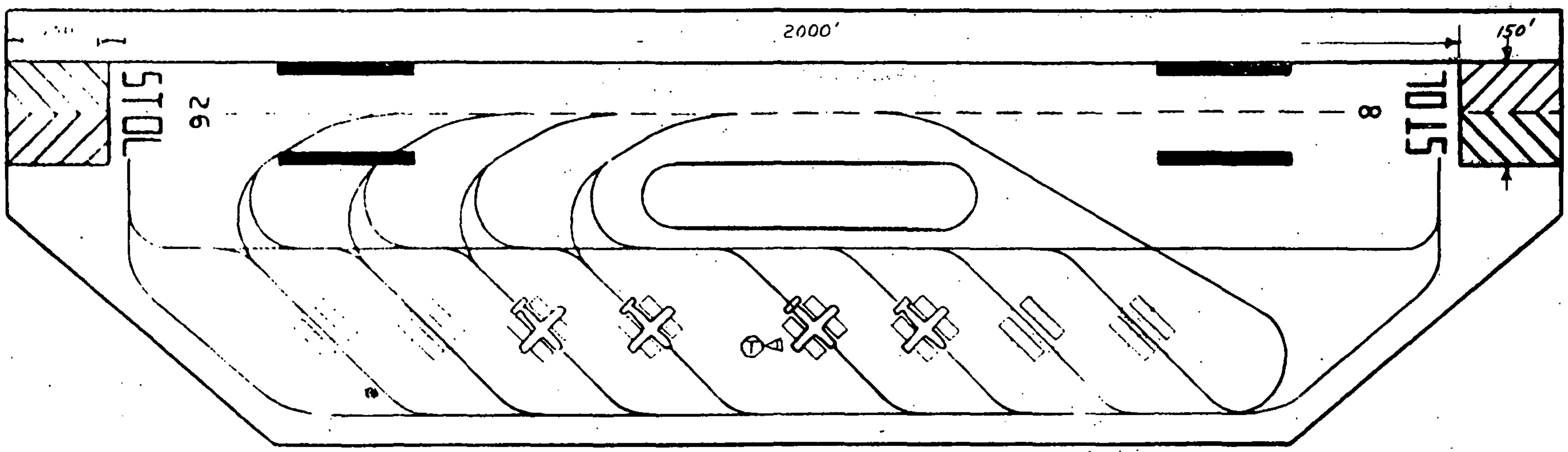
PALO ALTO AIRPORT
NOISE CONTOURS-100
PASS. 1975 CONV. STOL

FIGURE 8-3

GROUND SYSTEM ANALYSIS
AIR TERMINAL LOCATION FACTORS

- NOISE AND COMPATIBLE LAND USE
- AIRCRAFT DESIGN - STOL OR VTOL
- ATC CONSIDERATIONS
- LOCATIONS OF PASSENGER ORIGINATION AND DESTINATION
- OBSTACLES AND PROTECTION SURFACES
- EXISTING AIRPORT FACILITIES
- GROUND ACCESS
- AIR TERMINAL COSTS
- LAND COSTS
- WEATHER CONSIDERATIONS

ROOFTOP STOLPORT-4
INTRAURBAN SYSTEM



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AIR TRAFFIC CONTROL ANALYSIS

PROBLEM: INTRAURBAN STOL SYSTEM IS NOT ECONOMICALLY FEASIBLE UNDER CURRENT ATC REGULATIONS

- RUNWAY OPERATIONS RATE IS NOW A FUNCTION OF APPROACH SEPARATION REQUIREMENTS, NOT AIRCRAFT PERFORMANCE OR RUNWAY GEOMETRY

- OUR ANALYSIS SHOWS THAT AN EXPECTED RUNWAY OPERATIONS RATE OF 82 STOL AIRCRAFT PER HOUR IS POSSIBLE WITH

  V_{REF} = 77 KNOTS

  ARRIVAL-ARRIVAL SEPARATION = 2 N.MI.

  GO-AROUND RATE = 0.01%

  APPROACH FIX ARRIVAL TIME 4 SECONDS STANDARD DEVIATION

  BALANCED ARRIVAL-DEPARTURES

TECHNOLOGY DETERMINATION - ATC

1975 TRI-LEVEL AIR TRAFFIC SERVICE

- o SEE & BE SEEN UNEQUIPPED VFR GENERAL AVIATION
- o FLIGHT PLANNED TACTICALLY CONTROLLED EQUIPPED IFR
- o FLIGHT PLANNED STRATEGICALLY CONTROLLED TIME SYNCHRONIZED IFR INTRAURBAN STOL

1985 BI-LEVEL AIR TRAFFIC SERVICE

- o SEE & BE SEEN SEGREGATED UNEQUIPPED VFR GENERAL AVIATION
- o FLIGHT PLANNED STRATEGICALLY CONTROLLED TIME SYNCHRONIZED IFR AIRCRAFT

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CASH DIRECT OPERATING COST ASSUMPTIONS

- TWO MEN CREW
- FUEL PRICE 10 CENTS/GALLON + 2% NON-REVENUE FACTOR
- INSURANCE 2%
- DIRECT MAINTENANCE - $/FLIGHT HOUR + $/CYCLE
- DIRECT MAINTENANCE BURDEN - 1.5 X LABOR DOLLAR
- UTILIZATION - VARIABLE
- AIRFRAME PRICE $/LB VALUE PER FUNCTIONAL SYSTEM
- PROPULSION SYSTEM PRICE

AD 1546 D

REV SYM

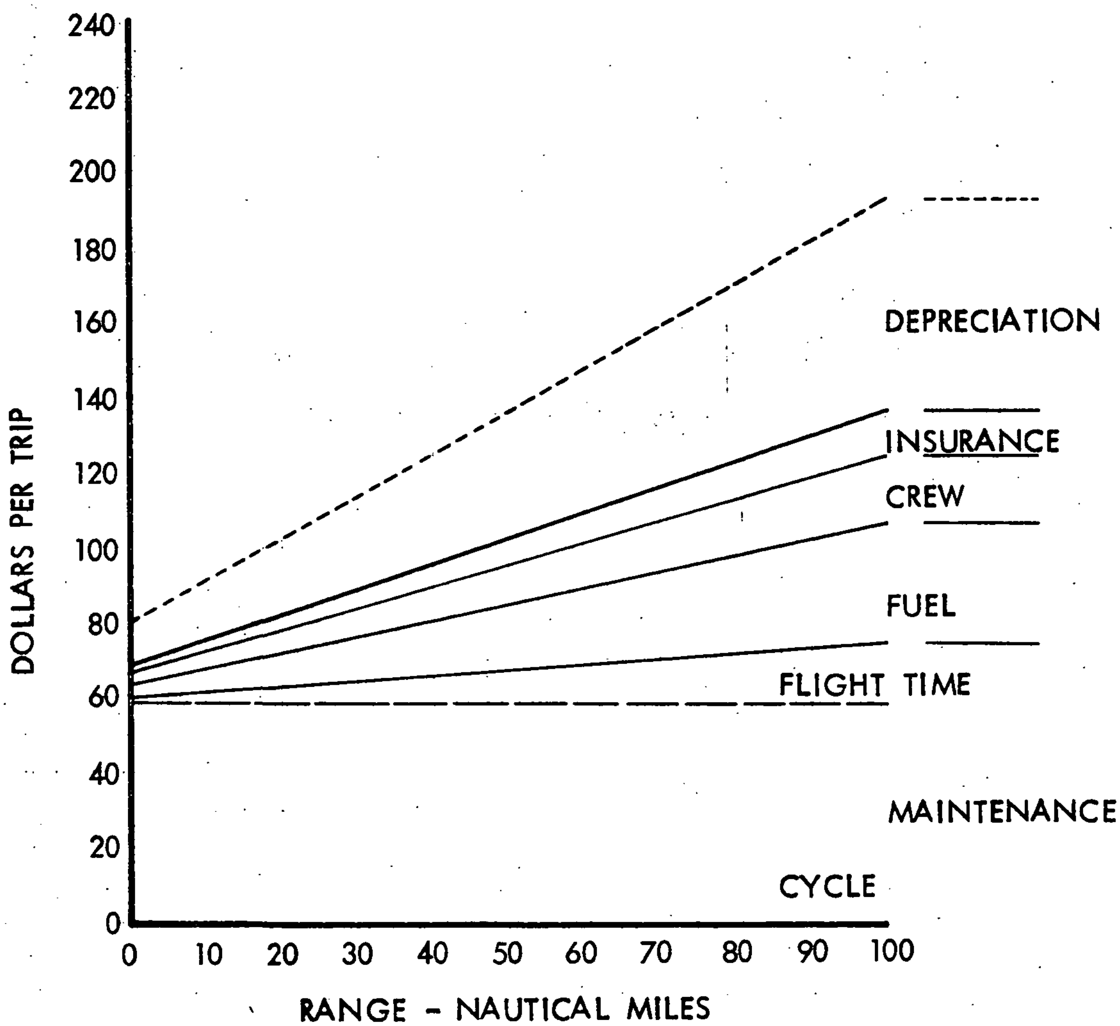
COMPARISON OF AIRCRAFT ACQUISITION COSTS, 1975 AND 1985 TECHNOLOGY

1970 Dollars in Millions

Payload - 100 Passengers (Nominal)

	Airframe Cost/Price		Engine Price		Airplane Cost/Price	
Technology:	1975	1985	1975	1985	1975	1985
Short Field Conventional STOL	$1.5	$1.2	$.8	$ .8	$2.3	$2.0
Augmentor Wing STOL	1.4	1.1	.5	.4	1.9	1.5
Ejector Wing VTOL	-	1.8	-	1.9	-	3.7
Tandem Rotor Helicopter	2.0	1.7	.5	.4	2.5	2.1
Tilt Rotor VTOL	-	1.6	-	.5	-	2.1

DIRECT OPERATING COST
$/TRIP VS. RANGE NAUTICAL MILES
CONVENTIONAL STOL
95 PASSENGERS



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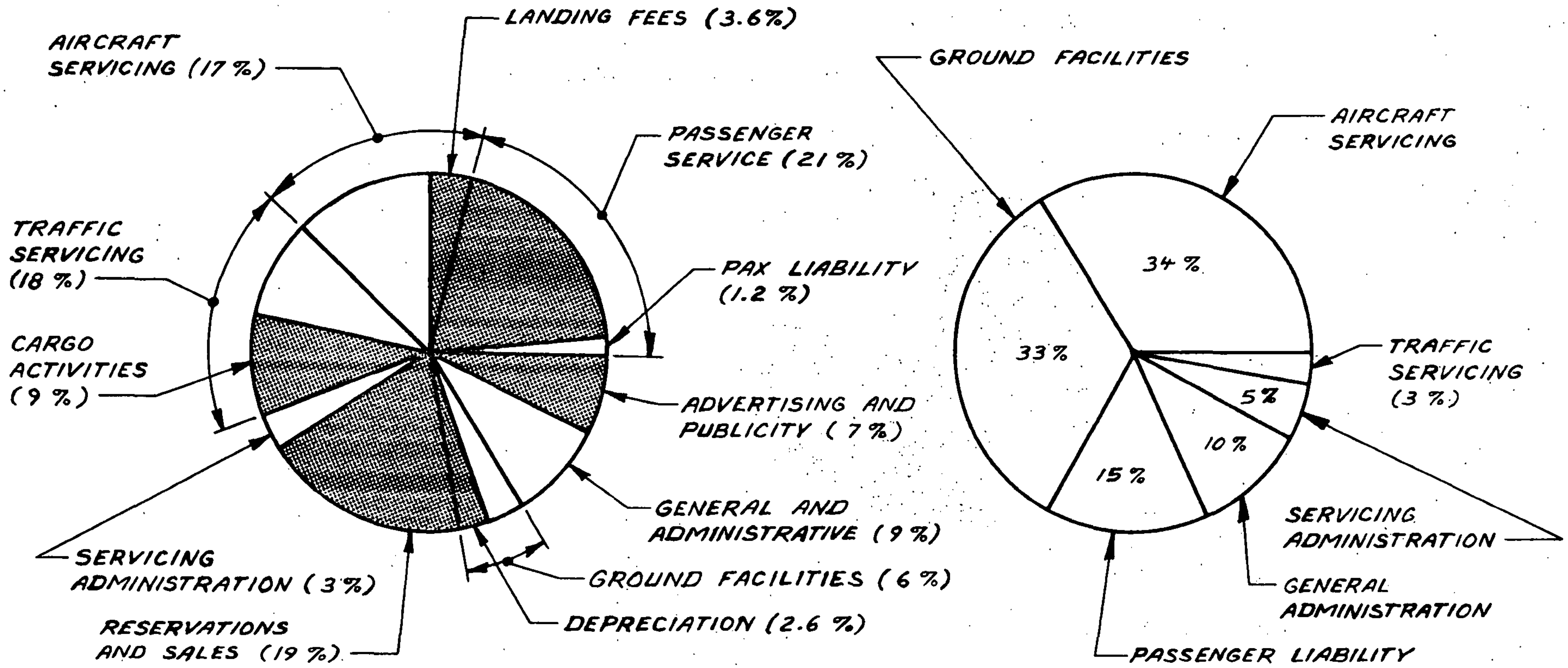
COMPARISON OF IOC FOR DOMESTIC TRUNKS AND THE POSTULATED INTRAURBAN TRANSPORTATION NETWORK



IOC - DOMESTIC TRUNKS
1969 - $2619.4 MILLION

IOC - STOL SYSTEM
BASE CASE $34.82 MILLION

▒ - COSTS NOT APPROPRIATE TO INTRAURBAN SYSTEM

TRAFFIC DATA
FROM
REGIONAL TRANSPORTATION PLANNING COMMISSION

- 2 TAPE FILE OF 30,000 HOME SURVEYS MADE IN THE 9 COUNTY BAY AREA. THESE TAPES CONTAIN DETAILED INFORMATION ABOUT THE PERSON MAKING THE TRIP, HIS ORIGIN AND DESTINATION (INCLUDING TIMES) BASED ON THE 291 ANALYSIS ZONES.
- 3 TAPES - EACH TAPE SHOWS TRAFFIC BETWEEN ALL COMBINATIONS OF THE 291 ANALYSIS ZONES FOR 4 PURPOSES:

  1 - HOME TO WORK
  2 - HOME TO PERSONAL BUSINESS
  3 - NON-HOME BASED
  4 - SUM OF 1 - 3

  TAPE 1 - 1965
  2 - 1980
  3 - 1990

REV SYM

TABLE 11.4-1

RESULTS OF NETWORK MODEL (1980)

1975 AIRCRAFT		(1) SYSTEM PARAMETERS			
		Person Trips via Air Mode			
Type	No. Seats	(2) Annual (Millions)	(3) % of All Modes	Fleet Size	Gates
Conventional STOL	49	41.9	2.1%	176	99
	95	41.0	2.1%	148	84
	153	35.6	1.8%	118	75
Augmentor Wing STOL	49	41.7	2.1%	185	101
	95	41.8	2.1%	168	85
	153	35.7	1.8%	126	75
Helicopter	98	42	2.1%	188	84

(1) Based on 1980 passenger demand

(2) Assumes 314 equivalent operating days per year

(3) Based on 1,970,000,000 annual inter-terminal area person-trips by all modes in 1980
(Note that on p. 50, Ref. 11-1, 1980 annual Bay Area person-trips = (314)(15,307,000) = 4,800,000,000)

AD 1546 D

REV SYM

TABLE 11.4-3

*REQUIRED INITIAL INVESTMENTS (1975)

1975 AIRCRAFT		INITIAL INVESTMENTS (MILLIONS OF 1970 $)			
			(2) Air Terminals		
Type	No. Seats	(1) Aircraft	Land	Facilities	Total
Conventional STOL	49	317	115	707	1112
	95	356	98	598	1052
	153	372	87	535	962
Augmentor Wing STOL	49	279	117	722	1100
	95	333	99	606	1014
	153	324	87	535	946
Helicopter	98	485	38	235	728

(1) Includes 20% engine spares and 4% airframe and electronics spares
(2) Based on average STOLport cost of $8.3M per gate, average VTOLport cost of $3.25M per gate (See Figure 8-41), and the average ratio of land cost to total cost of .14 and .07 for, respectively, STOLports and VTOLports (See Section 8.0).

*1975 investment for an air transportation system which would accommodate 1980 passenger demand.

TABLE 11.4-5

1980 ANNUAL SYSTEM LOSSES (1970 DOLLARS)

1975 AIRCRAFT TYPE	NO. SEATS	(1) LOSS PER PERSON IN 1980 BAY AREA POPULATION	(2) LOSS PER PERSON 18 YEARS OF AGE AND OVER	LOSS PER AIR PERSON-TRIP
CONVENTIONAL STOL	49	$26.30	$41.10	$3.90
	95	27.80	43.40	4.20
	153	26.60	41.50	4.63
AUGMENTOR WING STOL	49	24.70	38.60	3.66
	95	25.70	40.10	3.80
	153	26.00	40.60	4.50
HELICOPTER	98	21.50	33.60	3.17

(1) 1980 Population = 6.2 Million (p. 38, Ref. 11-1)
(2) In 1966, the population ratio of 18 years and over to total in U.S. was 126.2M/196.8M = 64% (See p. 262, 1968 World Almanac).

Conclusions

- All systems analyzed to date require subsidy.
  - Good possibility of best system meeting operating costs.
  - *Some possibility of limiting subsidy requirement to terminals only.*
- Unproductive ground and air time far more costly than for Intercity system.
  - Increasing gate time from 3 minutes to 8 minutes increases aircraft fleet by 20% with no change in revenue.
- The number of configurations can be reduced in phase II to one STOL and one VTOL for each time period without affecting the objectives.
  - Augmentor wing STOL
  - Helicopter 1975
  - Tilt rotor 1985

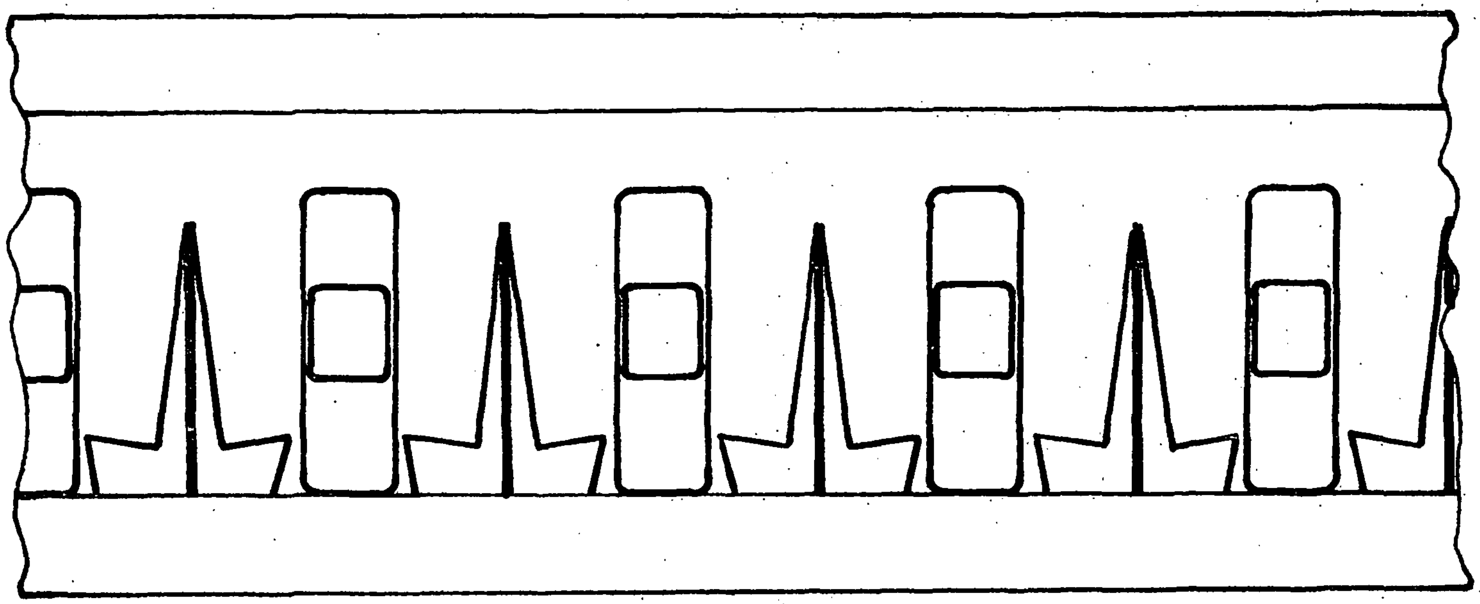
Conclusions (continued)

- The Intraurban system is not feasible under current ATC procedures and regulations.
  - Strategically controlled time synchronized system.
  - Reduced separation for busy STOLports.
  - Dedicated airspace and exclusive terminals.
- The Postulated ATC system for 1975 does not require a large development effort.
- The Downtown San Francisco area requires 3 to 5 STOLports to satisfy demand. Available locations severely limited. VTOLport locations are available.
- The Optimum size aircraft is not yet firmly established but appears to be within size classes selected.
- The maintenance costs of all concepts require more analysis in phase II.

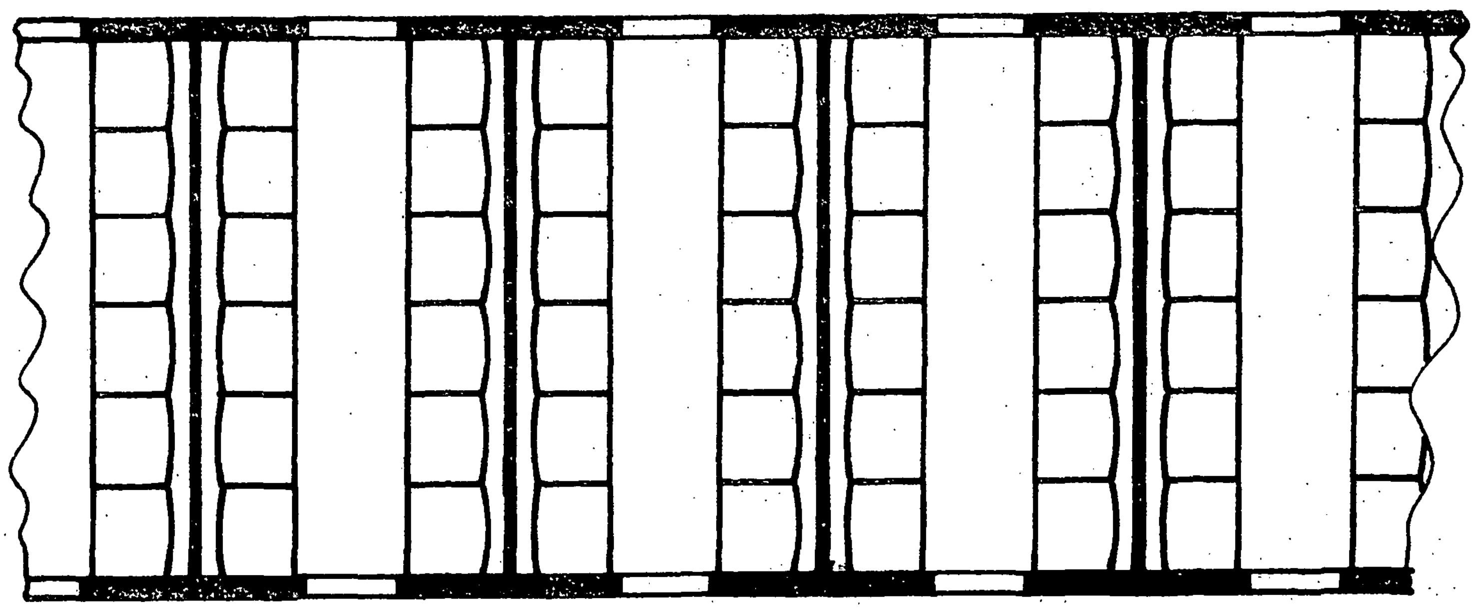
Recommendations for Phase II

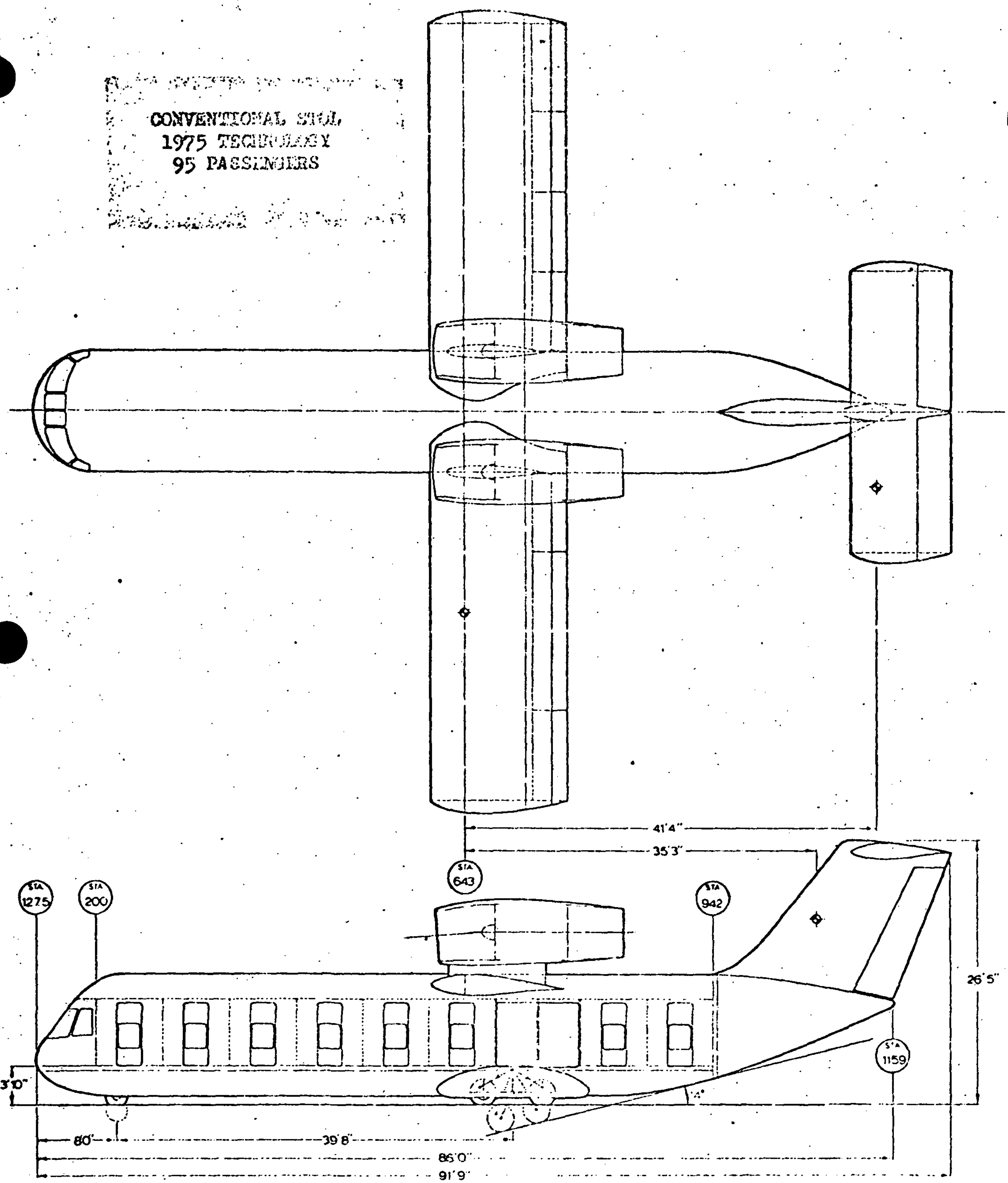
- o Reduce configurations to Augmentor Wing STOL, Helicopter, and Tilt Rotor.
- o Iterate on terminal locations with trade of maximizing traffic and reducing the number of terminals.
- o Reinvestigate maintenance costs of rotor configurations, and reanalyze cyclic cost percentage.
- o Analyze downtown San Francisco for additional terminal location to satisfy large demand.
- o Investigate mix of two sizes of aircraft.
- o Conduct sensitivity studies as planned.

CONFIGURATIONS

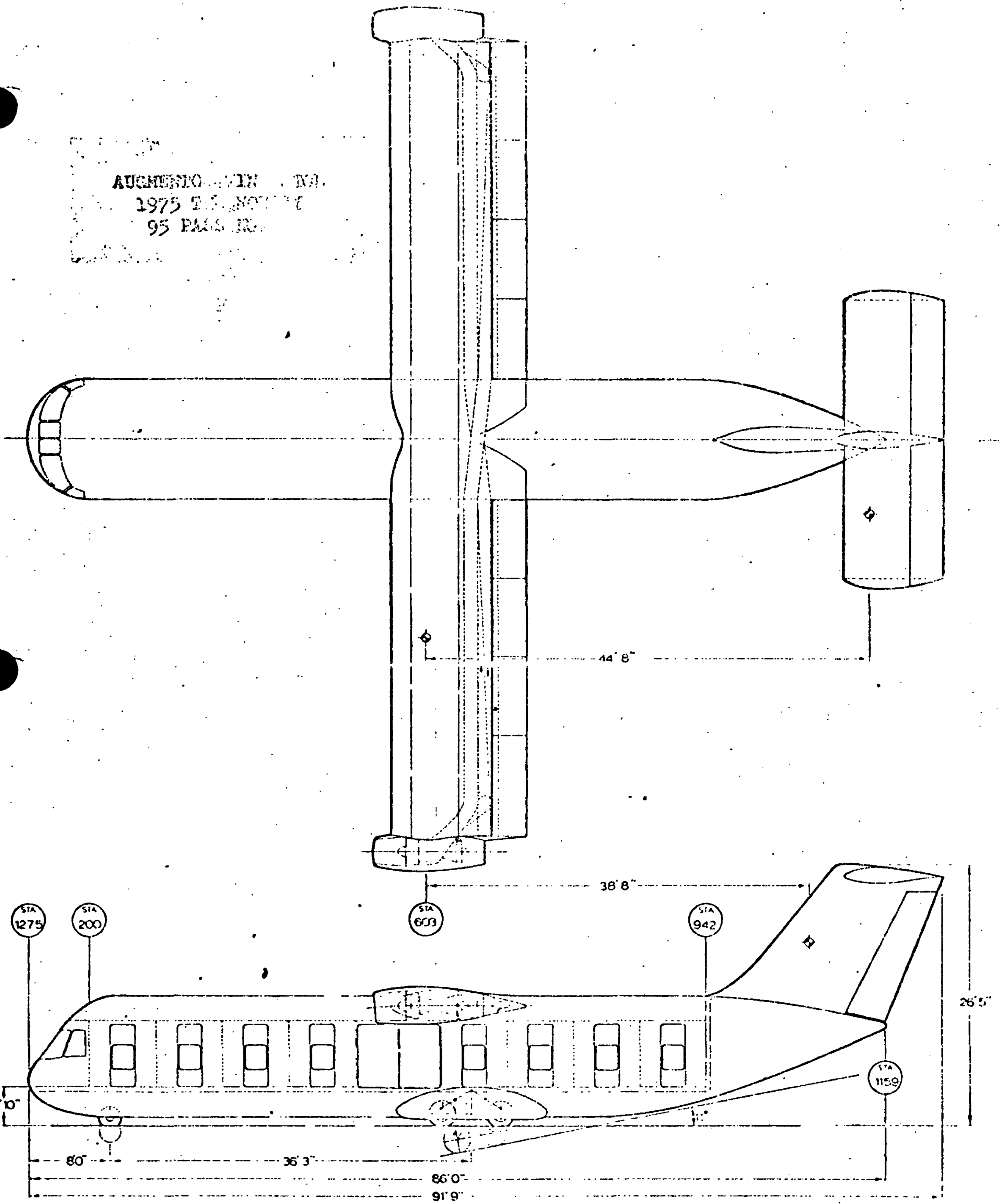


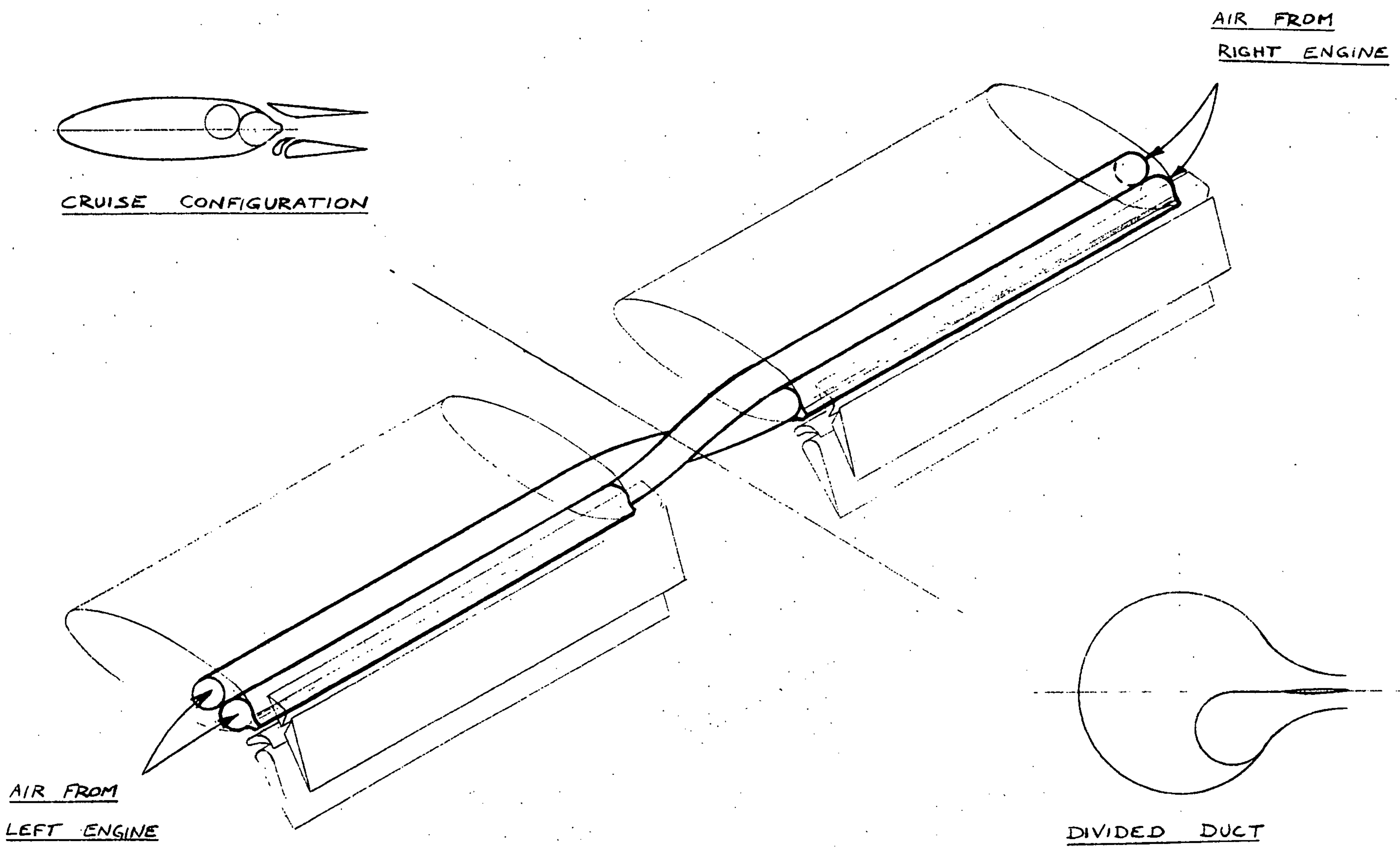
INTERIOR LAYOUT NUMBER I





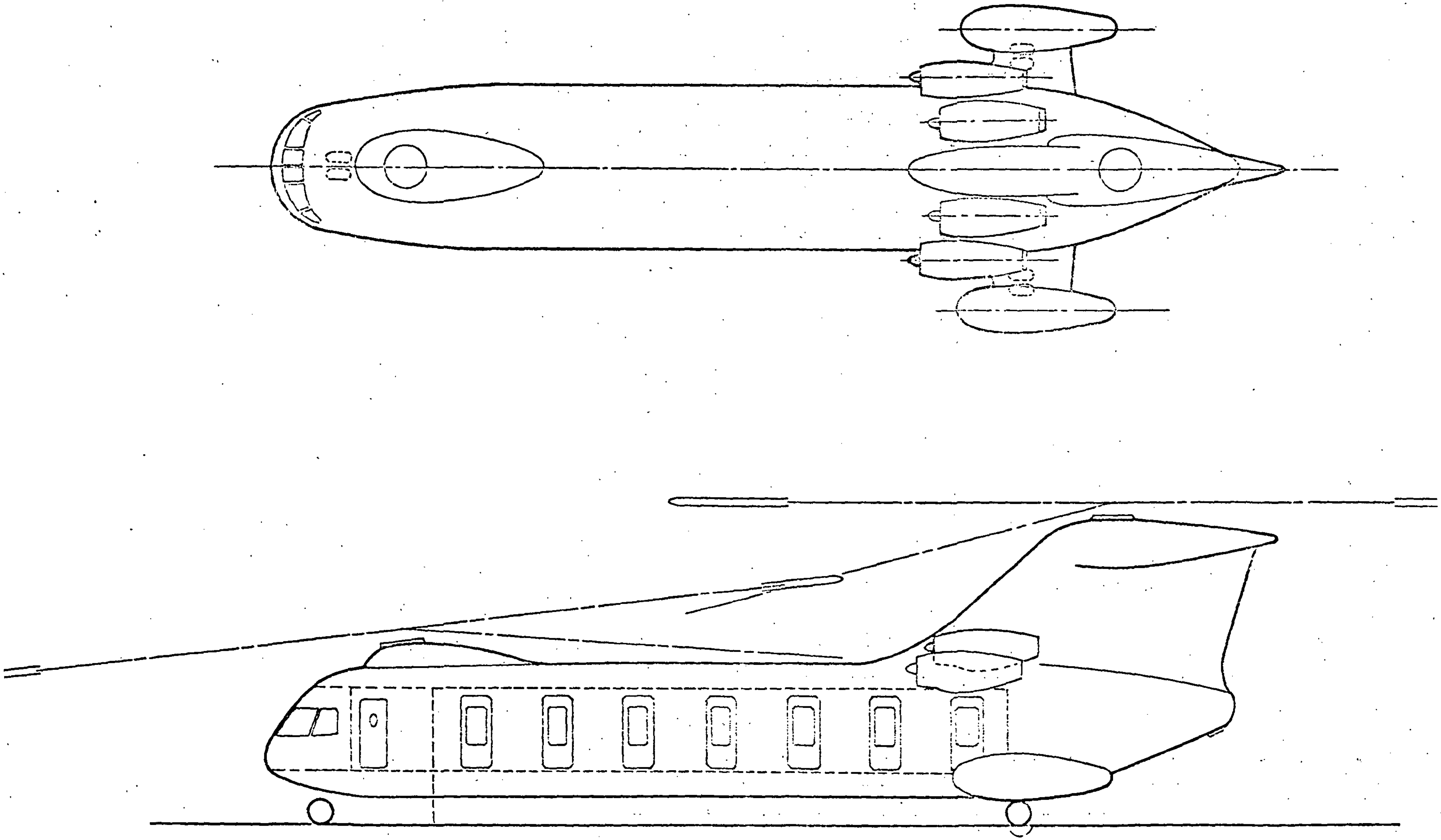
CONVENTIONAL STOL
1975 TECHNOLOGY
95 PASSENGERS
41'4"
35'3"
STA 643
STA 1275
STA 200
STA 942
STA 1159
26'5"
3'10"
4°
8'0"
39'8"
86'0"
91'9"

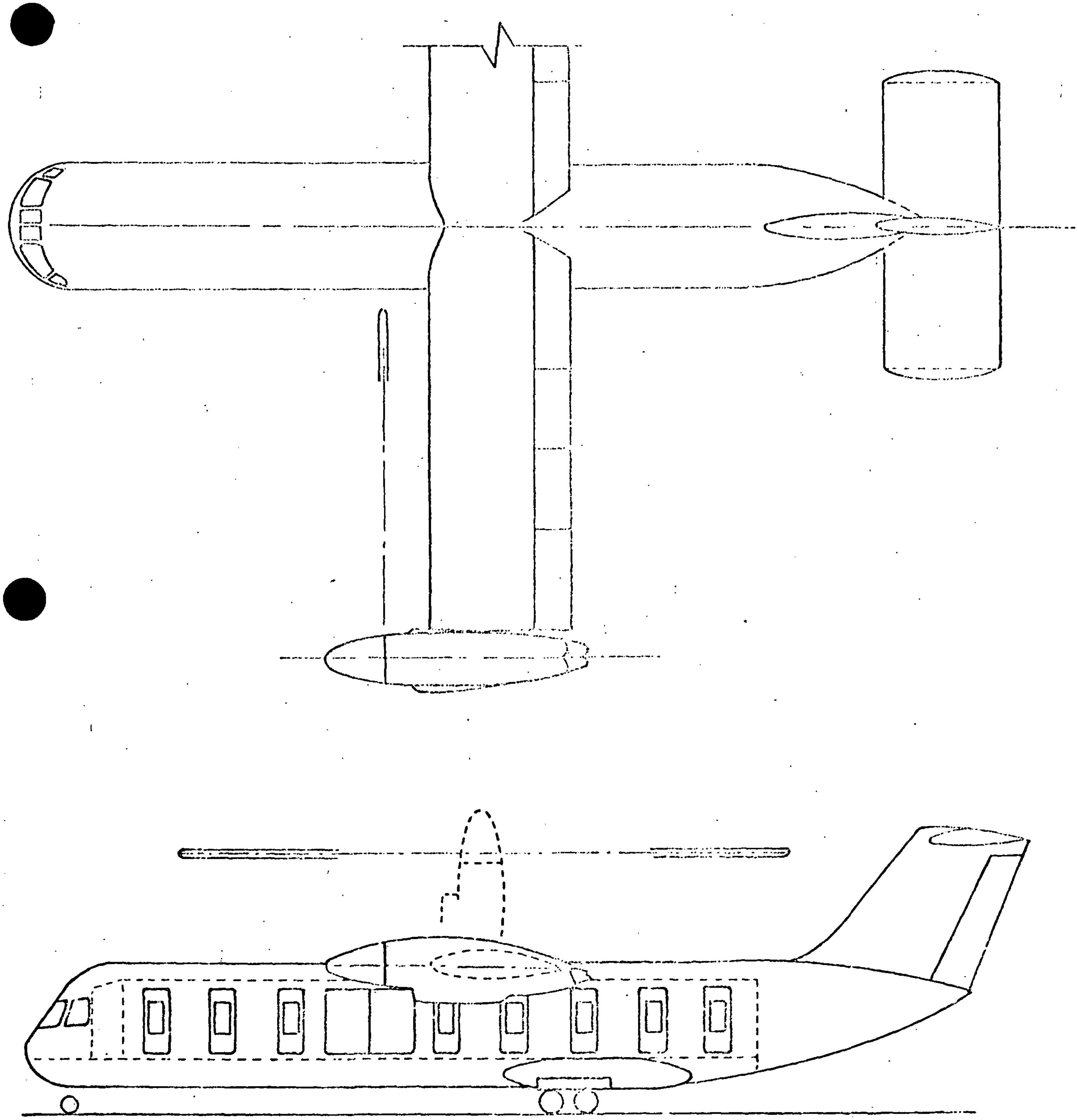

44' 8"
38' 8"
STA 1275
STA 200
STA 603
STA 942
STA 1159
26' 5"
3' 10"
80"
36' 3"
86' 0"
91' 9"



SCHEMATIC DIAGRAM OF 1975 AUGMENTOR WING DUCT SYSTEM.

Fig. 6-28



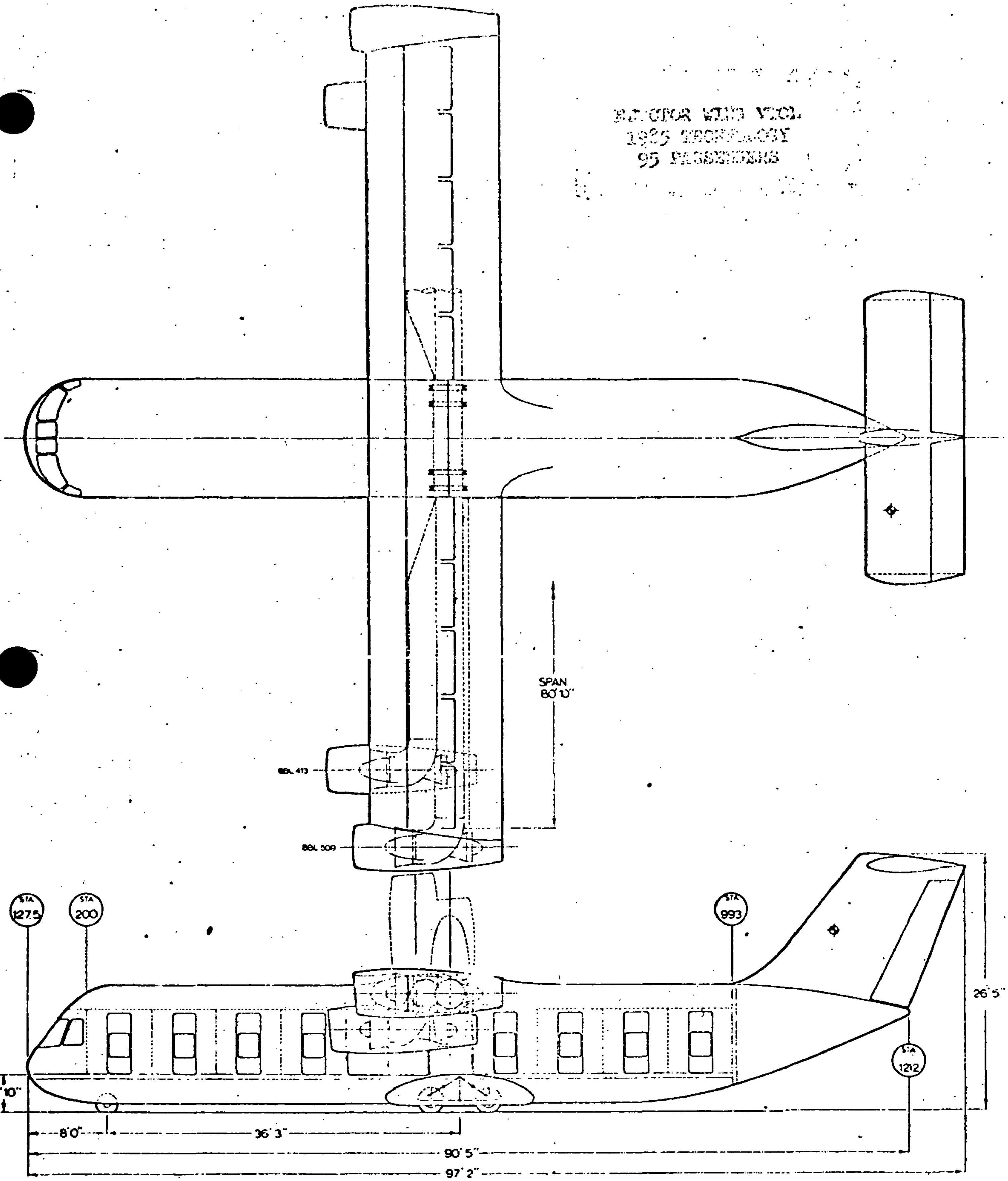


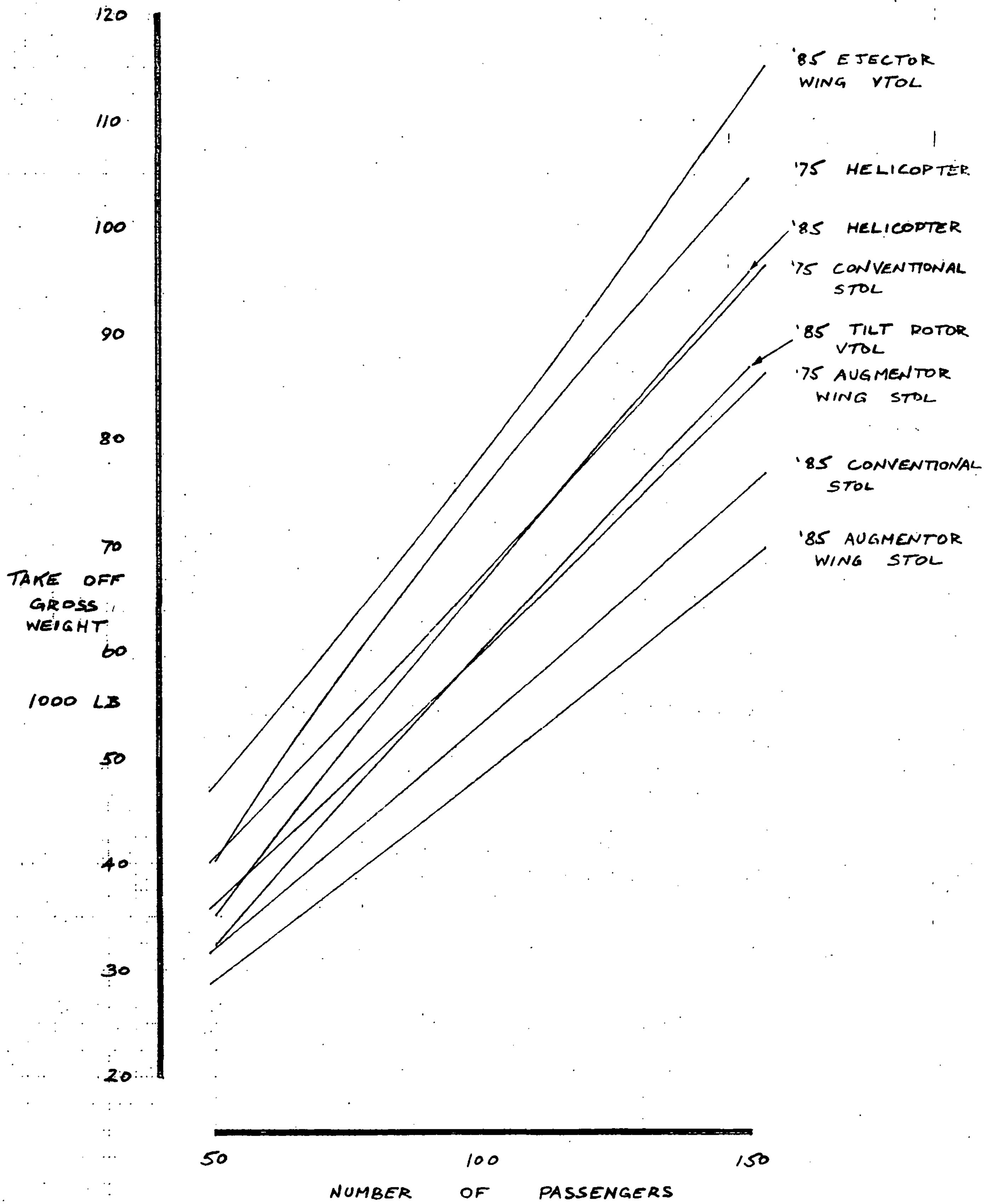
R.B. SHANNON 6/76

GENERAL ARRANGEMENT
1985 TILT ROTOR
100 PASSENGER

FIG 6-35
D6-25176
97

EJECTOR WING VTOL
1985 TECHNOLOGY
95 PASSENGERS





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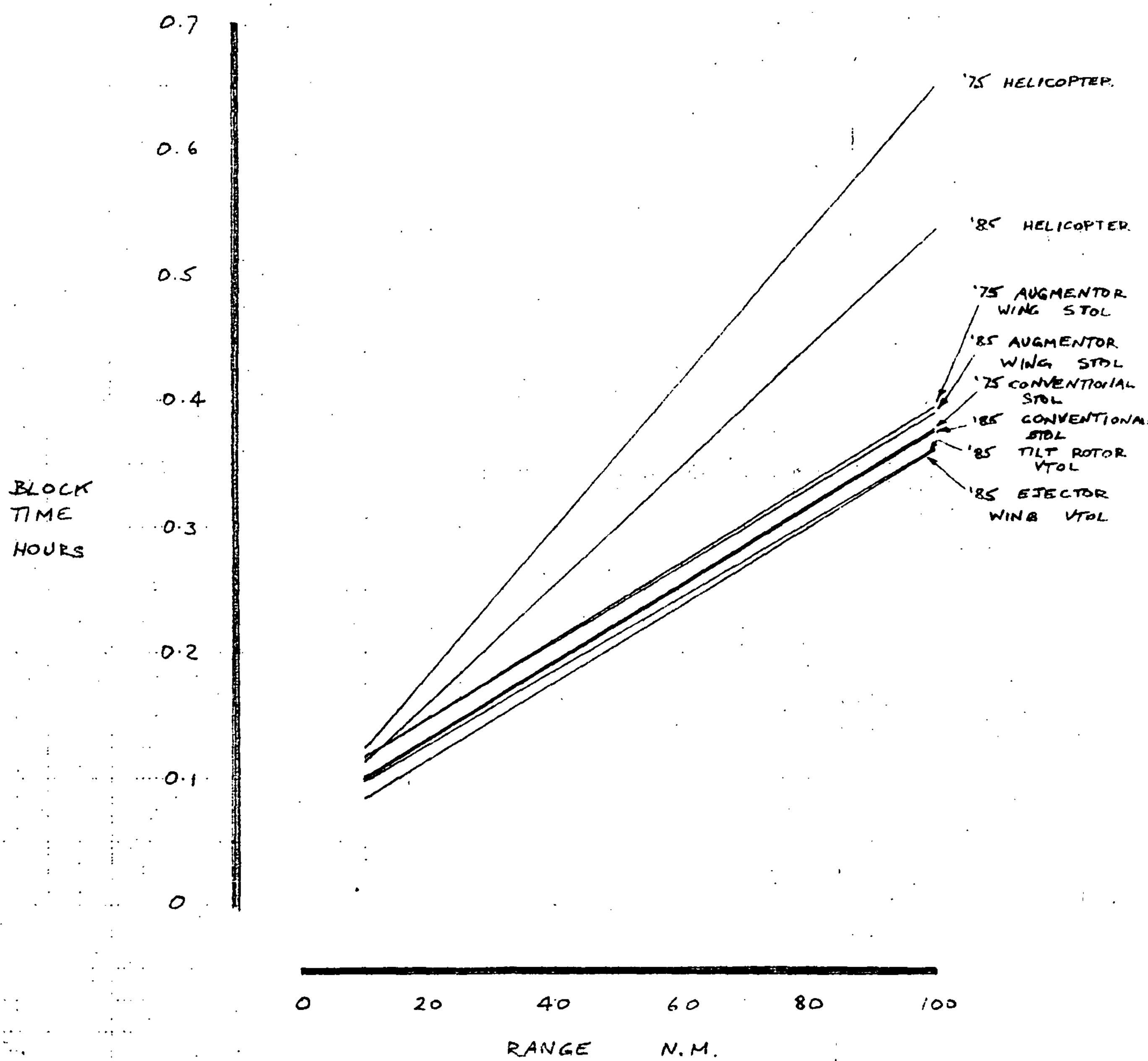
COMPARISON OF T.O.G.W. FOR BASE LINE AIRPLANES – PHASE I

Fig.6-37



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COMPARISON OF BLOCK TIMES FOR BASE LINE AIRPLANES — PHASE I

Fig. 6-50

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D6-25476

PROPULSION

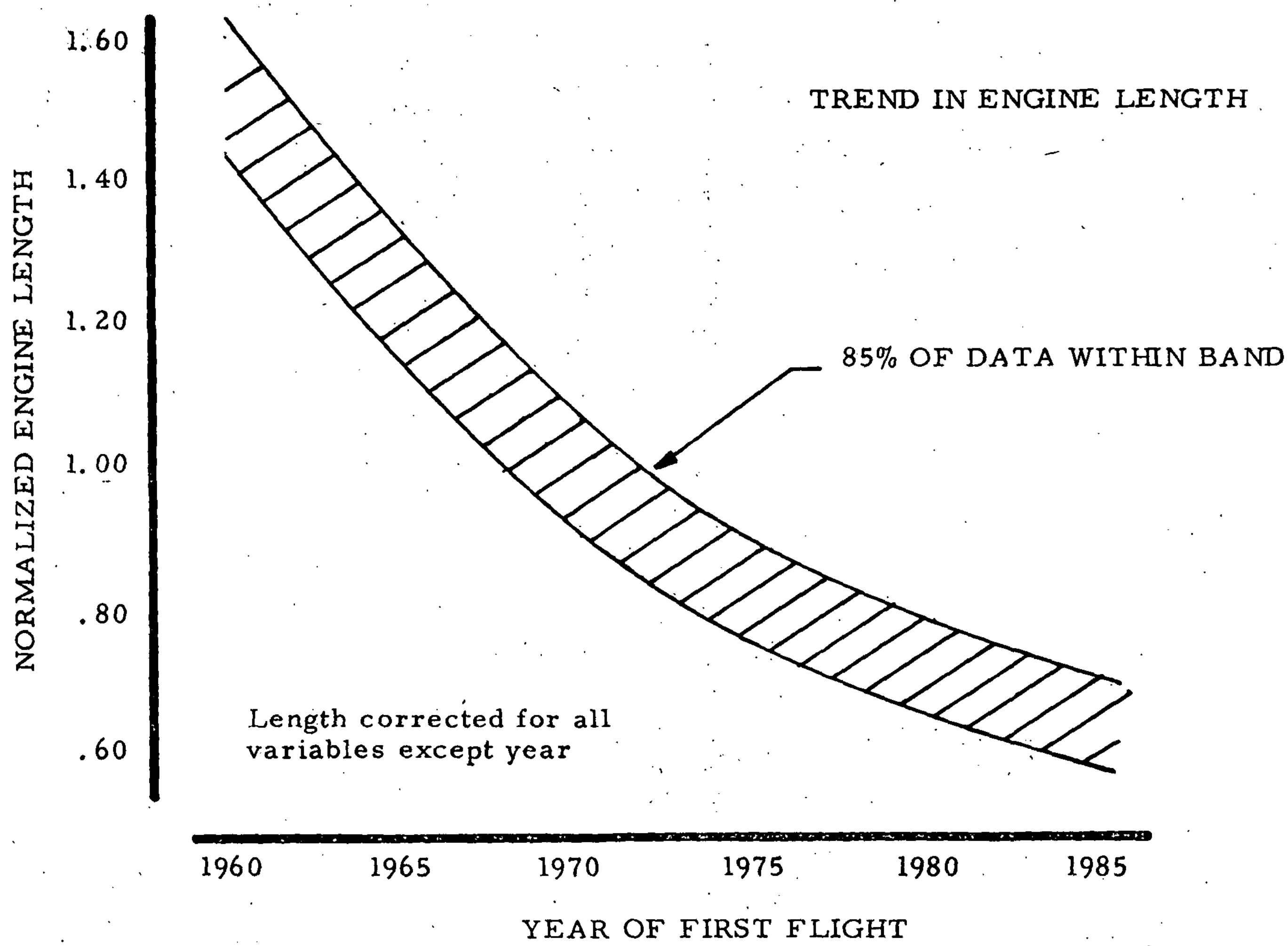

Fig. 6-8

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THE BOEING COMPANY

D6-25476

PAGE

BOEING CONCEPT OF AUGMENTOR WING PRIMARY ENGINE

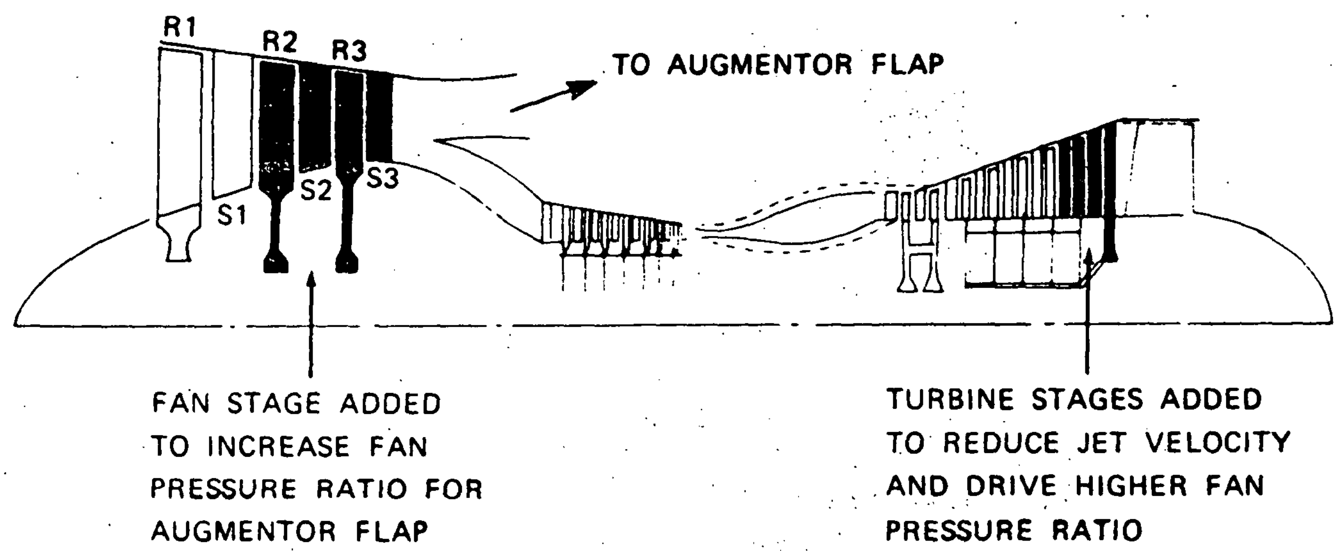


Fig. 6-13
D6-25476

AUGMENTOR-WING ENGINE
JET NOISE PERFORMANCE COMPARISON

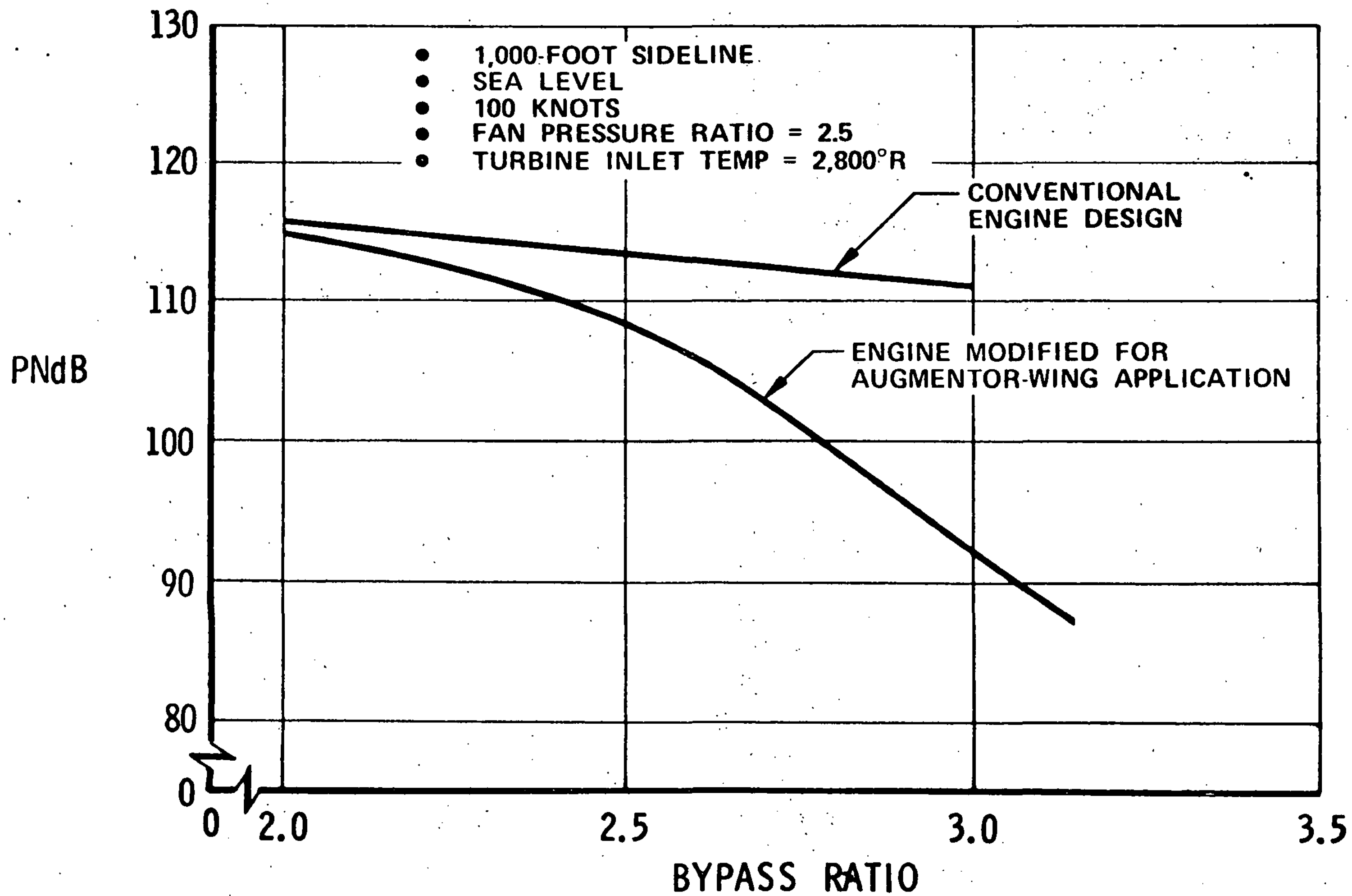
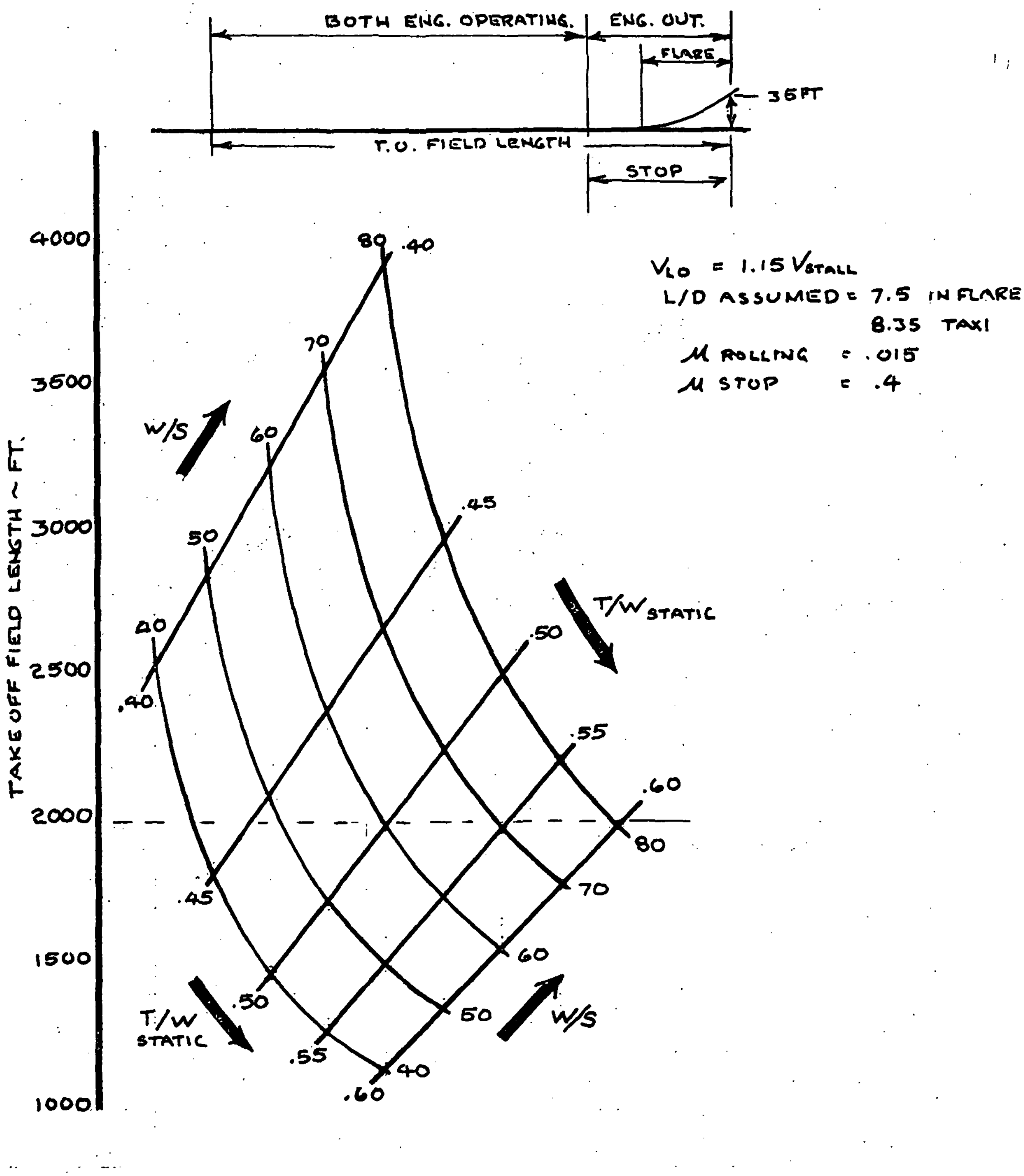


Fig. 6-14
D6-25476

P81-4799-8

AERODYNAMICS



R. LoKEN	8-1970	TAKE-OFF FIELD LENGTH	INTRA URBAN.
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STRUCTURES

SPECIFIC STRENGTH & MODULUS OF STRUCTURAL MATERIALS.

(1970 TO 1985 TIME PERIOD)

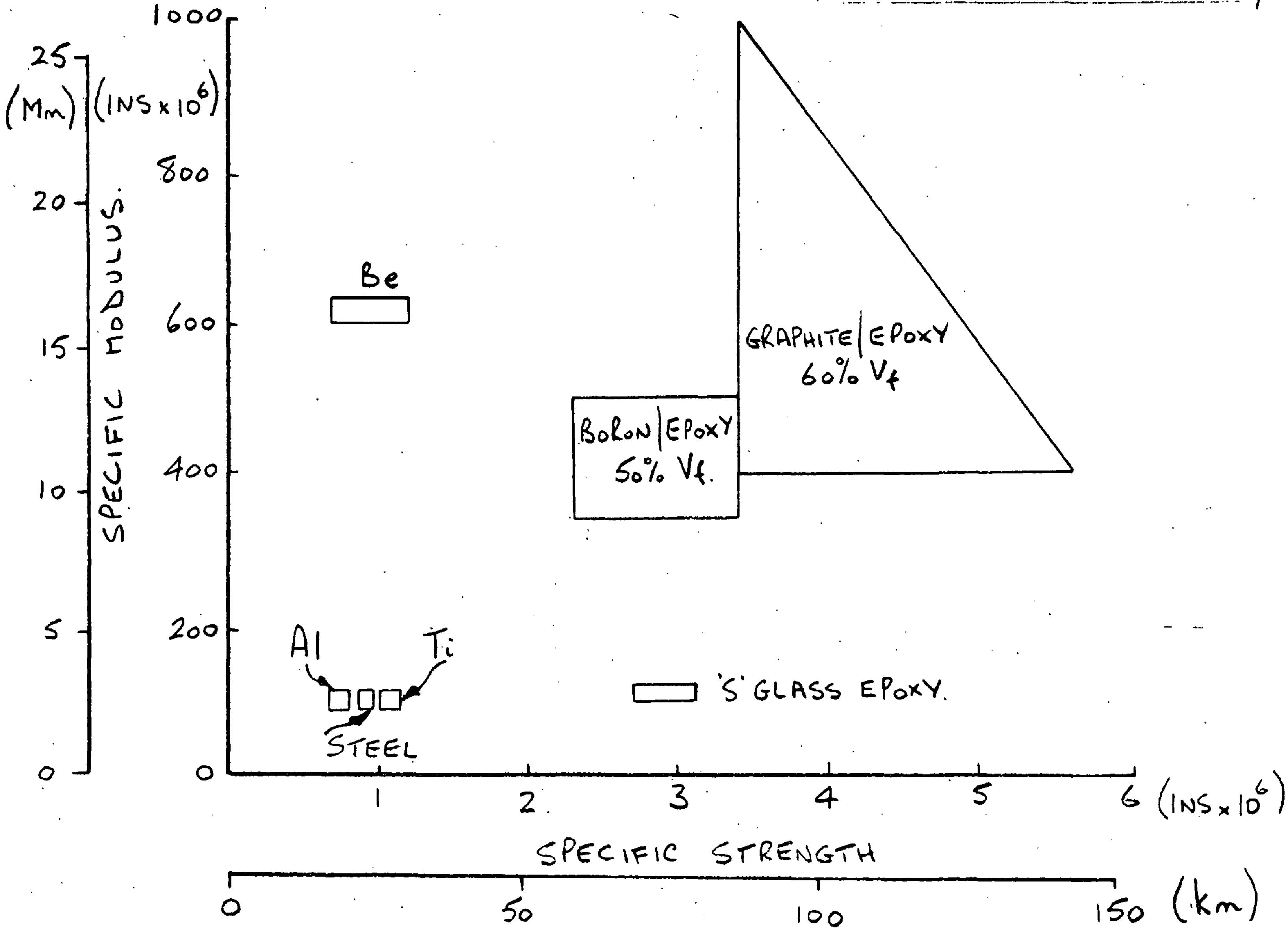


Fig. 6-18

D6-25476

GRAPHITE / EPOXY UTILIZATION

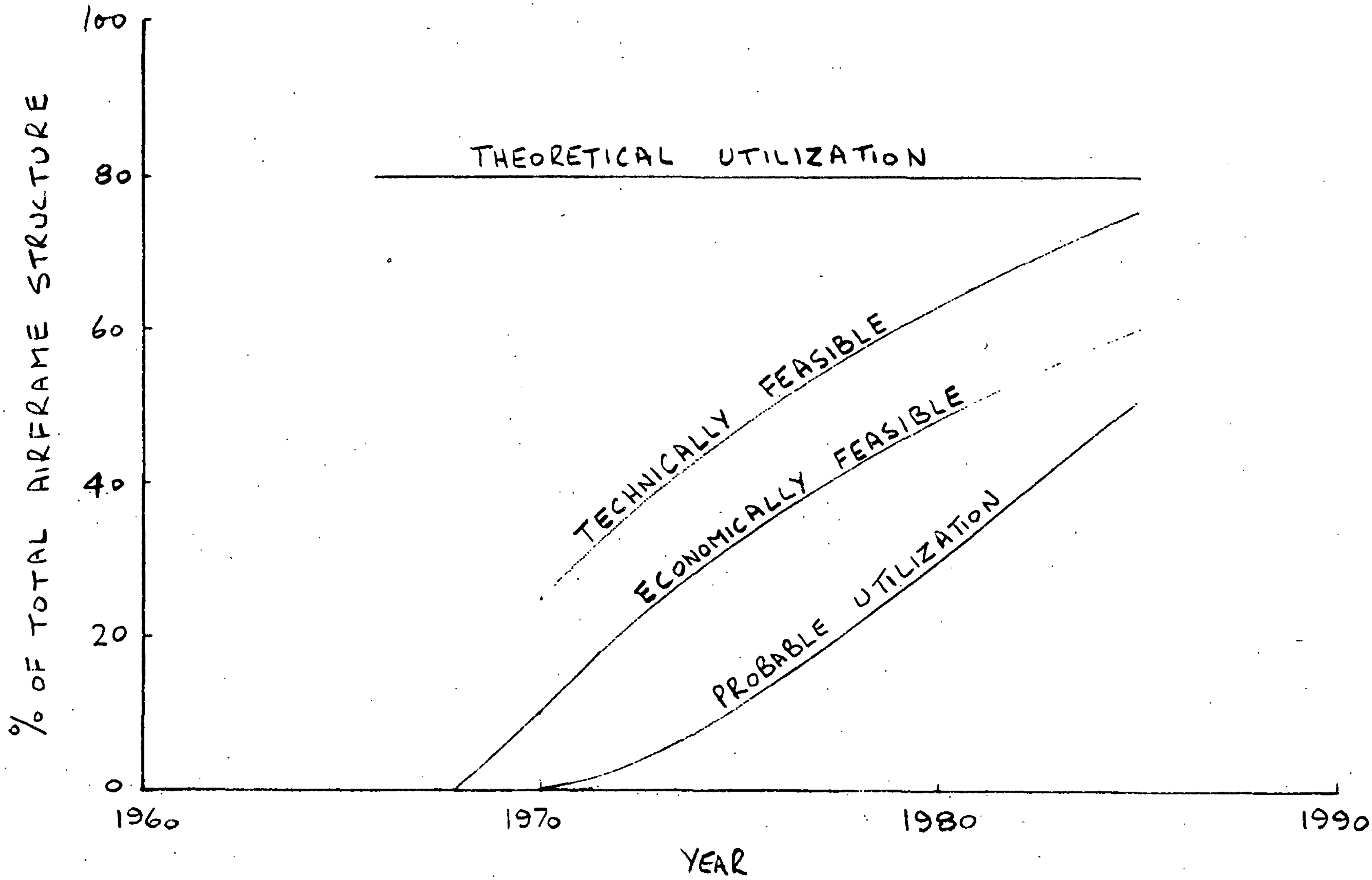


Fig. 6-23
D6-25476

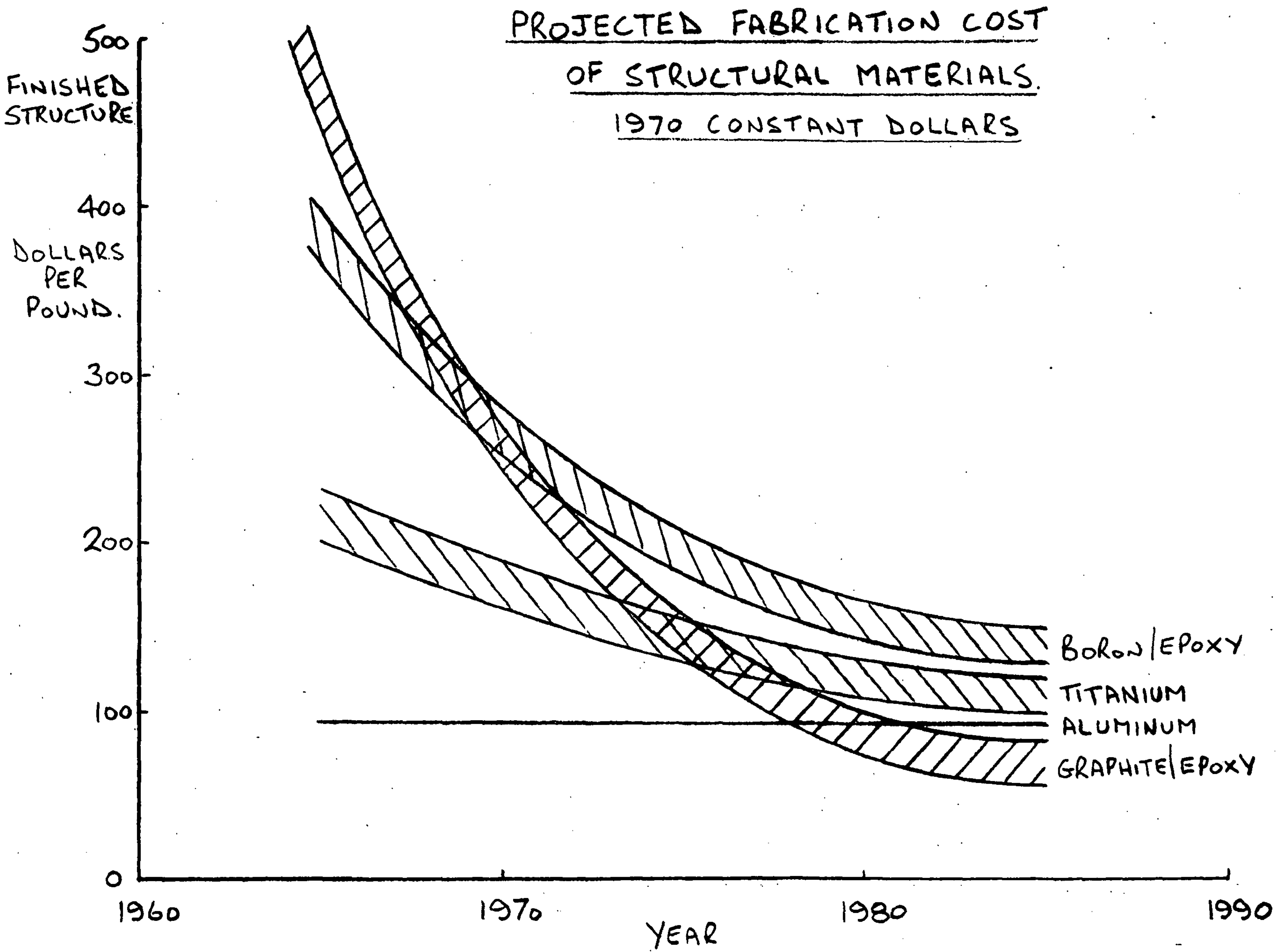


Fig. 6-24
D6-25476

NOISE

2. NOISE EXPOSURE FORECAST

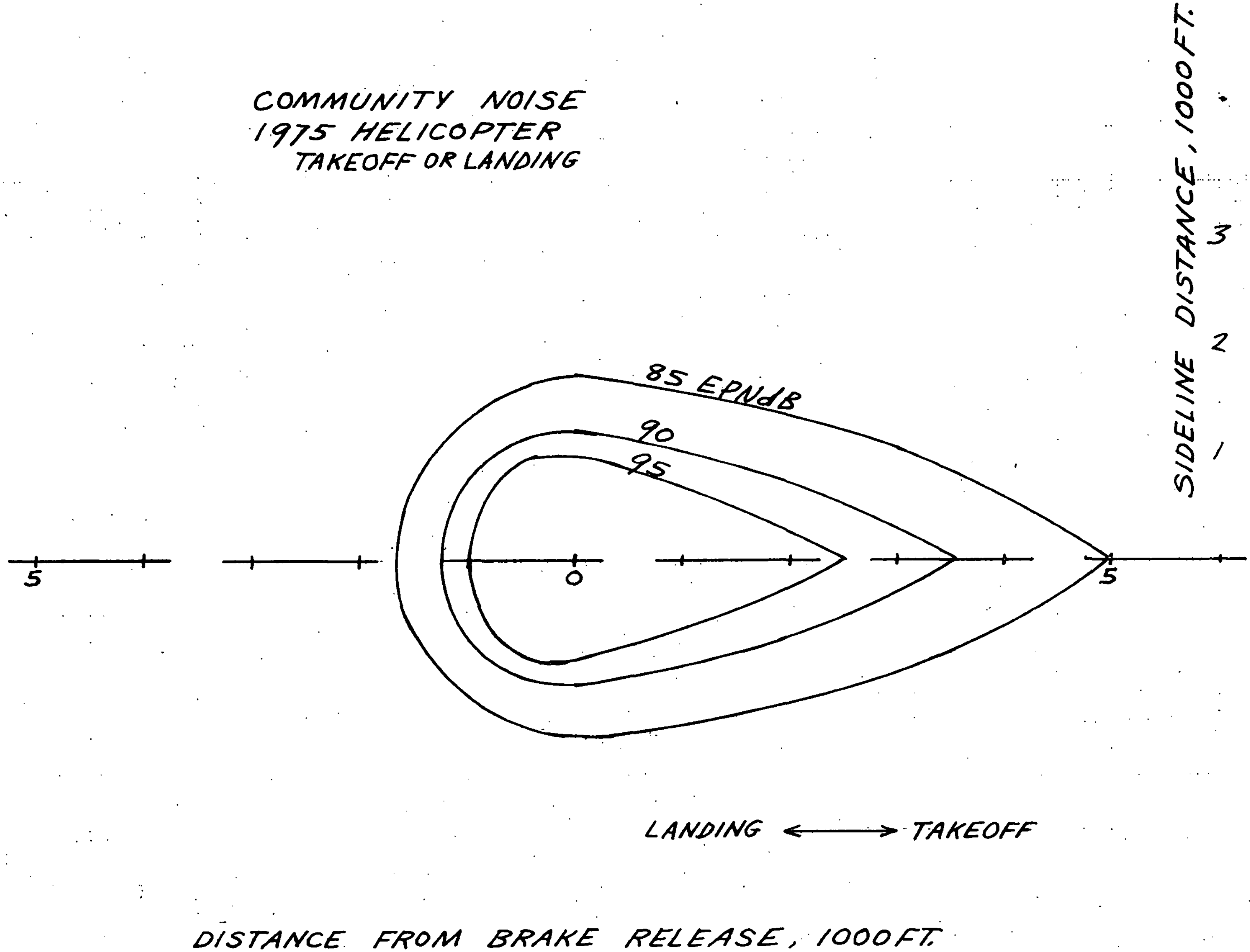
$$NEF = PNL_{EFF} + \Delta PNL_{OPS} - 75$$

$$NEF_A = PNL_{EFFA} + \Delta PNL_{OPS} - 75$$

$$NEF_A = PNL_{EFF} + \Delta PNL_A + \Delta PNL_{OPS} - 75 \quad \text{(APPROX.)}$$

48a1

COMMUNITY NOISE
1975 HELICOPTER
TAKEOFF OR LANDING



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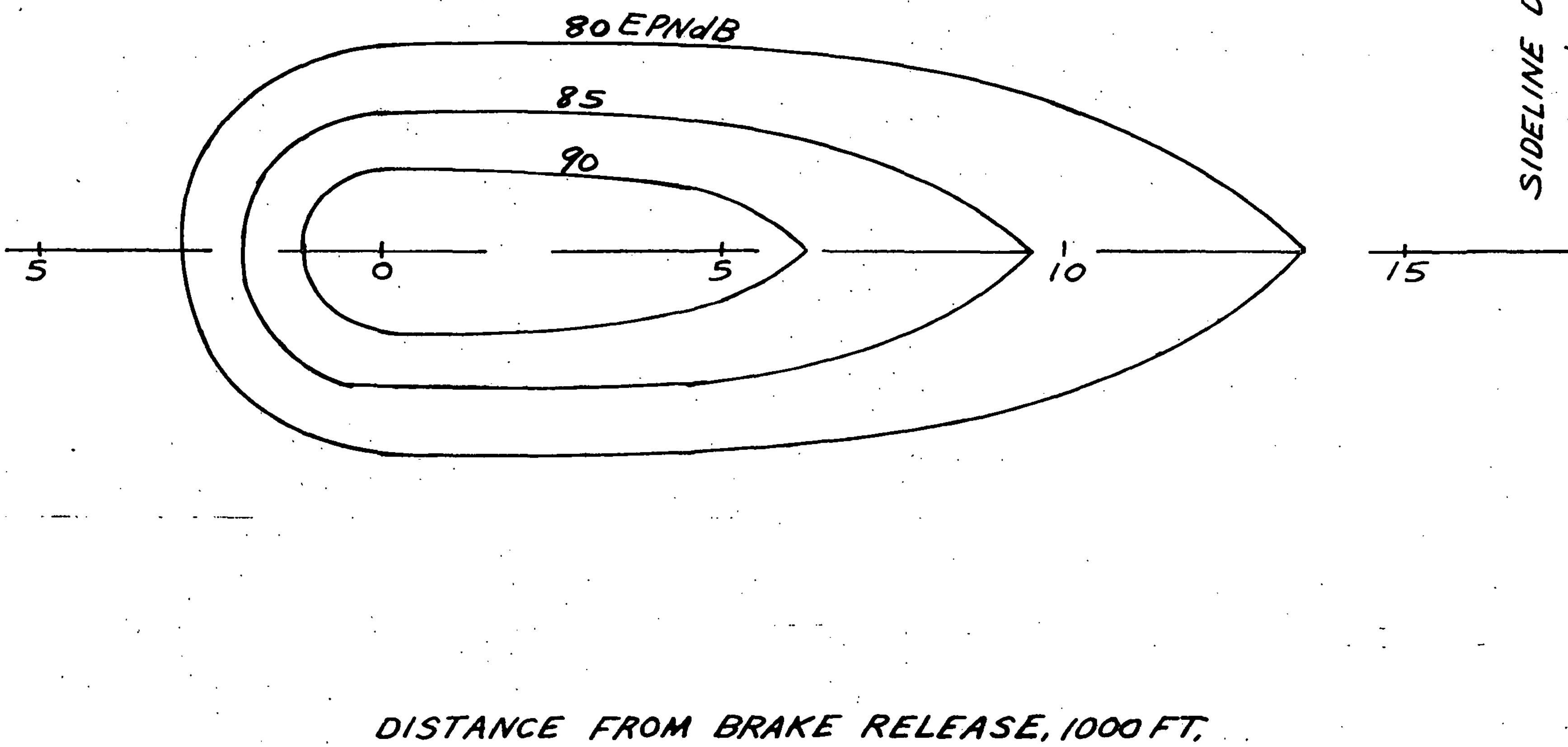
48(b)

COMMUNITY NOISE LEVEL
1975 AUGMENTOR WING
TAKEOFF, 100% F_N



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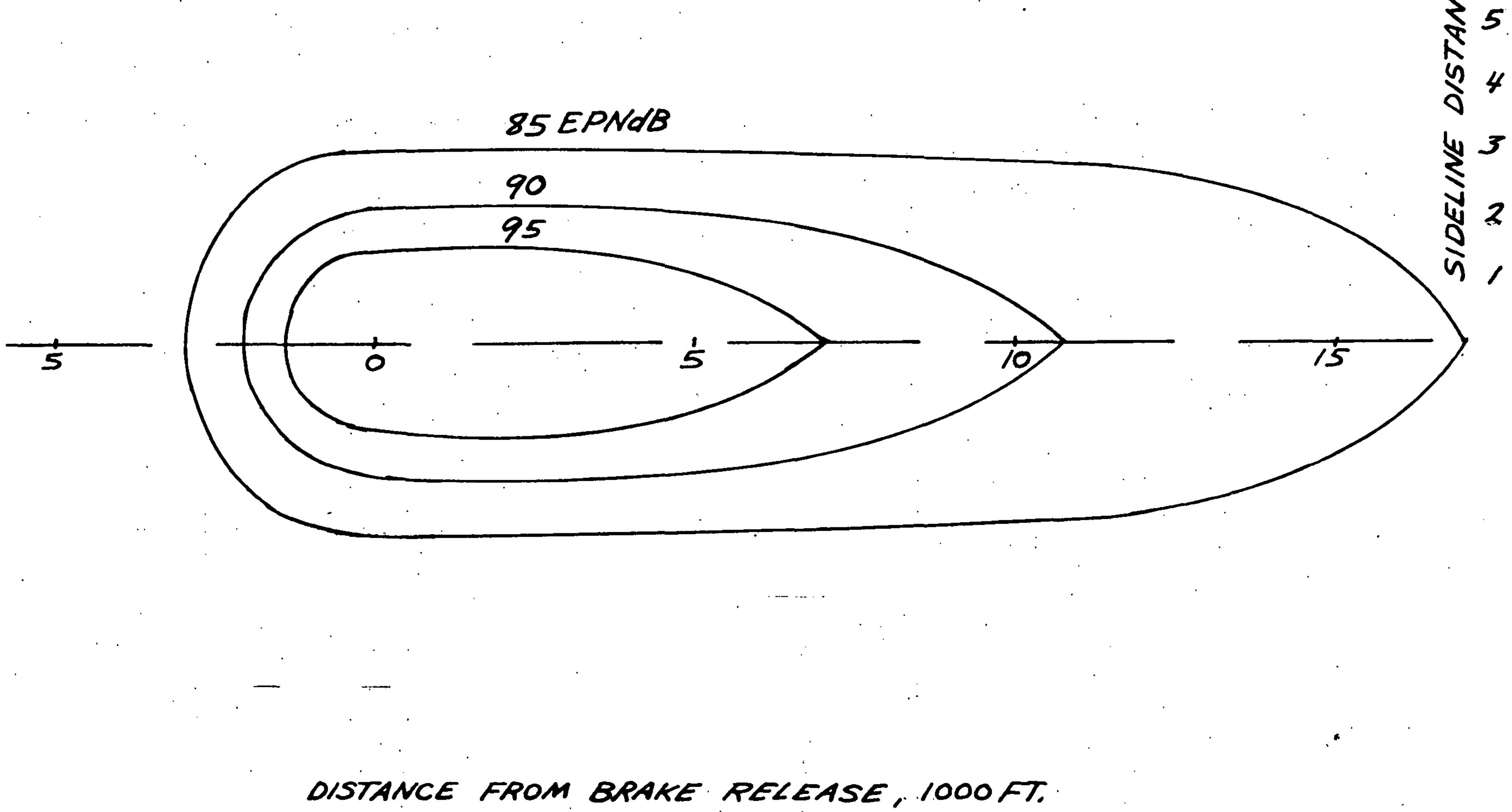
48(c)

COMMUNITY NOISE LEVEL
1975 CONVENTIONAL STOL
TAKEOFF, 100% F_N



COMMUNITY NOISE LEVEL
TAKEOFF, 100% F_N
C-STOL, TWO STF-362 ENGINES

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Loc	Name	PNL	PNL_A	PNL_A	OPS	PNL_{OPS}	NEF_A	Excess	
1	Off Shore Ferry Bldg.	95	95	-30	936	16	6		
2	Crissy Field	95	85	-20	244	11	11		
3	Mission Rock	95	85	-20	260	11	11		
4	Fort Funston	95	75	-13	99	7	14		
5	SF	95	95	-30	385	13	3		
6	San Carlos Airport	95	95	-30	552	14	4		
7	Palo Alto	95	70	-8	330	12	24	9	
8	Los Altos Hills	95	95	-30	334	12	2		
9	San Jose	95	85	-20	490	15	15		
10	Los Gatos	95	75	-13	98	7	14		
11	Reed Hill	95	65	-4	210	10	14	4	RES.
12	Morgan Hill	95	55	0	314	12	32	22	RES.
13	Livermore	95	55	0	142	8	28	18	RES.
14	Fremont	95	65	-4	376	13	29	19	RES.
15	Oakland Int'l	95	95	-30	380	13	3		
16	Oakland Al	95	75	-13	328	12	19	4	
17	Berkeley Bart	95	75	-13	52	9	16		
18	San Pablo	95	75	-13	50	16	23	8	
20	Buchanan	95	75	-13	240	11	18	3	
21	Antioch Field	95	75	-13	102	7	14		
24	Napa Co. Airp.	95	75	-13	102	7	14		
26	Cotati Nav. Air	95	75	-13	44	15	22	7	
29	Gnoss Field	95	75	-13	119	8	15		
30	Corte Madera	95	85	-20	98	7	7		

$NEF_A = PNL_{EFF} + PNL_A + PNL_{OPS} - 75$

Reference: Coord Sheet G-8580-70-169, August 10, 1970, "Noise Exposure Forecast Calculation," B. T. Hulse to W. C. Brown.

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48(d)

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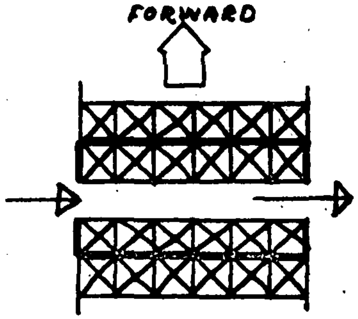
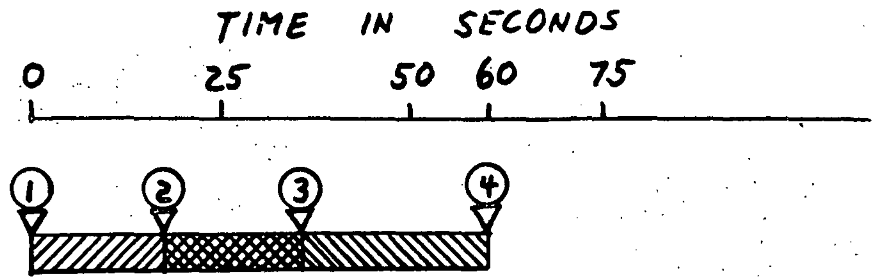
GROUND SYSTEMS

GROUND SERVICING FACILITIES

- BASIC CRITERIA TO MAXIMIZE PROFIT POTENTIAL
  - MINIMUM SERVICE TIME
  - MINIMUM GROUND SERVICE CREW
- NORMAL CTOL GROUND SERVICE ITEMS NOT REQUIRED BY INTRAURBAN VEHICLE
  - AIR CONDITIONING SERVICE
  - GROUND POWER SERVICE
  - GALLEY SERVICE
  - POTABLE WATER SERVICE
  - TOILET SERVICE
  - AIR START SERVICE
  - TOW TRACTOR
- REQUIRED INTRAURBAN VEHICLE GROUND SERVICE
  - PASSENGER HANDLING
  - BAGGAGE HANDLING (ONLY ON FLIGHTS TO OR FROM MAJOR AIR CARRIER AIRPORTS)
  - FUEL SERVICING

PASSENGER FLOW





- 95 PASSENGER CONFIGURATION
- 12 PASSENGERS / COMPARTMENT
- 8 DOORS EACH SIDE

① RIGHT DOOR OPENS, PASSENGERS DEPLANE

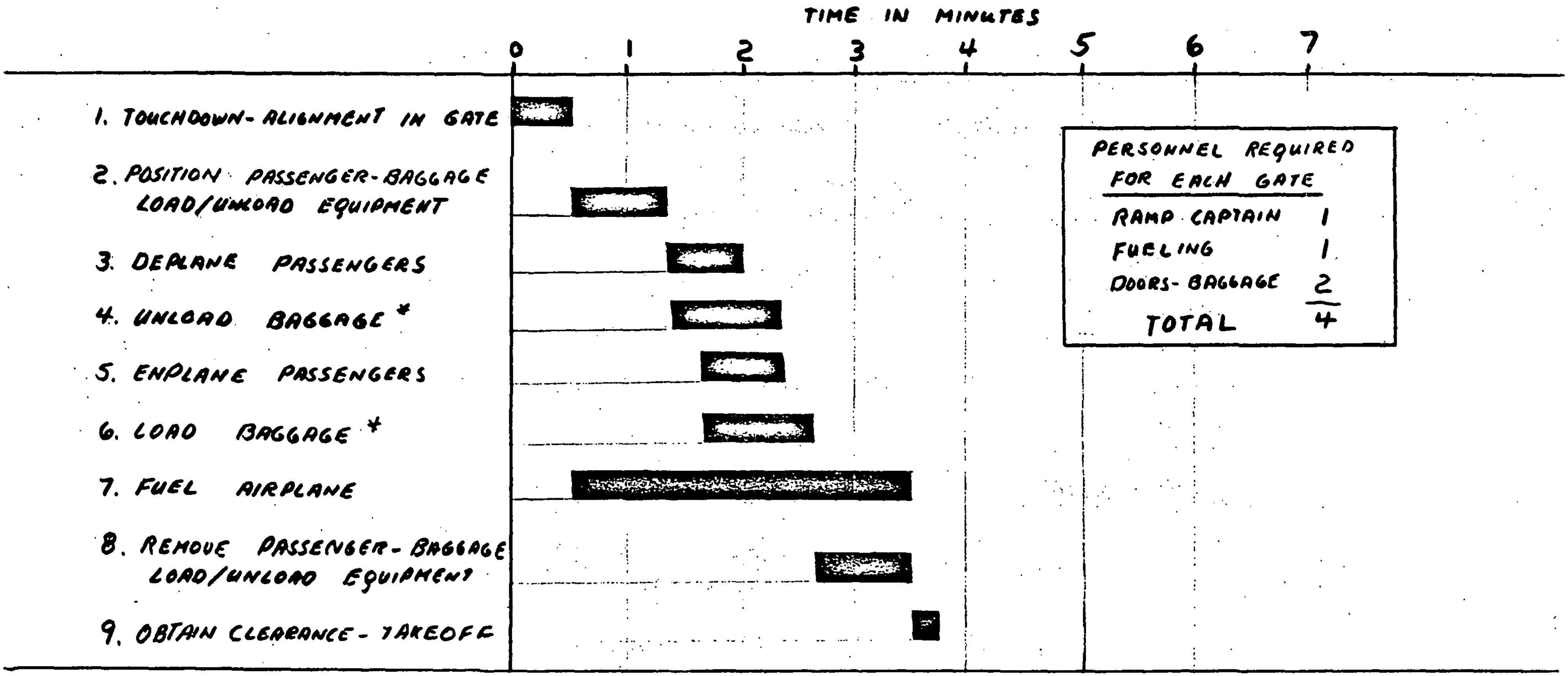
② LEFT DOOR OPENS, PASSENGERS ENPLANE

③ LAST PASSENGER OUT, RIGHT DOOR CLOSES

④ LAST PASSENGER IN, LEFT DOOR CLOSES

▨ PASSENGERS DEPLANING, ▩ PASS. DE AND ENPLANING, ▧ PASSENGERS ENPLANING

VTOL GROUND OPERATIONS
INTRAURBAN SYSTEM



PERSONNEL REQUIRED FOR EACH GATE	
RAMP CAPTAIN	1
FUELING	1
DOORS-BAGGAGE	2
TOTAL	4

* TO OR FROM HUB AIRPORT STOLPORT ONLY

- 100 PASSENGER VTOL
- ENGINES NOT STOPPED
- NO "WALK AROUND" INSPECTION
- VTOL LANDS AND TAKES OF AT GATE POSIT
- PASSENGER-BAGGAGE LOAD/UNLOAD EQUIPMENT ELEVATES FROM FLUSH WITH GATE SLAB TO ALONGSIDE EACH SIDE OF VTOL.
- 3000 LB FUEL ADDED VIA SEMIAUTOMATIC FUELING CONN. LOCATED ON FUSELAGE UNDERBODY.

STOLPORT AND VTOLPORT GATE REQUIREMENTS
INTRAURBAN SYSTEM

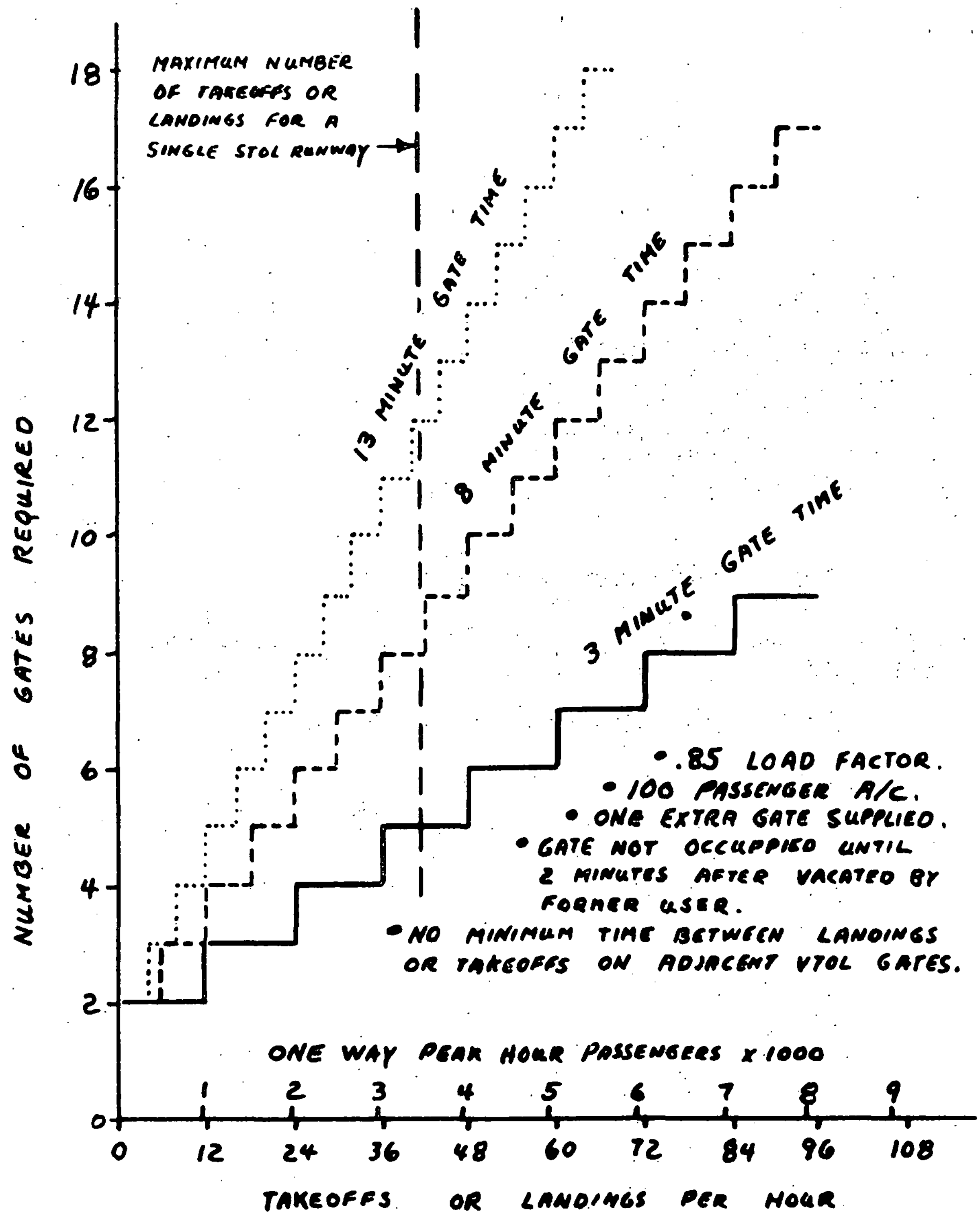


FIGURE 8-21

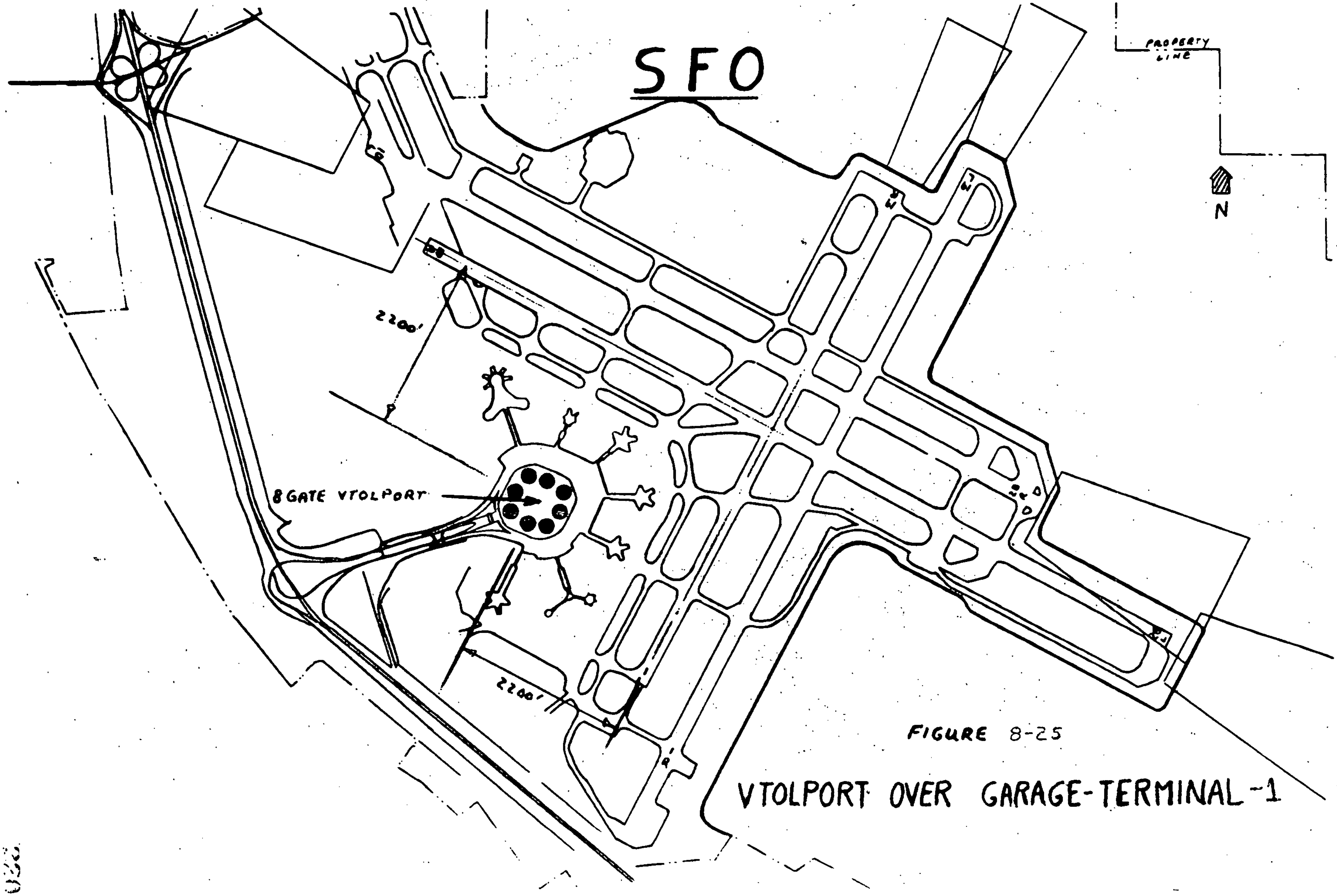


FIGURE 8-25

VTOLPORT OVER GARAGE-TERMINAL-1

AIR TERMINAL COST COMPONENTS

- LAND
- CLEAR ZONE AIR RIGHTS
- RUNWAYS AND TAXIWAYS (STOLPORTS ONLY)
- AIR VEHICLE PARKING APRONS
- AUTOMOBILE PARKING
- CONTROL TOWER AND GROUND AIR NAVIGATION EQUIPMENT
- ACCESS ROADS
- STRUCTURE
- PASSENGER TERMINAL
- FURNISHINGS, EQUIPMENT, AND UTILITIES
- A&E DESIGN FEE AND CONSTRUCTION CONTINGENCIES
- CLEARING, GRADING, DRAINAGE, AND DEMOLITION

AIR TERMINAL COST SUMMARY*

STOLPORTS ZONE NR	TERMINAL TYPE	NR. OF GATES	*COST	VTOLPORTS ZONE NR	TERMINAL TYPE	NR. OF GATES	*COST
1	C	16	348.0	1	F	16	86.5
2	A	5	38.6	2	F	5	32.4
3	C	5	94.5	3	F	5	31.6
4	B	2	37.4	4	F	2	17.4
5	D	4	53.5	5	G	4	12.4
6	A	7	19.6	6	E	7	11.8
7	A	5	16.0	7	E	5	9.6
8	B	5	18.0	8	E	5	9.5
9	A	8	18.3	9	E	8	12.0
10	B	3	15.0	10	E	3	7.6
11	A	4	14.2	11	E	4	8.4
12	A	5	14.8	12	E	5	9.1
13	A	3	13.6	13	E	3	7.7
14	B	6	19.5	14	E	6	10.5
15	D	7	54.8	15	G	7	17.8
16	C	6	76.3	16	F	6	35.3
17	B	2	26.4	17	E	2	8.2
18	B	4	21.1	18	E	4	9.3
20	A	6	17.4	20	E	6	10.6
21	A	3	13.1	21	E	3	7.6
22	B	2	16.3	22	E	2	6.8
24	A	3	14.0	24	E	3	7.8
26	A	3	13.2	26	E	3	7.6
29	A	4	15.2	29	E	4	8.8
30	B	4	26.3	30	E	4	10.0
		TOTAL	1015.1			TOTAL	396.3

*. 1980 costs in 1970 dollars in $million. See Para. 8.4.9.

FIGURE 8-41

AIR TRAFFIC CONTROL

TIME-SYNCHRONIZED ATC CONCEPT

ATC ASSIGNS FLIGHT PATHS

<u>FLIGHT PATH REQUIREMENTS</u>

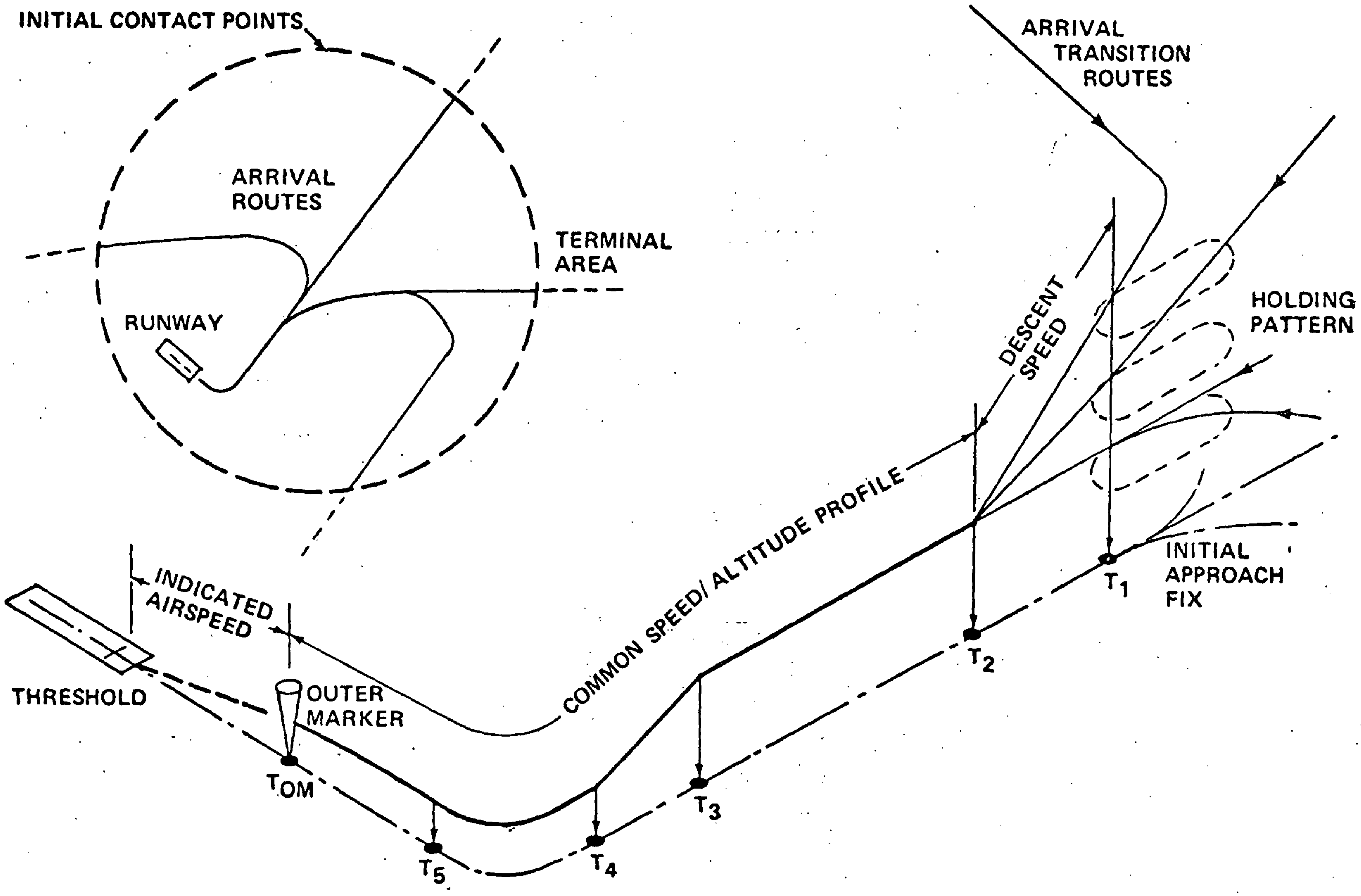
- CONTINUOUSLY DEFINED IN TERMS OF HORIZONTAL POSITION, ALTITUDE AND TIME
- NONCONFLICTING
- PROVIDE SEQUENCING AND SPACING
- EFFICIENT USE OF AIRSPACE
- MINIMAL FLIGHT PENALTIES

AIRCRAFT FLY ASSIGNED FLIGHT PATHS

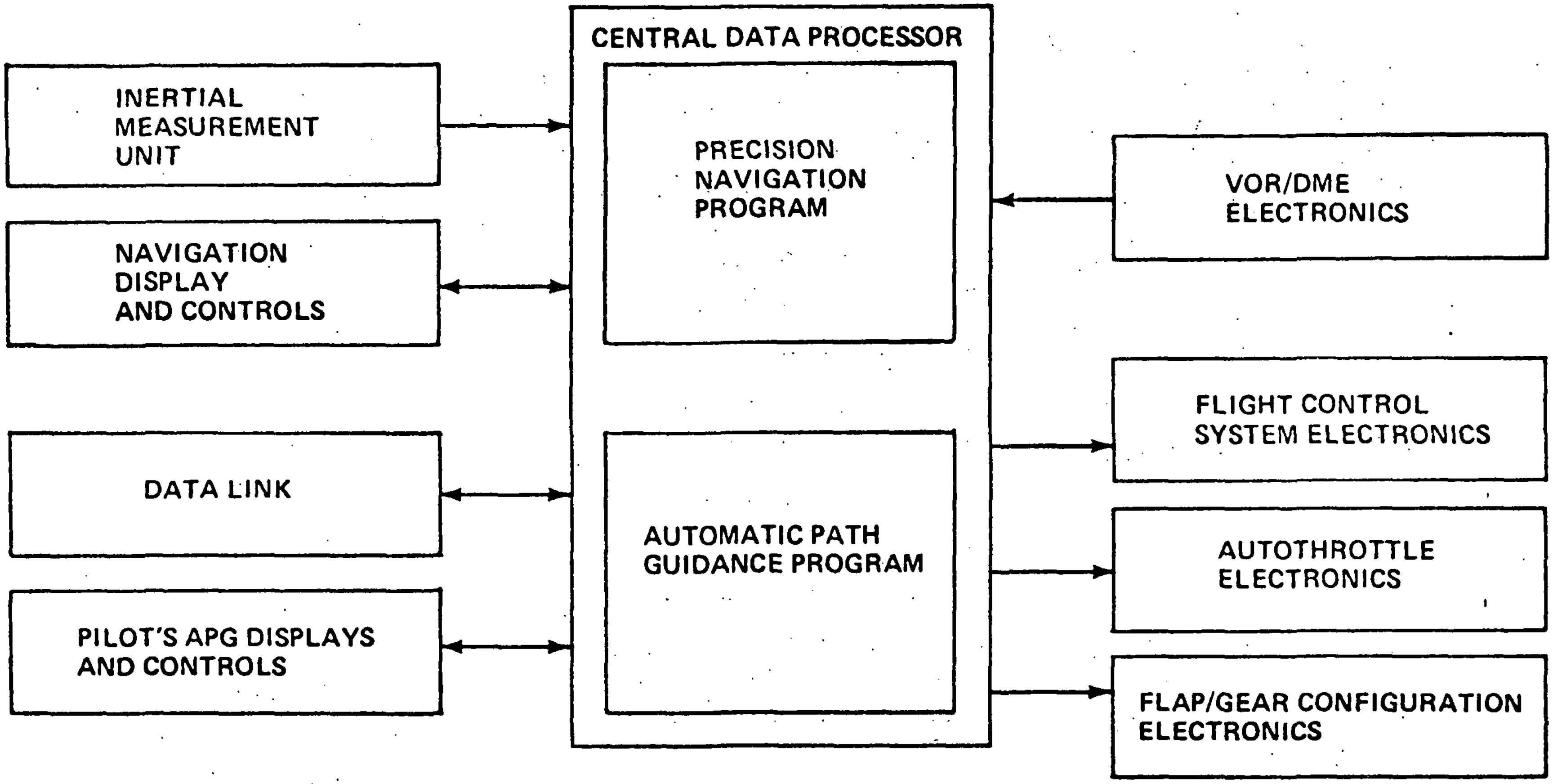
<u>FLIGHT CONTROL REQUIREMENTS</u>

- POSITION VS. TIME TO AN ACCURACY SMALL COMPARED TO DESIRED SPACING

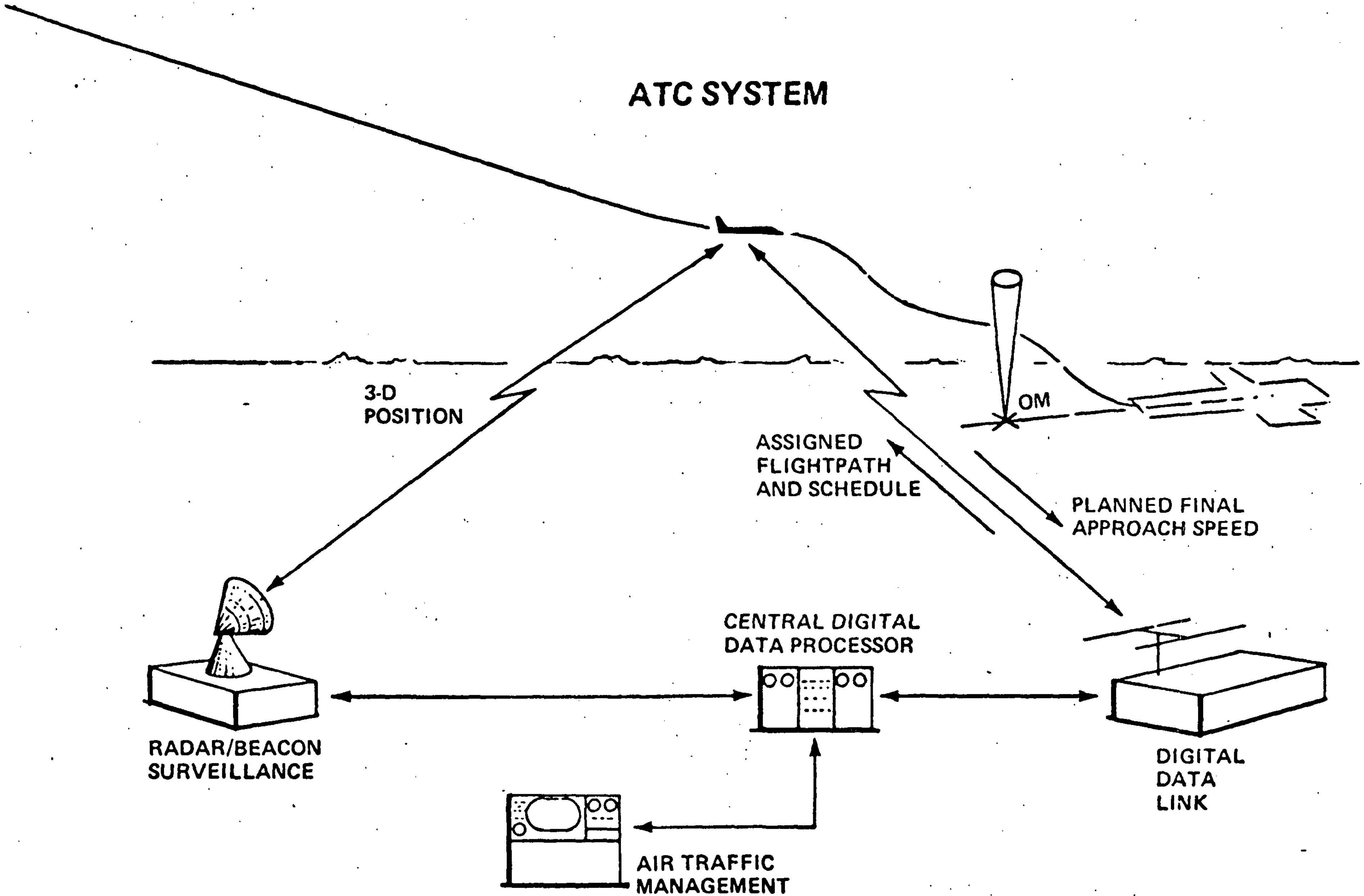
TIME-SYNCHRONIZED APPROACH CONTROL CONCEPT

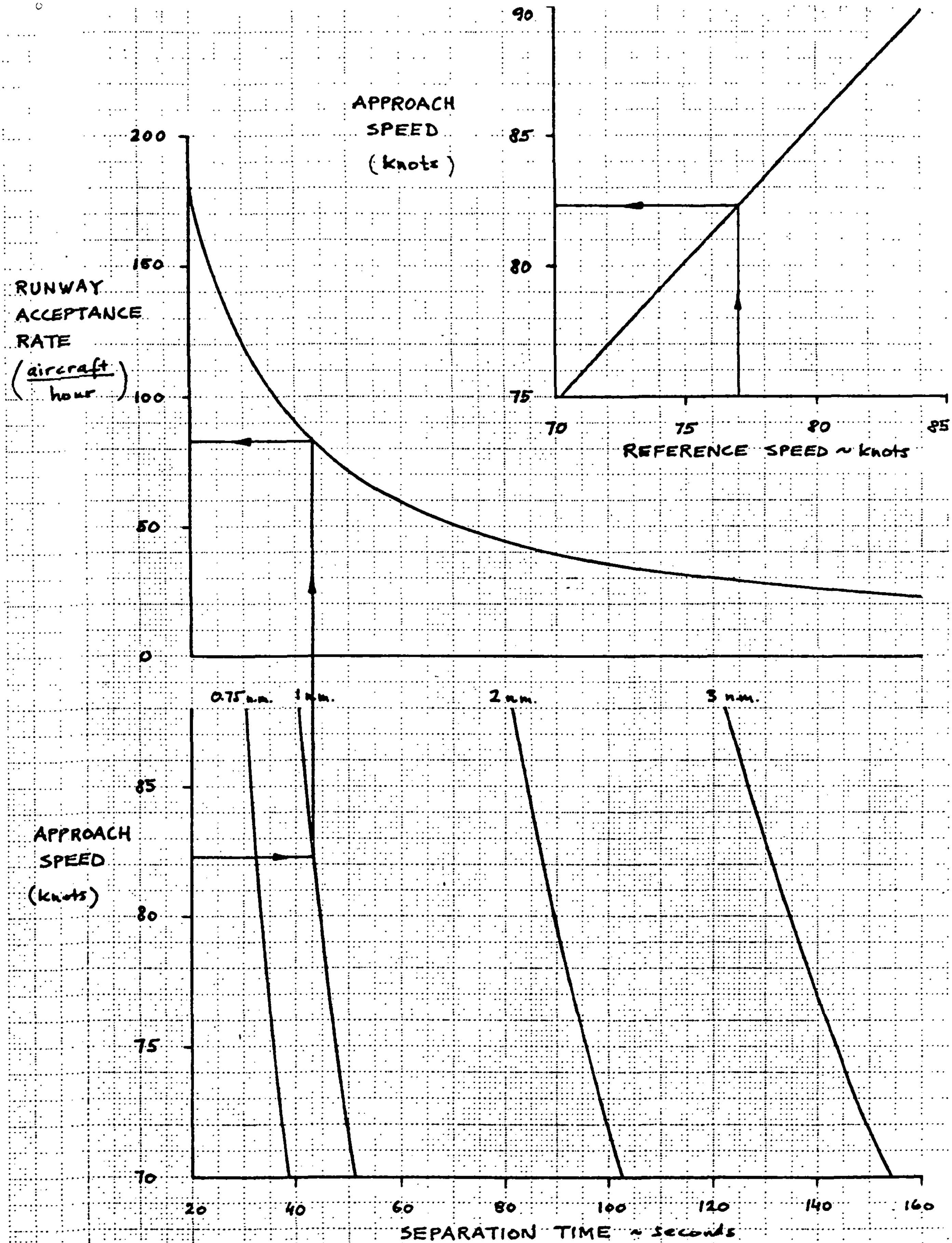


AIRCRAFT SYSTEM



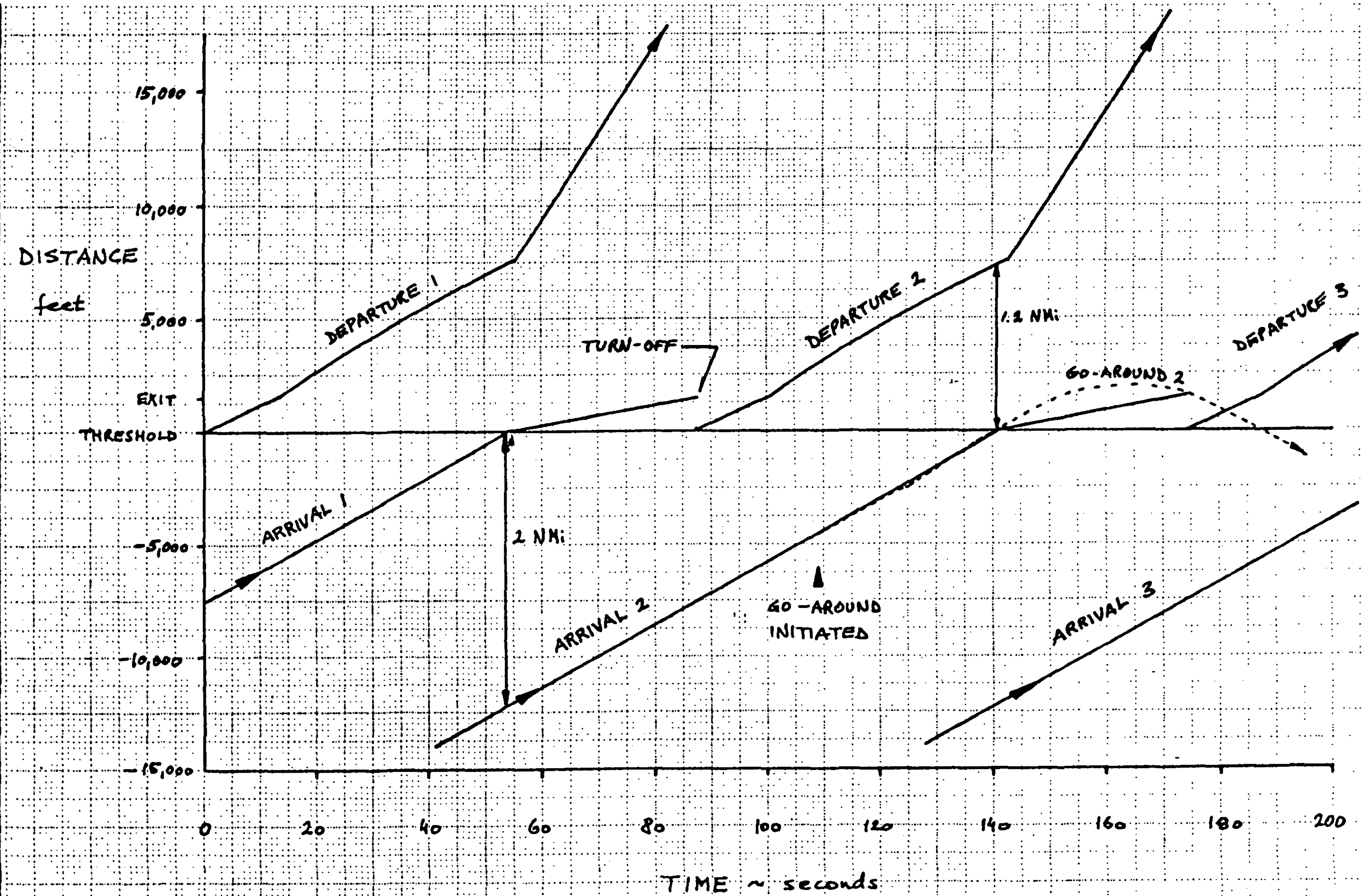
ATC SYSTEM


3-D
POSITION
ASSIGNED
FLIGHTPATH
AND SCHEDULE
OM
PLANNED FINAL
APPROACH SPEED
CENTRAL DIGITAL
DATA PROCESSOR
RADAR/BEACON
SURVEILLANCE
DIGITAL
DATA
LINK
AIR TRAFFIC
MANAGEMENT



			REVISED	DATE	RUNWAY ACCEPTANCE RATE VS. REFERENCE SPEED
CALC					
CHECK					
APR					
APR					THE BOEING COMPANY

#63



CALC
CHECK
APR
APR
REVISED
DATE

2 NMi ARRIVAL-ARRIVAL SEPARATION
DISTANCE VS. TIME

THE BOEING COMPANY

OPERATING COSTS

CASH DIRECT OPERATING COST

CREW COST

- 2 MEN CREW
- 5 DAY WEEK, 4-1/2 TO 7-1/2 HOURS/DAY *
- CREW PAY - DOLLARS/YEAR - 1970 PAY SCALE

  INCLUDE

  CAPTAIN

  FIRST OFFICER

  WELFARE, PAYROLL TAXES, TRAINEES, INSTRUCTORS, ETC.

  TOTAL

  4-1/2 HOURS/DAY - $33,000/YEAR

  7-1/2 HOURS/DAY - $52,000/YEAR

- DOLLARS/BLOCK HOUR = $\frac{\text{CREW PAY - DOLLARS/YEAR}}{\text{CREW BLOCK HOURS}}$

  4-1/2 HOURS/DAY - 51.00/BLOCK HOUR

  7-1/2 HOURS/DAY - 46.00/BLOCK HOUR

* FAA AND ALPA MAXIMUM HOURS ARE NOT OBSERVED

DIRECT MAINTENANCE

AIRFRAME SYSTEMS

METHODOLOGY

KNOWN CONVENTIONAL AIRCRAFT COSTS BY SYSTEM X V/STOL FACTORS* = V/STOL AIRCRAFT COSTS, BY SYSTEM

RATIONALE

- BASIC AIRFRAME SYSTEMS ARE GROUPED BY TYPE OF FUNCTION. FUNCTIONS ARE RELATIVELY UNCHANGED.
- COSTS DETAILED BY AIRFRAME FUNCTIONAL SYSTEMS ENABLE COMPREHENSIVE ANALYSIS
- LEVEL OF CONVENTIONAL AIRCRAFT SYSTEM COSTS DEVELOPED FROM REPORTED FORM 41 REGRESSION ANALYSIS

* TAKING INTO ACCOUNT PRICES AND QUANTITY OF MAINTAINABLE ITEMS, TECHNOLOGY, ACCESSIBILITY, OPERATING ENVIRONMENT, DESIGN CRITERIA, ETC.

DIRECT MAINTENANCE

ENGINE

METHODOLOGY

RECORDED ENGINE COST X FACTOR* = ENGINE COSTS

RATIONALE

- CONSIDERS ENVIRONMENTAL AS WELL AS DESIGN FACTORS
- RECOGNIZES SIMILARITY TO EXISTING ENGINES
- ENGINE TECHNOLOGY IS REPRESENTATIVE OF CURRENT FAN ENGINE DESIGNS WHICH HAVE PREDICTABLE MAINTENANCE AND OPERATING COST CHARACTERISTICS.

* NEW TECHNOLOGY, OPERATING ENVIRONMENT

ALLOCATED INVESTMENT COST - DIRECT

- DEPRECIATION -

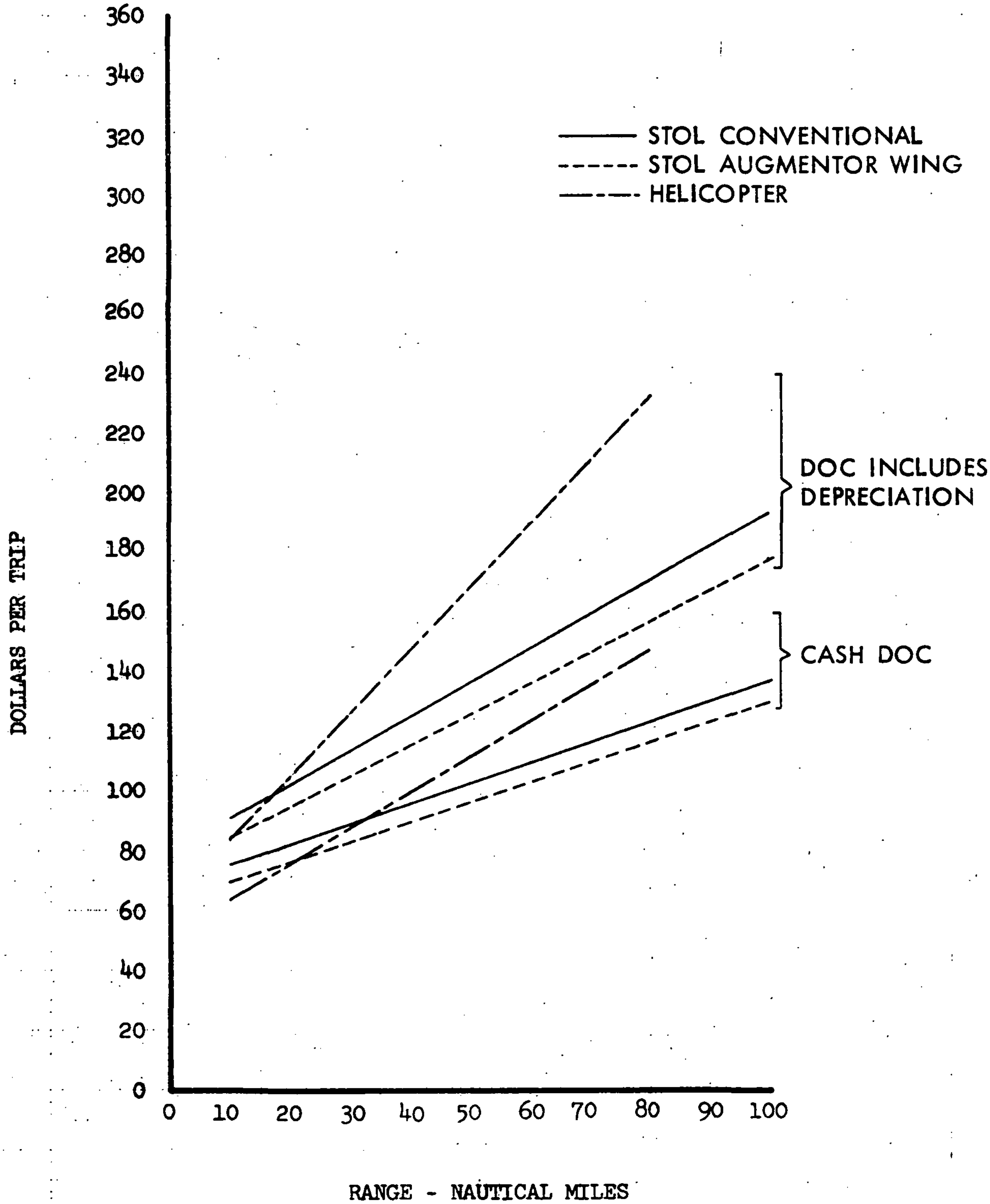
  AIRFRAME AND ENGINE - 10 YEARS TO 15% RESIDUAL

- INITIAL SPARES -

  AIRFRAME - 4%

  ENGINE - 20%

DIRECT OPERATING COST
$/TRIP VS. RANGE - NAUTICAL MILES
1975



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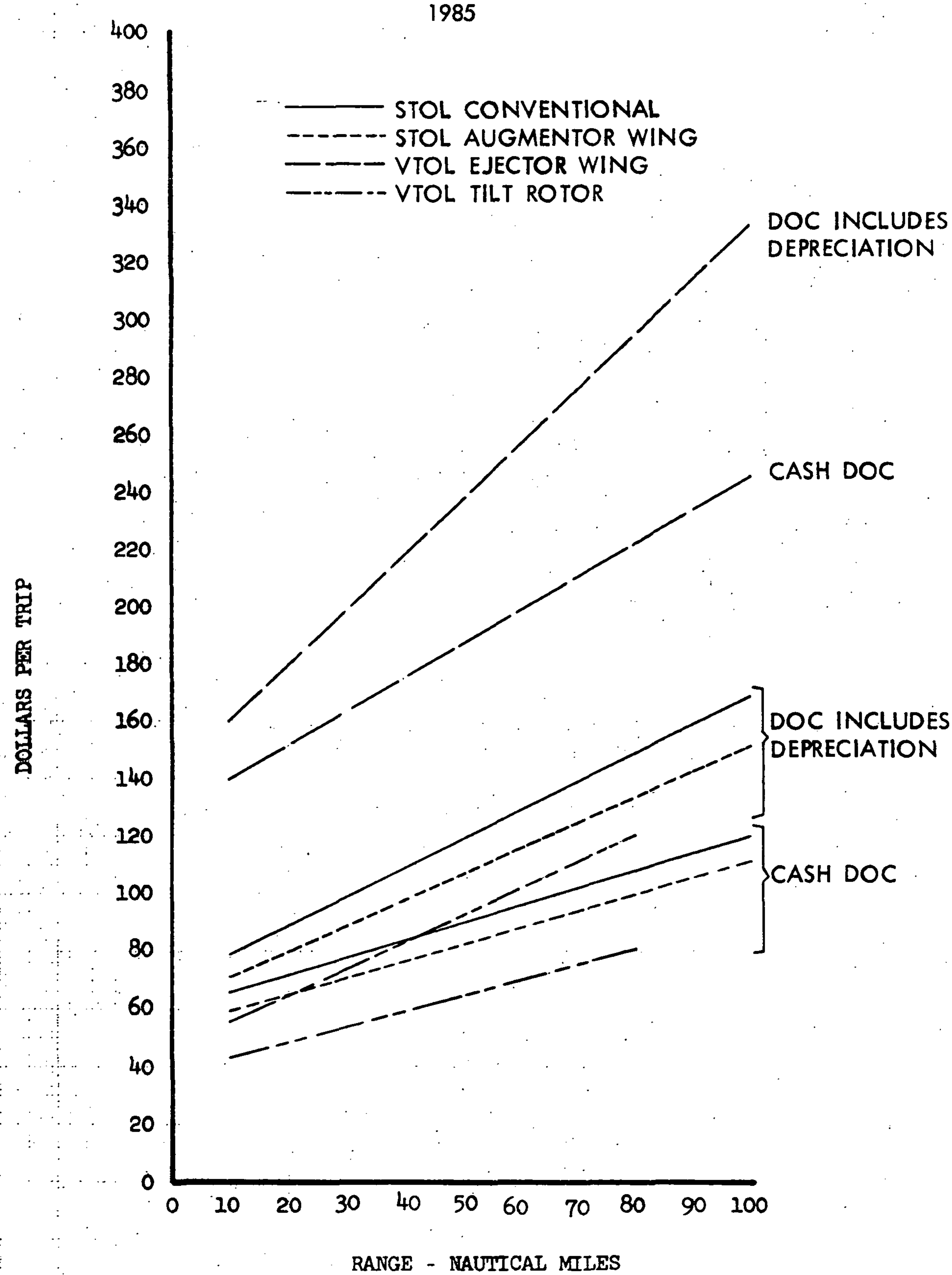
DIRECT OPERATING COST
$/TRIP VS RANGE - NAUTICAL MILES
1985



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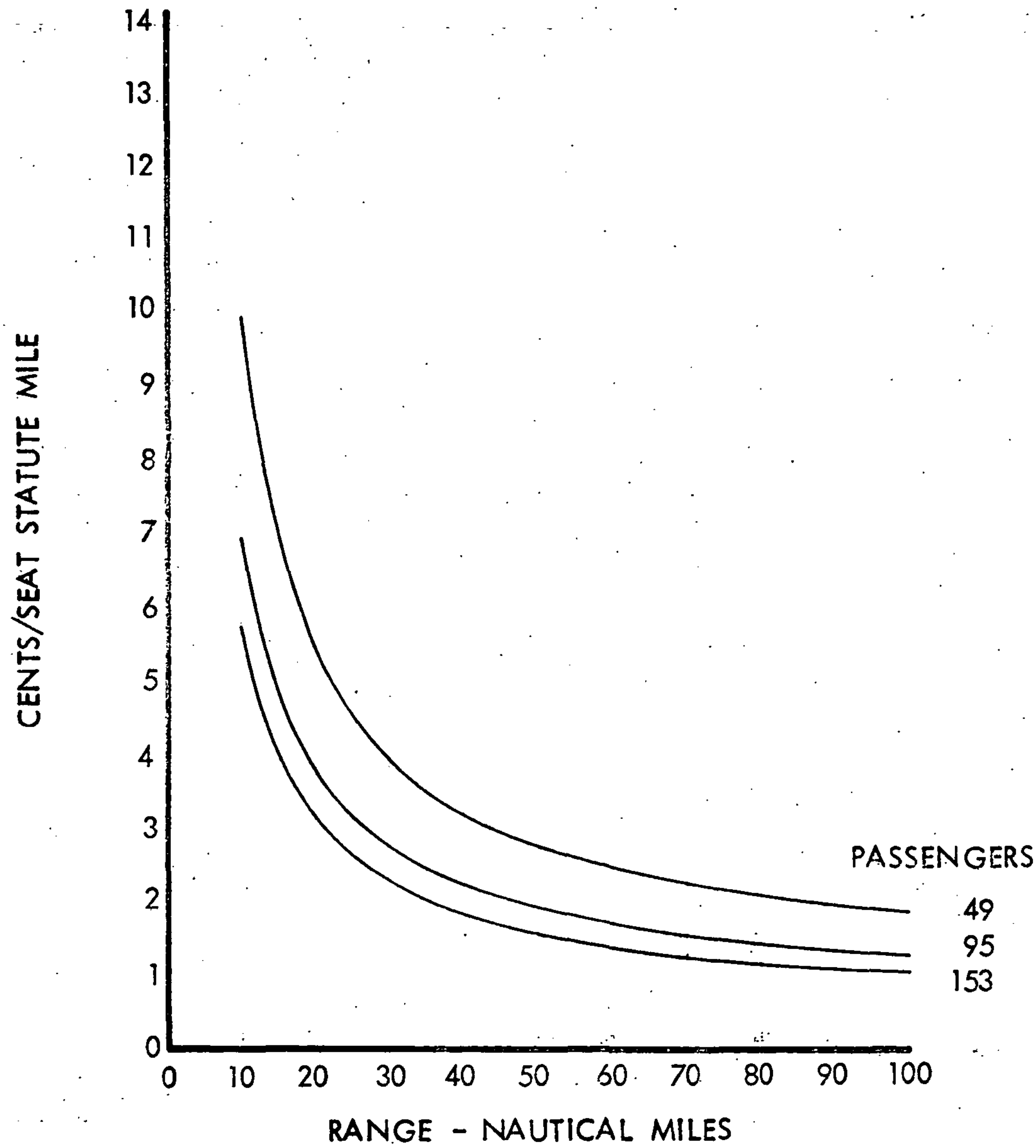
CASH DIRECT OPERATING COST
CENTS/SEAT STATUTE MILE VS. RANGE NAUTICAL MILES
STOL CONVENTIONAL AIRPLANE
1975



CALC			REVISED	
CHECK				
APR				
APR				

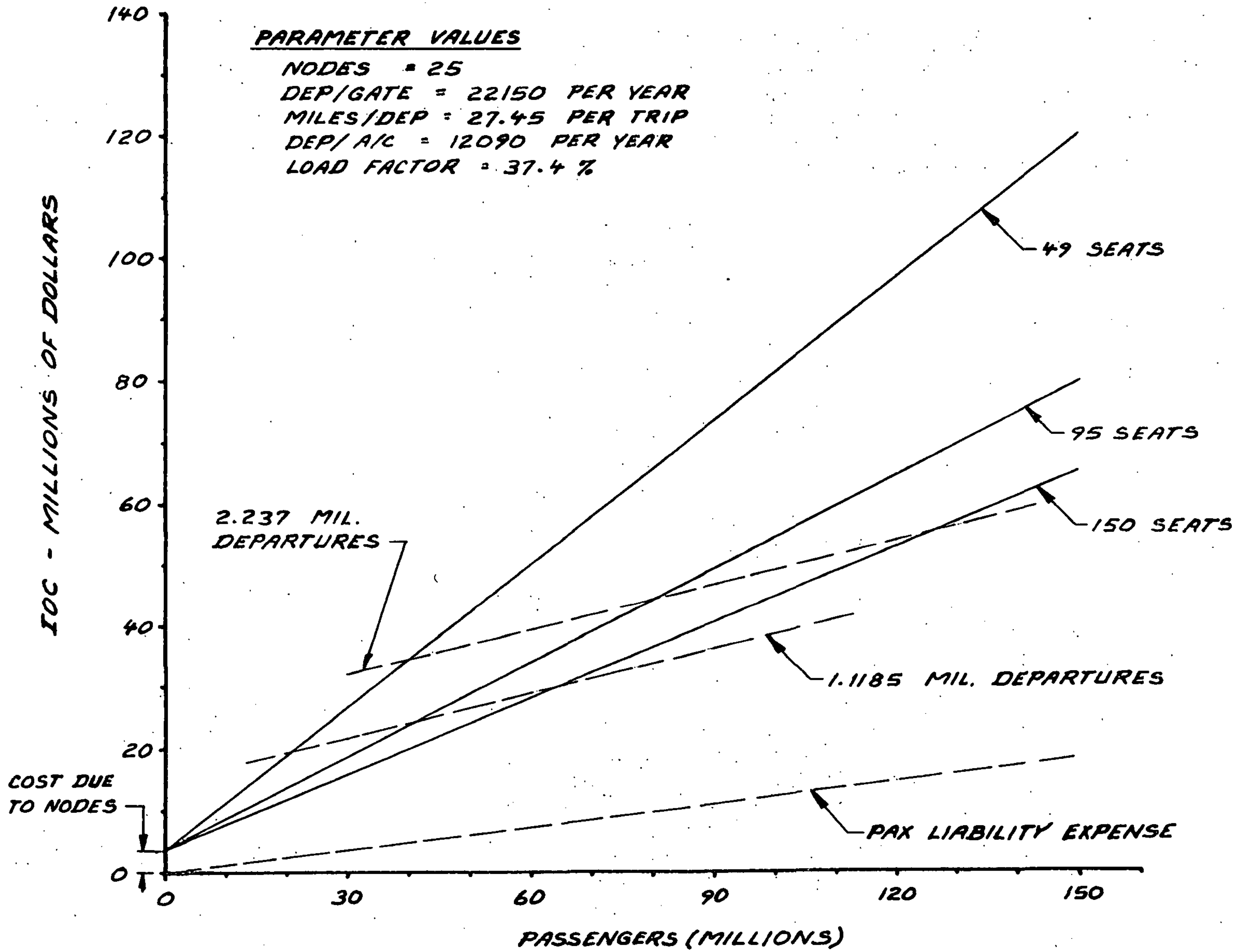
SUMMARY OF STOL IOC COMPONENTS

COST CATEGORY	NODES	DEPARTURES (Millions)	GATES	MILES FLOWN (Millions)	FLEET SIZE	DEPARTURES⊗SEATS (Millions)
A/C Servicing	.058705		.097842		.002446	
Traffic Servicing	.04202		.0010130 (1+.04(seats))			
Servicing Admin.	.015255		.013868		.000347	
General & Admin.	.0286		.026		.00065	
Ground Facility		2.7		.0175		.0403
Passenger Liability Expense						.125(LF)
TOTAL IOC	.14458	2.7	.138723	.0175	.003443	.0403+.125(LF)

$$IOC = .14458(\text{nodes}) + 2.7(\text{departures}) + .138723(\text{gates})$$
$$+ .00004052(\text{seats})(\text{gates}) + .0175(\text{miles flown})$$
$$+ .003443(\text{fleet size}) + .0403(\text{departures})(\text{seats})$$
$$+ .125(LF)(\text{Seats})(\text{Departures})$$

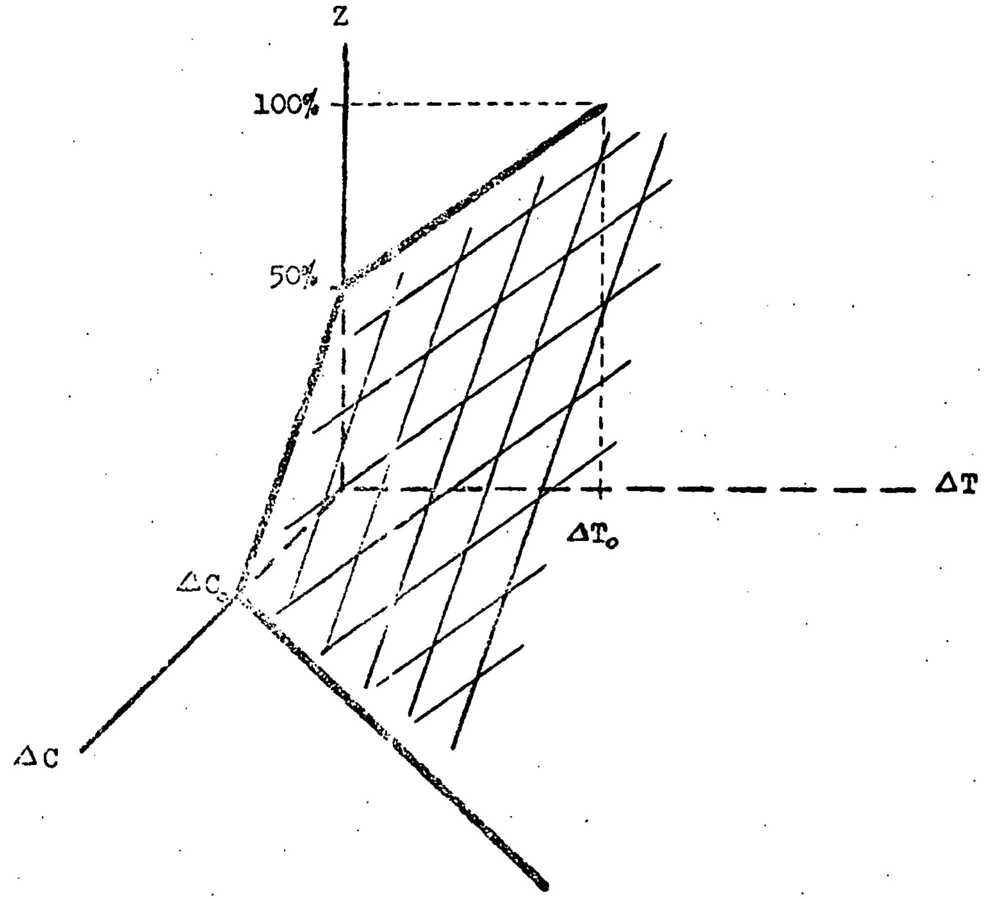
IOC is in millions of dollars

IOC COST CURVES FOR A LOAD FACTOR OF 37.4%



SYSTEM ANALYSIS

MODE SPLIT



Z = PERCENT PERSONS DIVERTED TO STOL FROM EXISTING MODE

ΔC = NEW MODE DOOR-TO-DOOR O/W TRIP COST MINUS EXISTING MODE COST

ΔT = EXISTING MODE DOOR-TO-DOOR O/W TRIP TIME MINUS NEW MODE TIME

PRELIMINARY MODE SPLIT INTERCEPTS

IN CONSIDERATION OF A NEW MODE OF TRAVEL VS. AN EXISTING MODE,

1. WHERE DOOR-TO-DOOR TRIP TIMES ARE EXACTLY EQUAL, NOBODY WOULD TAKE NEW MODE IF ITS COST EXCEEDED EXISTING MODE'S COST BY $2 OR MORE.

2. WHERE DOOR-TO-DOOR TRIP COSTS ARE EXACTLY EQUAL, EVERYBODY WOULD TAKE NEW MODE IF THEY SAVED AT LEAST 30 MINUTES OF TRIP TIME.

NETWORK ANALYSIS BASIC APPROACH

1. USE DEMAND MODEL TO CALCULATE DEMAND FOR AIR SERVICE BETWEEN 870 SUPERZONE PAIRS.

2. RUN NETWORK MODEL TO PRODUCE SCHEDULE FOR SEGMENTS WHICH HAVE ONE WAY DEMANDS OF AT LEAST 250 PAX PER DAY.

3. PERFORM ECONOMIC EVALUATION BASED UPON ACTUAL SCHEDULES.

DEMAND MODEL

* INPUT

(1) 291 X 291 MATRIX OF DAILY TRAVEL DEMAND BETWEEN 291 ANALYSIS ZONES.

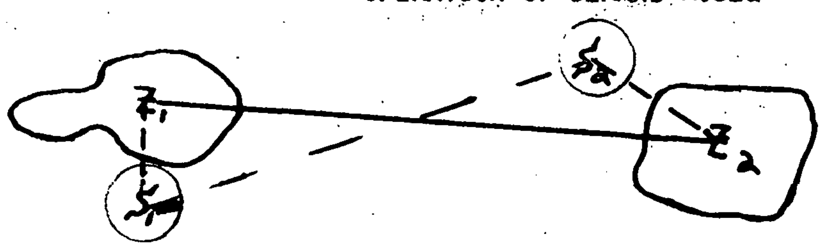
(2) CENTROIDS OF THE 291 ZONES.

(3) LOCATIONS OF STOL PORTS.

* OUTPUT

DAILY DEMAND FOR AIR MODE BETWEEN ALL STOL PORT PAIRS.

OPERATION OF DEMAND MODEL



FOLLOWING PROCESS IS FOLLOWED FOR ALL 291 X 291 ZONE PAIRS:

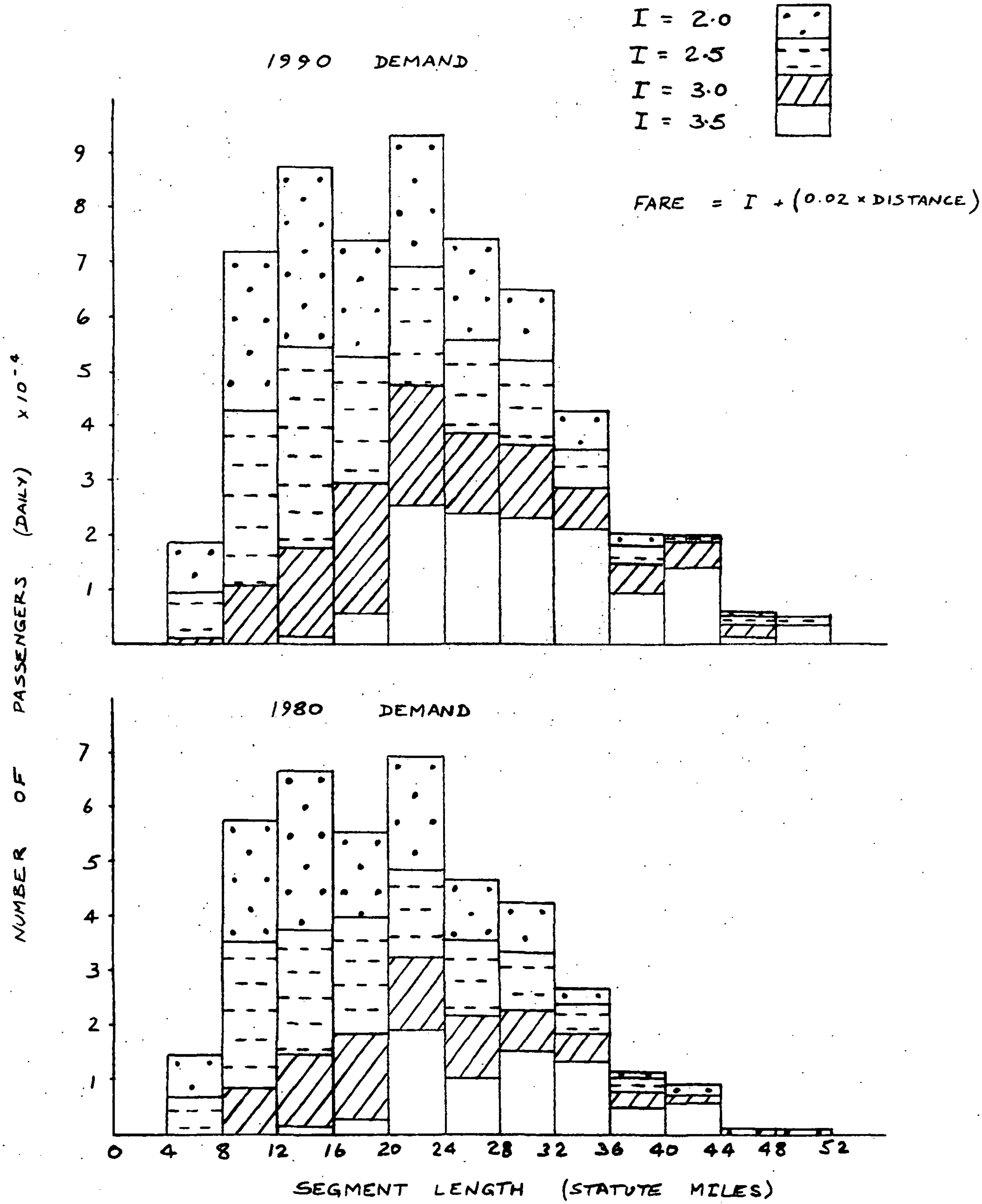
(1) FIND S_1 AND S_2, NEAR STOL PORTS Z_1 AND Z_2, RESPECTIVELY.
(Z_i = CENTROID OF ZONE i)

(2) COMPUTE TIME AND COST TO TRAVEL Z_1 Z_2 BY AUTO

(3) COMPUTE TIME AND COST TO TRAVEL:

- Z_1 S_1 BY AUTO
- S_1 S_2 BY AIR
- S_2 Z_2 BY TRANSIT

(4) USE MODE SPLIT EQUATION WITH VALUES FOUND IN 2 AND 3 TO GET PERCENT OF DEMAND DIVERTED TO AIR MODE. MULTIPLY THIS PERCENTAGE BY TOTAL DEMAND FROM Z_1 TO Z_2 TO GET AIR DEMAND. ACCUMULATE ALL SUCH DEMANDS FOR EACH STOL PORT PAIR TO GET TOTAL AIR DEMANDS BETWEEN ALL STOL PORTS.


1990 DEMAND
I = 2.0
I = 2.5
I = 3.0
I = 3.5
FARE = I + (0.02 × DISTANCE)
NUMBER OF PASSENGERS (DAILY) × 10⁻⁴
1980 DEMAND
SEGMENT LENGTH (STATUTE MILES)
0 4 8 12 16 20 24 28 32 36 40 44 48 52

TRANSPORTATION NETWORK MODEL

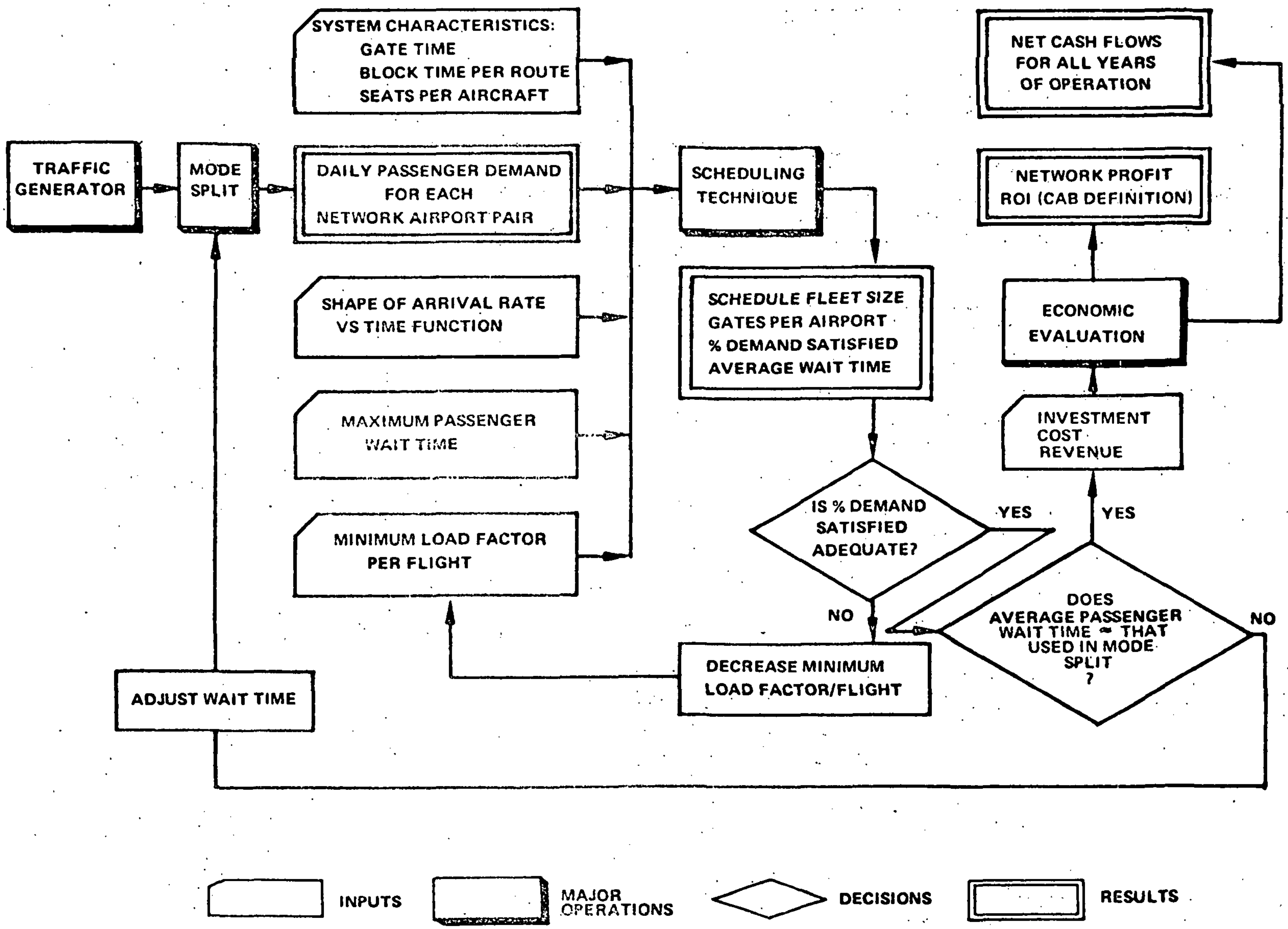


FIGURE 3.

D6-24296

REV SYM

TABLE 11.4-6

RESULTS OF NETWORK MODEL (1990)

1985 AIRCRAFT		PERSON TRIPS VIA AIR MODE		(1) SYSTEM PARAMETERS	
TYPE	NO. SEATS	(2) ANNUAL (MILLIONS)	(3) % OF ALL MODES	FLEET SIZE	GATES
CONVENTIONAL STOL	95	59.1	2.4%	150	106
AUGMENTOR WING STOL	95	58.5	2.4%	165	101
TILT ROTOR VTOL	100	59.2	2.4%	148	103
EJECTOR WING VTOL	95	59.2	2.4%	143	105
HELICOPTER	98	58.5	2.4%	172	105

(1) Based on 1990 passenger demand
(2) Assumes 314 equivalent operating days per year
(3) Based on 2,444,000,000 annual inter-terminal area person-trips by all modes in 1990
(Note that on p. 50, Ref. 11-1, 1990 annual Bay Area person-trips = (314)(18,471,000) = 5,800,000,000).

REV SYM

TABLE 11.4-8

*REQUIRED INITIAL INVESTMENTS (1985)

1985 AIRCRAFT		INITIAL INVESTMENTS (MILLIONS 1970 $)			
		(1)	(2) AIR TERMINALS		
TYPE	NO. SEATS	AIRCRAFT	LAND	FACILITIES	TOTAL
CONVENTIONAL STOL	95	316	123	757	1196
AUGMENTOR WING STOL	95	275	117	721	1113
TILT ROTOR VTOL	100	334	23	312	669
EJECTOR WING VTOL	95	575	24	317	916
HELICOPTER	98	388	24	317	729

(1) Includes 20% engine spares and 4% airframe and electronic spares
(2) Based on average STOLport cost of $8.3M per gate, average VTOLport cost of $3.25M per gate (See Figure 8-41), and the average ratio of land cost to total cost of .14 and .07 for, respectively, STOLports and VTOLports (See Section 8.0).

*1985 investment for an air transportation system which would accommodate 1980 passenger demand.

REV SYM

TABLE 11.4-9

1990 ANNUAL SYSTEM LOSSES (MILLIONS OF 1970 $)

1985 Aircraft Type	No. Seats	8% Interest Cost On Total Investment	*Sinking Fund Deposits (1) Operating Loss	(2) Aircraft and Spares	(3) Terminal Facilities	Total
Conventional STOL	95	96	5	20	21	142
Augmentor Wing STOL	95	89	-11 (Profit)	18	20	116
Tilt Rotor VTOL	100	53	-52 (Profit)	22	8	31
Ejector Wing VTOL	95	73	196	37	9	315
Helicopter	98	58	-18 (Profit)	25	9	74

(1) Does not include depreciation charges against aircraft or terminals
(2) 10 year life; salvage value = 15% of initial cost; interest rate = 6% compounded annually
(3) 20 year life; salvage value = 0; interest rate = 6% compounded annually

*Capital recovery accumulation to be re-invested in asset replacements

TABLE 11.4-10

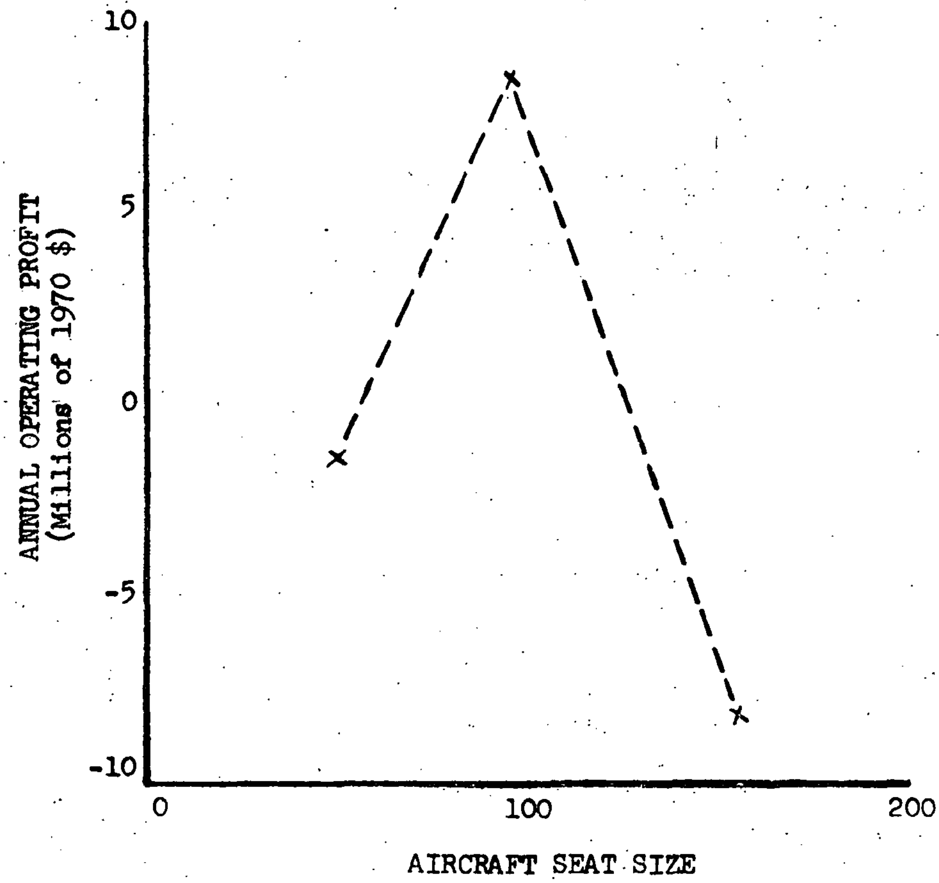
1990 ANNUAL SYSTEM LOSSES (1970 DOLLARS)

Type	No. Seats	Loss Per Person in 1990 Bay Area Population	Loss Per Person 18 Years of Age and Over	Loss Per Air Person-Trip
Conventional STOL	95	$18.90	$29.60	$2.40
Augmentor Wing STOL	95	15.50	24.20	2.00
Tilt Rotor VTOL	100	4.10	6.40	0.50
Ejector Wing VTOL	95	42.00	65.60	5.30
Helicopter	98	9.90	15.50	1.30

(1) 1990 Population = 7.5 Million (p. 43, Ref. 11-1)
(2) In 1966, the population ratio of 18 years and over to total in U.S. was 126.2M/198.6M = 64%
(See p. 262, 1968 World Almanac).

FIGURE 11.4-1

1980 OPERATING PROFIT
VS.
SEAT SIZE
FOR TOLERANCE TIME = 20 MINUTES



APPLICATION RESULTS

BASE CASE

	49 SEAT		95 SEAT	
FLEET SIZE	80		62	
AVERAGE LOAD FACTOR	.36		.22	
MEAN DAILY UTILIZATION	5.92		5.81	
TOTAL FLIGHTS (DAILY)	3,143		2,412	
NBR. FERRY FLIGHTS	216		183	
PAX CARRIED	52,252	(92%)	48,417	(85%)
MEAN PASSENGER WAIT TIME (MINUTES)			9.43	
DAILY RPM	1,398,808		1,290,696	
TOTAL GATES REQUIRED	58		47	
TOTAL DAILY DOC	$219,843.55		$219,524.95	
TOTAL DAILY IOC	$59,519.57		$54,626.06	
TOTAL DAILY REVENUE	$184,732.14		$171,063.52	
TOTAL DAILY LOSS	$94,630.99		$103,087.49	

EFFECTS OF FARE LEVEL

FARE = $3 + I * RANGE

1980 DEMAND, 9 MIN. AVE. WAIT TIME, 49 SEAT AIRCRAFT

	I = .02	I = .03	I = .05
TOTAL DAILY DEMAND	36,954	27,293	9,113
PERCENT CARRIED	91	88	83
NUMBER OF SEGMENTS	39	32	11
NUMBER OF STOL PORTS	20	19	11
FLEET SIZE	56	41	14
MEAN DAILY UTILIZATION	5.76	6.0	6.26
NUMBER OF DAILY FLIGHTS	2,087	1,585	513
MEAN LOAD FACTOR	.348	.329	.323
DAILY OPERATING LOSS	$71,114	$62,684	$24,523
LOSS PER PAX	$2.11	$2.61	$3.24

EFFECTS OF GATE TIME

1980 DEMAND, 9 MIN. AVE. WAIT TIME, 49 SEAT AIRCRAFT

FARE = $3 + .02 * RANGE

	GATE TIME		
	3 MIN.	8 MIN.	13 MIN.
TOTAL PAX CARRIED	33,499	34,103	33,885
FLEET SIZE	56	71	86
MEAN LOAD FACTOR	.348	.346	.336
MEAN DAILY UTILIZATION	5.76	4.62	3.91
NUMBER OF DAILY FLIGHTS	2,087	2,148	2,194
DAILY DOC	$148,897	$160,001	$170,166
DAILY OPERATING LOSS	$71,114	$80,452	$91,757

LOCKHEED
CALIFORNIA COMPANY

Figure 4. Detailed Flow Chart - Phase I

LOCKHEED-CALIFORNIA COMPANY

Study of Aircraft
in
Intraurban Transportation Systems

NASA/Ames Contract NAS Z-5989

AGENDA

3 December 1970

I. INTRODUCTION - Management Overview — E. G. Stout - Study Leader

1. Title - Study of Aircraft in Intraurban Transportation Systems
2. Summary Flow Chart - Phase I Aircraft Concepts Selection
3. Summary Flow Chart - Phase II Aircraft Concepts Evaluation
4. Market Scenario
5. Study Area Selection
6. V/STOLports and Service Zones - Detroit Metropolitan Area
7. Topography
8. Climate
9. Regional Population
10. Political
11. Demand Analysis - Assumptions
12. Demand Analysis - Data Base
13. Transportation Complement
14. Operational Requirements
15. Scenario Overview
16. Candidate Intraurban Aircraft Concepts Matrix
17. Representative Aircraft Concepts
18. Detailed Flow Chart - Phase I (handout)
19. Selected Aircraft Concepts
20. Standard Fuselage Configuration

21. **Aircraft** Synthesis - Flow Diagram
22. Typical Performance Carpet Plot - Takeoff Field Length
23. Typical ASSET Computer Weight Print-out
24. Cost Analysis - Flow Diagram
25. Typical ASSET Computer Cost Print-out
26. Typical Synthesis Carpet Plot - Gross Weight
27. Typical Synthesis Carpet Plot - Flyaway Cost
28. Typical Synthesis Carpet Plot - DOC
29. Total System Synthesis - Flow Diagram
30. Bar Chart - Total System Cost Comparison
31. Bar Chart - Percent Makeup of Total System Cost
32. Bar Chart - Percent Makeup of IOC
33. Bar Chart - Percent Makeup of DOC
34. Fare vs Service Summary
35. VTOL Comparison - 20 Minute Service
    VTOL Comparison - minimum Fare
36. STOL Comparison - 20 Minute Service
    STOL Comparison - Minimum Fare
37. Concept Selection Summary
38. Conclusions and Recommendations - Phase I

BREAK

II. SYSTEM ANALYSIS AND COSTS — L. A. Vaughn - Systems Analysis

Detail discussion of Market Scenario, Demand Analysis and Total System Costs.

III. AIRCRAFT CONCEPTS — H. C. Matteson - Advanced Systems Design

Detail discussion of Aircraft Concepts Selection and parametric performance date bank.

IV. TOTAL SYSTEM SYNTHESIS AND EVALUATION — D. E. Sherwood - Synthesis and Evaluation

Detail discussion of Aircraft and Total System Synthesis and Evaluation

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I. INTRODUCTION - Management Overview — E. G. Stout - Study Leader

1. Title - Study of Aircraft in Intraurban Transportation Systems
2. Summary Flow Chart - Phase I Aircraft Concepts Selection
3. Summary Flow Chart - Phase II Aircraft Concepts Evaluation
4. Market Scenario
5. Study Area Selection
6. V/STOLports and Service Zones - Detroit Metropolitan Area
7. Topography
8. Climate
9. Regional Population
10. Political
11. Demand Analysis - Assumptions
12. Demand Analysis - Data Base
13. Transportation Complement
14. Operational Requirements
15. Scenario Overview
16. Candidate Intraurban Aircraft Concepts Matrix
17. Representative Aircraft Concepts
18. Detailed Flow Chart - Phase I (handout)
19. Selected Aircraft Concepts
20. Standard Fuselage Configuration

21. Aircraft Synthesis - Flow Diagram
22. Typical Performance Carpet Plot - Takeoff Field Length
23. Typical ASSET Computer Weight Print-out.
24. Cost Analysis - Flow Diagram
25. Typical ASSET Computer Cost Print-out
26. Typical Synthesis Carpet Plot - Gross Weight
27. Typical Synthesis Carpet Plot - Flyaway Cost
28. Typical Synthesis Carpet Plot - DOC
29. Total System Synthesis - Flow Diagram
30. Bar Chart - Total System Cost Comparison
31. Bar Chart - Percent Makeup of Total System Cost
32. Bar Chart - Percent Makeup of IOC
33. Bar Chart - Percent Makeup of DOC
34. Fare vs Service Summary
35. VTOL Comparison - 20 Minute Service
    VTOL Comparison - minimum Fare
36. STOL Comparison - 20 Minute Service
    STOL Comparison - Minimum Fare
37. Concept Selection Summary
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II. SYSTEMS ANALYSIS AND COSTS — L. A. Vaughn - Systems Analysis

1. Title - DOC/IOC/TSC
2. Cost Analysis Objectives
3. Cost Ground Rules
4. DOC Flow Diagram
5. Design and Development Cost Elements
6. Production Cost Elements
7. Crew and Fuel and Oil Equations
8. Maintenance Elements
9. Sample Maintenance Equations - Equipment and Furnishings
10. IOC Elements
11. Facilities Concept
12. Facilities Equation
13. Personnel Equations
14. Total System Cost Flow Diagram
15. Total System Cost Premises
16. DOC/IOC Summary
17. TSC Summary
18. TSC Comparison (1975 vs 1985)
19. Breakdown of Fare
20. Sensitivity Analysis - Operational Parameters
21. Subsidy Definition
22. Fare and TSC vs Subsidy

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III AIRCRAFT CONCEPTS

H. C. Matteson - Advanced Systems Design

1. Aircraft Concepts
2. Concept Matrix
3. Aircraft Design Ground Rules
4. Aircraft Design Ground Rules
5. Study Approach
6. Fuselage
7. Four Door Interior Arrangements
8. Timeline - Enroute Stop
9. Unload/Load Cycle Time
10. Fuselage Interior vs Capacity
11. General Arrangement - 60 Passenger - 5 Abreast - 2 Aisles
12. 1975, 1985 Tilt Wing VTOL
13. 1975, 1985 Compound Helicopter
14. General Arrangement - Point Design 60 Passenger Compound Helicopter - 1975
15. General Arrangement - Point Design 60 Passenger Compound Helicopter - 1985
16. 1975, 1985 Deflected Slipstream STOL
17. 1985 Augmentor Wing STOL

18. Flap - Propulsion Concept -- Augmentor Wing
19. 1985 Autogyro STOL
20. General Arrangement - Point Design
    60 Passenger Autogyro STOL - 1985
21. 1975, 1985 CTOL
22. Propulsion Technology
23. Propulsion Technology (Cont'd)
24. Pratt & Whitney 1975 Turboprop - Takeoff Thrust vs M
25. Pratt & Whitney 1975 Turboprop - Maximum Control Thrust vs M
26. Pratt & Whitney 1975 Turboprop - Part Throttle SFC's
27. Pratt & Whitney 1975 Turboprop - Scaling Data
28. Aerodynamic Technology
29. Performance Trends - Autogyro
30. Size Trends Technology - Compound - 1975 - 1985
31. Size Trends Technology - Autogyros - 1975 - 1985
32. Community Noise
33. Community Noise
34. Structures/Materials/Weights Technology
35. Aircraft Systems Technology
36. Avionics Technology
37. Avionics Weight Summary
38. Safety/Survival

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IV. TOTAL SYSTEM SYNTHESIS & EVALUATION

D. E. Sherwood
Synthesis & Evaluation

1. Problem
2. What Are The Costs?
3. What Is The Market?
4. What Are The Aircraft Characteristics?
5. What Is A Solution?
6. Overall Summary Flow Chart - Phase I
7. Aircraft Synthesis
8. Required Fuel/Weight
9. Total Time to Climb
10. Takeoff Field Length
11. Landing Field Length
12. Weight Make-up
13. Takeoff Gross Weight
14. Aircraft Flyaway Cost
15. Direct Operating Cost
16. Effect of Field Length
17. Effect of Payload on Takeoff Gross Weight
18. Total System Synthesis
19. Matrix of Investigation
20. System Cost vs Runway Length
21. Total System Cost Comparison

22. Percent Makeup of Total System Cost
23. Field Length Effect - 1975 Technology
24. Field Length Effect - 1985 Technology
25. System Cost vs Aircraft Size
26. Passenger Capacity Effect - 1975 Technology
27. Problem of Analysis
28. Methods of Analysis
29. Minimum Fare Method - Step 1
30. Minimum Fare Method - Step 2
31. Minimum Fare Method - Step 3
32. Potential Passenger Traffic Volume
33. 20 Minute Schedule Method - Step 1
34. 20 Minute Schedule Method - Step 2
35. 20 Minute Schedule Method - Step 3
36. Comparison of Methods
37. Comparison of VTOL Concepts
38. Comparison of STOL Concepts
39. Concept Selection Summary
40. Fare vs Service Summary
41. Conclusions and Recommendations

LONG DOCUMENT

(INSERT PAGE HERE)