ADVANCED TECHNOLOGY TRANSPORT

DISCUSSIONS WITH NASA
LANGLEY FIELD, VA.
JULY 31, 1970

D6-22483

THE BOEING CO.
DESIGN SPEED
GROSS-WEIGHT COMPARISON

- RANGE: NONSTOP TRANSCONTINENTAL
- PAYLOAD: 175 PASSENGERS

TAKEOFF GROSS WEIGHT RATIO

DESIGN MACH NUMBER

PAYLOAD TOGW
DESIGN SPEED DOC COMPARISON

- RANGE: NONSTOP TRANSCONTINENTAL
- PAYLOAD: 175 PASSENGERS

DOC RATIO

MACH NUMBER

DESIGN MACH NUMBER . . . . . . . . 0.98 1.2
TIME SAVED . . . . . . . . . . 46 MIN 1 HR-45 MIN WESTBOUND
COMPARED TO MACH 0.84 DESIGN . . 34 MIN 51 MIN EASTBOUND

(85% ANNUAL WINDS)

SURCHARGE FOR EQUIVALENT TRIP PROFIT (S/PASS.) (LF 55%)
767-80A (MACH 0.84)
GENERAL ARRANGEMENT

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROSS WT (LB)</td>
<td>244,500</td>
</tr>
<tr>
<td>OEW (LB)</td>
<td>134,650</td>
</tr>
<tr>
<td>PASSENGERS (15/85)</td>
<td>175</td>
</tr>
<tr>
<td>RANGE (NMI)</td>
<td>3,000</td>
</tr>
<tr>
<td>WING AREA (SQ FT)</td>
<td>2,040</td>
</tr>
<tr>
<td>THRUST/ENG SLS (LB)</td>
<td>19,700</td>
</tr>
</tbody>
</table>
767-200A (MACH 0.84)
176 PASSENGERS
15/85% MIX, 38\%/34\% PITCH

26 1ST CLASS
150 TOURIST

206.5\" DIA

FIRST CLASS
SECT A-A

OPTIMUM CONTAINER

TOURIST
SECT B-B
767-81D (MACH 0.98)
175 PASSENGERS
15/85% MIX, 38'/34'' PITCH

26 1st CLASS
149 TOURIST

FIRST CLASS
SECTION A-A

TOURIST
SECTION B-B

TOURIST
SECTION C-C

LD-1 OPTIMUM CONTAINER

200'' DIA

42'' 18.25'' 63''

42'' 18.25''

54'' 24.75'' 26''

44''
### 767-93A (MACH 1.2)

**GENERAL ARRANGEMENT**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>GROSS WT (LB)</td>
<td>496,400</td>
</tr>
<tr>
<td>OEW (LB)</td>
<td>274,000</td>
</tr>
<tr>
<td>PASSENGERS (15/85)</td>
<td>175</td>
</tr>
<tr>
<td>RANGE (NMI)</td>
<td>2,900</td>
</tr>
<tr>
<td>WING AREA (SQAFT)</td>
<td>4,594</td>
</tr>
<tr>
<td>THRUST / ENG SLS (LB)</td>
<td>71,720</td>
</tr>
</tbody>
</table>

![Diagram of 767-93A aircraft with dimensions and measurements]
767-93A (MACH 1.2)
202 PASSENGERS*

15/85% MIX, 38”/34” PITCH

*PERFORMANCE CALCULATED AT 175 PASSENGERS
### MACH 0.84
- **767-80A**
- **Takeoff Gross Weight (LB):** 244,500
- **Operating Empty Weight (LB):** 134,100
- **Engines - No. @ LBS Thrust Each/BPR:** 4 @ 19,700/6
- **Design Range (NMI):** 2,875
- **TOFL (FT) 90°F:** 6,520
- **Approach Speed (Kn):** 125
- **Initial Cruise Alt (FT) @ M Cruise:** 34,000 @ 0.84
- **Noise (FAR 36 Rqmt/Actual EPNdB):**
  - Takeoff With Cutback: 101.5/100.7
  - Sideline: 105.3/95.1
  - Approach: 103.3/106.5
- **Study Price (1970 $):** $14.0 Mil
- **DOC @ 1,000 NMI ($ /ASM):** 1.23

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### MACH 0.98
- **767-81D**
- **Takeoff Gross Weight (LB):** 287,300
- **Operating Empty Weight (LB):** 166,150
- **Engines - No. @ LBS Thrust Each/BPR:** 4 @ 27,100/5
- **Design Range (NMI):** 2,820
- **TOFL (FT) 90°F:** 6,310
- **Approach Speed (Kn):** 135
- **Initial Cruise Alt (FT) @ M Cruise:** 39,000 @ 0.98
- **Noise (FAR 36 Rqmt/Actual EPNdB):**
  - Takeoff With Cutback: 102.8/98.2
  - Sideline: 105.8/100.0
  - Approach: 105.5/106.0
- **Study Price (1970 $):** $17.2 Mil
- **DOC @ 1,000 NMI ($ /ASM):** 1.34

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### MACH 1.2
- **767-93A**
- **Takeoff Gross Weight (LB):** 496,400
- **Operating Empty Weight (LB):** 274,000
- **Engines - No. @ LBS Thrust Each/BPR:** 3 @ 71,700/2
- **Design Range (NMI):** 2,760
- **TOFL (FT) 90°F:** 6,080
- **Approach Speed (Kn):** 150
- **Initial Cruise Alt (FT) @ M Cruise:** 39,000 @ 1.2
- **Noise (FAR 36 Rqmt/Actual EPNdB):**
  - Takeoff With Cutback: 105.7/108.6
  - Sideline: 107.3/118.0
  - Approach: 107.3/112.4
- **Study Price (1970 $):** $25.6 Mil
- **DOC @ 1,000 NMI ($ /ASM):** 1.96
**Supersonic Transport**

Sonic Boom (Mach 2.7)

**Transonic Transport**

No Sonic Boom (Mach 1.05)

- 40-Knot Tail Wind
- Ground Speed: 641 Knots

**Transonic Transport**

No Sonic Boom (Mach 1.23)

- 64-Knot Head Wind
- Ground Speed: 641 Knots

**Transonic Transport**

Sonic Boom Cutoff Altitude

- Zero Wind
- Ground Speed: 641 Knots
<table>
<thead>
<tr>
<th>DISTANCE</th>
<th>MACH 0.84</th>
<th>MACH 0.98</th>
<th>MAC BOOMLESS MACH 1 TO 1.2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EASTBOUND</td>
<td>WESTBOUND</td>
<td>EASTBOUND</td>
</tr>
<tr>
<td>TRANSCONTINENTAL (2,240 NMI)</td>
<td>4:56</td>
<td>5:50</td>
<td>4:22</td>
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<tr>
<td>CHICAGO-WEST COAST (1,600 NMI)</td>
<td>3:40</td>
<td>4:16</td>
<td>3:16</td>
</tr>
<tr>
<td>CHICAGO-EAST COAST (640 NMI)</td>
<td>1:45</td>
<td>2:04</td>
<td>1:36</td>
</tr>
</tbody>
</table>

85% ANNUAL WINDS
## Time Saved by Transonic Transport as Compared to Mach 0.84 Cruise Speed

<table>
<thead>
<tr>
<th>Distance</th>
<th>Mach 0.93</th>
<th>Max &quot;Boomless&quot; Speed (Mach 1.07-1.25)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Eastbound</td>
<td>Westbound</td>
</tr>
<tr>
<td>Transcontinental (2,240 NMI)</td>
<td>34 MIN</td>
<td>46 MIN</td>
</tr>
<tr>
<td>Chicago-West Coast (1,600 NMI)</td>
<td>24</td>
<td>32</td>
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<tr>
<td>Chicago-East Coast (640 NMI)</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>Tag Ends (300 NMI or less)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>85% Annual Winds</td>
<td></td>
<td></td>
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</tbody>
</table>
DISTRIBUTION OF "BOOMLESS" CRUISE MACH NUMBERS

TOP 100 CITY PAIRS > 1,000 MILES APART

WEIGHTED AVERAGE 1966 O&D TRAFFIC
TOLERANCE: 10K GUSTS + 10K SAFE ALTITUDE

PB2-4597
SPEED CONTROL

METHOD A — GROUND TEMPERATURE & WINDS (STATISTICAL)

$V_G$ MONITORED WITH AN
INERTIAL OR AREA NAVIGATION
SYSTEM

$V_{G1}$ GROUND TRACK $V_{G2}$ $V_{G3}$

AIRLINE OPERATIONS

FLIGHT PLAN PREPARED TO INCLUDE ALLOWABLE
GROUND SPEED ($V_G$) ALONG THE FLIGHT TRACK

ALLOWABLE GROUND SPEED ($V_G$) BASED UPON STATISTICAL
DATA OF GROUND TEMPERATURE, WIND VELOCITY & DIRECTION
FOR ROUTES FLOWN

PB2-4597
SPEED CONTROL

METHOD B - UPPER AIR DATA

$M_T$ MONITORED WITH MACHMETER

UPPER AIR TEMPERATURES, WIND VELOCITY & DIRECTION FROM RADIOSONDE DATA

RADIOSONDE

EXISTING WEATHER STATIONS

$M_T_1$, $M_T_2$, $M_T_3$

U.S. WEATHER CENTER

AIRLINE OPERATIONS

FLIGHT PLAN PREPARED TO INCLUDE ALLOWABLE $M_T$ ALONG FLIGHT TRACK FOR FLIGHT LEVEL SELECTED

Threshold Mach Number ($M_T$)

Contour map for each flight level prepared by U.S. Weather Bureau & transmitted to airlines along with other weather maps

PB2-4597
SPEED CONTROL

METHOD C — GROUND TEMPERATURE AND WIND (ACTUAL)

ALLOWABLE GROUND SPEED ($V_G$) ALONG TRACK COMPUTED ONBOARD

$V_G$ MONITORED WITH AN INERTIAL OR AREA NAVIGATION SYSTEM

GROUND TEMPERATURES, WIND VELOCITY & DIRECTION TRANSMITTED FROM EACH VOR SITE
SPEED CONTROL
METEOROLOGICAL STUDY ROUTES

ROUTES SHOWN ARE REPRESENTATIVE OF CURRENT HIGH-ALTITUDE JET ROUTES
AIR TRAFFIC CONTROL

CURRENT DOMESTIC ENVIRONMENT

- Airplanes of varying speeds are flying at same altitudes
- Separation is maintained by timed fixes over positive navigation aids & by radar surveillance
- Airplanes are diverted or speed changed by ATC to avoid intercept
- Primary navigation device is VOR/VORTAC
- Radar surveillance is used for monitor & flight control
- Off-airways flights are currently being flown
- ATC controls airspace to 50,000 feet

TRANSONIC AIRPLANE ENVIRONMENT EVALUATION

- Current and projected flight densities at various altitudes, locations & times of day
- ATC effect on block time if TST is cruising at current jet altitudes
- ATC effect on block time due to TST climb & descent through existing cruise altitudes
- Minimum TST cruise altitude to minimize ATC constraint
NST Demands New Propulsion Installation Concepts

New Pod Geometry
New Accessories Installation
New Inlet Concepts
New Aft Cowl/Reverser/Nozzle

\[ Mn = 0.85 \]
\[ BPR = 6.6 \]
Equal Take-off Thrust

\[ Mn = 0.98 \]
\[ BPR = 5.0 \]
POWERPLANT: INSTALLATION

SUBSONIC M € 0.085

NEAR SONIC

SUBSONIC M € 0.085

NEAR SONIC

SUPERSONIC M > 2.0 (U.S. SST)

POD GEOMETRY
LIP CONTRACTION (DhL/Dth)^2
MAX. DIAMETER (DhL/Dmax)
LIP SPILLAGE
NACELLE SPILLAGE (OVER MAX. DIA)
SMOOTHNESS

ACCESSORIES
INSTALLATION
ACCESS, LOCATION

INLET DEVELOPMENT

FIXED FAT LIP OR
THIN LIP WITH BLOW-IN DOORS

THIN LIP WITH VARIABLE CONTRACTION RATIO (BELL MOUTH FOR T/O)
OR BLOW-IN DOORS

VARIABLE NOZZLE

VAR. AREA PRIMARY NOZZLE DESIRABLE FOR REDUCTION OF PRIM. JET NOISE

VAR. AREA NOZZLE (C/D) FOR PRESSURE RATIO ADJUSTMENT & AFTER BURNING MANDATORY

REVERSER

CASCADE FAN REVERSER
PRIMARY REVERSER OR SPOILER, DELETION OF PRIMARY SPOILER FOR HIGH BPR

CASCADE OR UMBRELLA BUCKET OR TARGET TYPE
FAN REVERSER, PRIMARY REVERSER OR SPOILER, DELETION OF PRIMARY SPOILER FOR HIGH BPR

AFT COWL MAX. BOATTAIL ANGLES

FAN
8 - 10

6 - 8

PRIMARY
12 - 15
10 - 13
3 - 4.5
NST Proposed Propulsion Development Program

Design Accessories Installation
- Build Mock Up
- Develop Generator/Starter
- Test Generator/Starter
- Build Flight Worthy Accessories For Demo. Eng.
- Develop Electronic Fuel Control

Design Composite Inlet
- Evaluate Variable Geometry Schemes
- Build Most Promising Configurations
- Ground Test
- Fly Most Promising Configuration

Design Variable Apex Nozzle
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<td>Pod Geometry</td>
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<tr>
<td>Accessory Inst.</td>
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<tr>
<td>Inlet Development</td>
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<tr>
<td>Variable Nozzle</td>
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<tr>
<td>Aft. Cowl</td>
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<tr>
<td>Reverser</td>
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<tr>
<td>NST Pod</td>
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<tr>
<td>Pod Geometry - Definition</td>
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<tr>
<td>Accessories Inst. - Design</td>
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<td>Inlet Development - Design</td>
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<td>Variable Nozzle - Design</td>
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<td>Aft. Cowl - Design</td>
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<tr>
<td>Reverser - Design</td>
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<tr>
<td>NST Pod - Design</td>
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<tr>
<td>Mechanical Design</td>
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<td>Electrical Design</td>
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<td>Flight Hardware</td>
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<td>Ground Tests</td>
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<tr>
<td>Flight Test</td>
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</tbody>
</table>
SUBSONIC ENGINE
BPR 6.6, 26500LB S.L.S. T/O THRUST
POD GEOMETRY

\[
\left( \frac{D_{HL}}{D_{TH}} \right)^2 = 1.25
\]

\[
\frac{D_{HL}}{D_{MAX}} = 0.81 - 0.83
\]
NEAR SONIC ENGINE
BPR 5.0, 26,500 lb SLS T/O THRUST
POD GEOMETRY

\[
\left( \frac{D_{HL}}{D_{TH}} \right)^2 = 1.07 - 1.11
\]

\[
\frac{D_{HL}}{D_{MAX}} = 0.85 - 0.87
\]
SUBSONIC ENGINE
BPR 6.6, 26500 LB. S.L.S. T/O THRUST
ACCESSORY LOCATION
CHIN MOUNTED
NEAR SONIC ENGINE
EPR 5.0, 26500 LBS S.L.S. T/O THRUST
ACCESSORY LOCATION:
ACCESSORY BAY IN LOWER BIFURCATION
INTEGRATED GENERATOR

INTEGRATED GENERATOR
Subsonic Engine
8PR 6.6, 26500 Lb S.L.S. 170 Thrust
Inlet Development.

Fat Lip, Fixed Geometry
Inlet

Thin Lip, Long Blow-In
Door Inlet
NEAR SONIC ENGINE
BPR 5:1, 26,500 LBS S.L.S. T/O THRUST
INLET DEVELOPMENT

THIN LIP, VARIABLE CONTRACTION RATIO INLET

THIN LIP, LONG BLOW-IN DOOR INLET
SUBSONIC ENGINE
BPR 6.6, 26,500 Lb S.L.S. 170 THRUST
REVERSERS

CASCADE FAN REVERSER

TARGET TYPE PRIMARY SPOILER

PRIMARY SPOILER DEFLECTED

UMBRELLA TYPE FAN REVERSER
NEAR SONIC ENGINE
BPR 5.0, 20,500 lb S.L.S. V/D THRUST
REVERSERS

CASCADE FAN REVERSER

TARGET TYPE PRIMARY SPOILER

PRIMARY SPOILER DELETED

UMBRELLA TYPE FAN REVERSER
SUBSONIC ENGINE
BPR 6:6, 26500 LBS. SLS. FIOTHUST
NOZZLES

FIXED GEOMETRY
CONVERGENT FAN
AND PRIMARY NOZZLES
NEAR SONIC ENGINE
8 PR 5:0, 26500 LBS S.L.S. T/O THRUST
NOZZLES

CONVERGENT/DIVERGENT FAN NOZZLE
FOR CRUISE, CONVERGENT FOR T/O
AND APPROACH

CONVERGENT/DIVERGENT
PRIMARY NOZZLE FOR CRUISE,
CONVERGENT FOR T/O AND
APPROACH