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NASA Annual HSR Workshop
Boeing HSCT Program Summary

M. L. Henderson

Boeing Commercial Airplane Group

May 14, 1991

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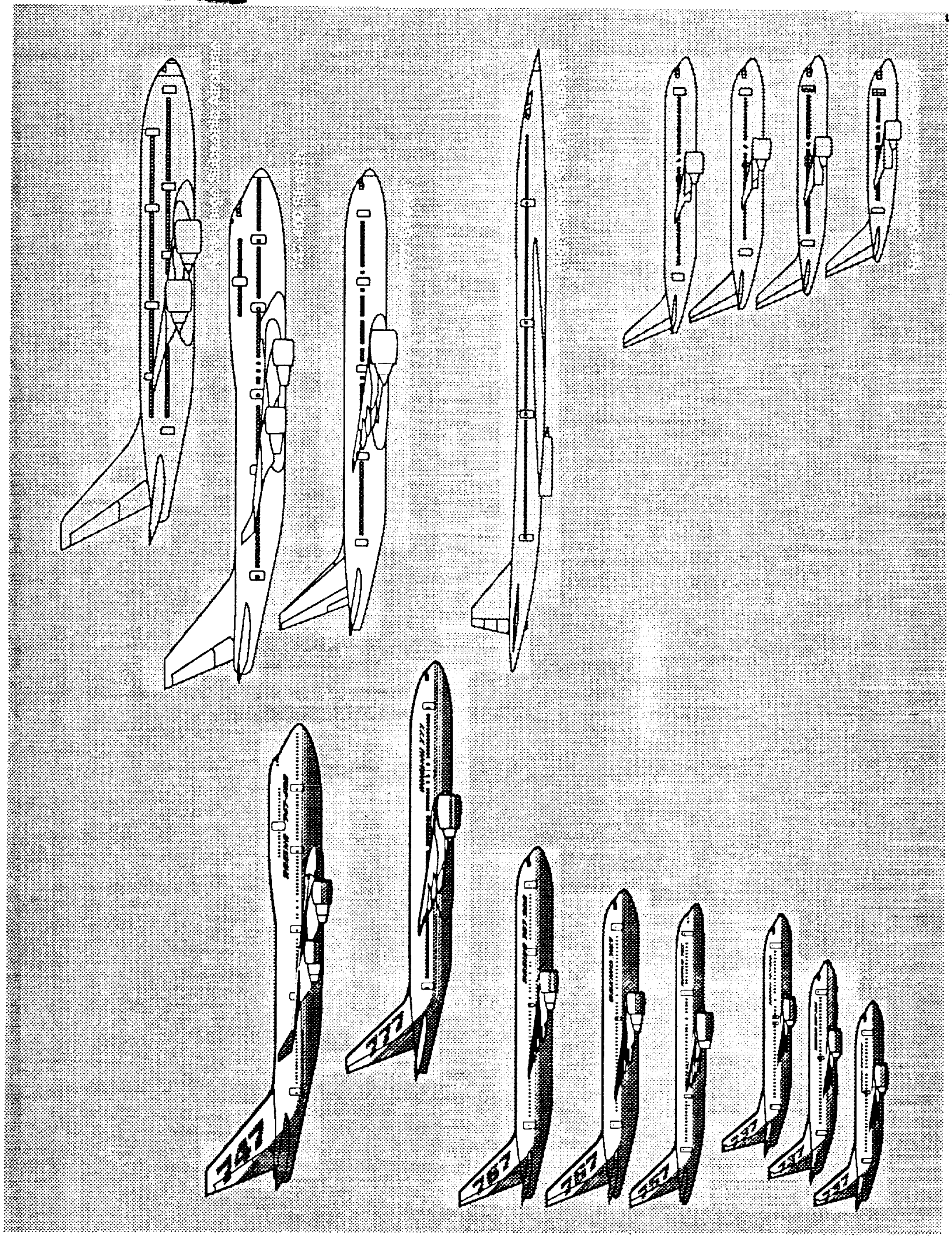
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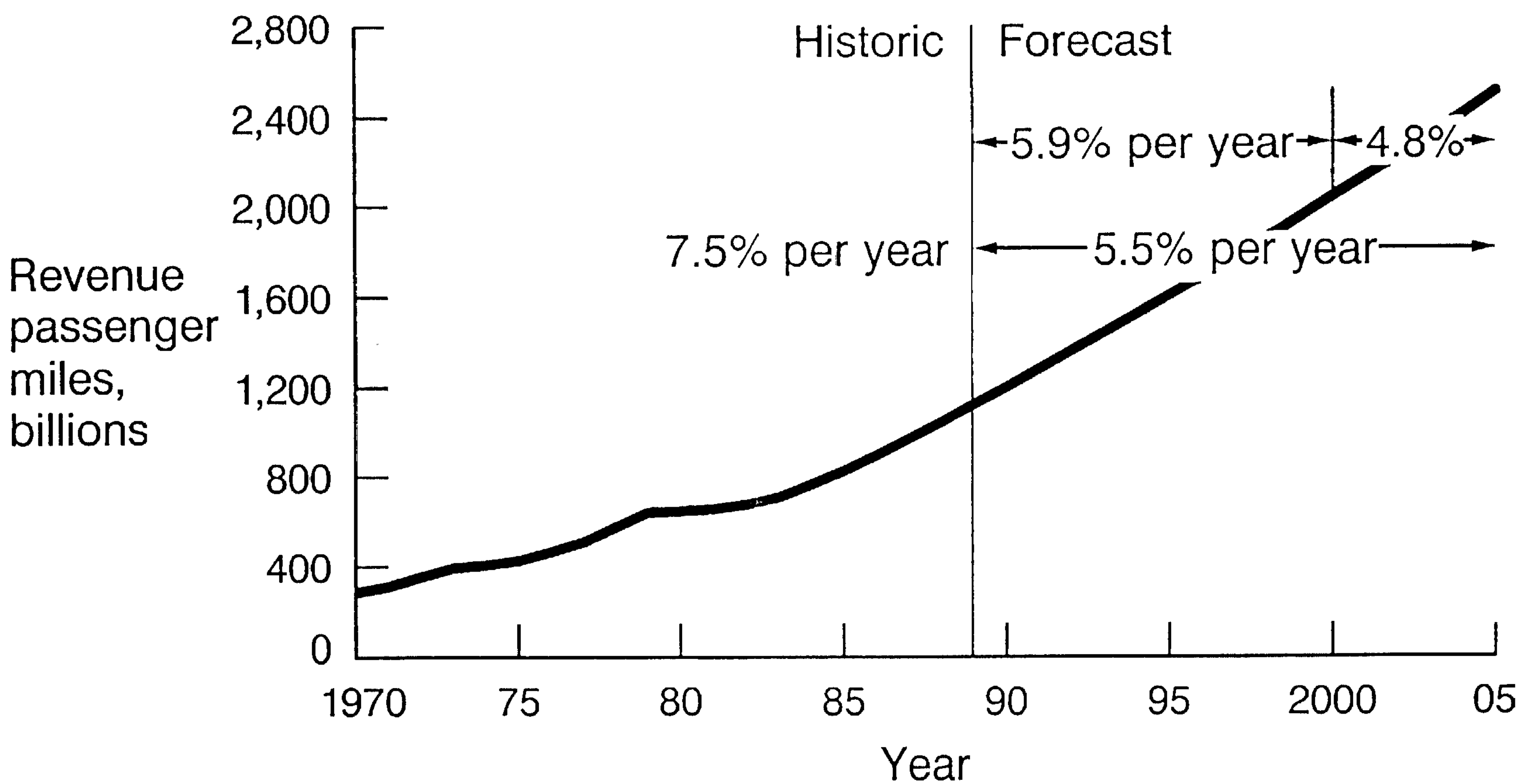
Why Are We Looking At An HSCT Now?

- The forecast for long range scheduled international traffic is sufficiently large in the post year-2005 time period to support a fleet of HSCT's
- Technologies are projected to be available to create an HSCT that will have the required performance and operating economics, and which can be sold at a price that will provide a reasonable return to Boeing and the airlines.
- With relatively modest surcharges over competing subsonic fares, it is expected that an HSCT providing roughly a 50% time savings would capture a significant market share.
  - Passengers appear to be willing to pay...but how much?
  - Potential for stimulation of travel.
- Boeing cannot afford to pass on this potential market opportunity... we must continue to do our homework.

World Air Travel Forecast Through 2005

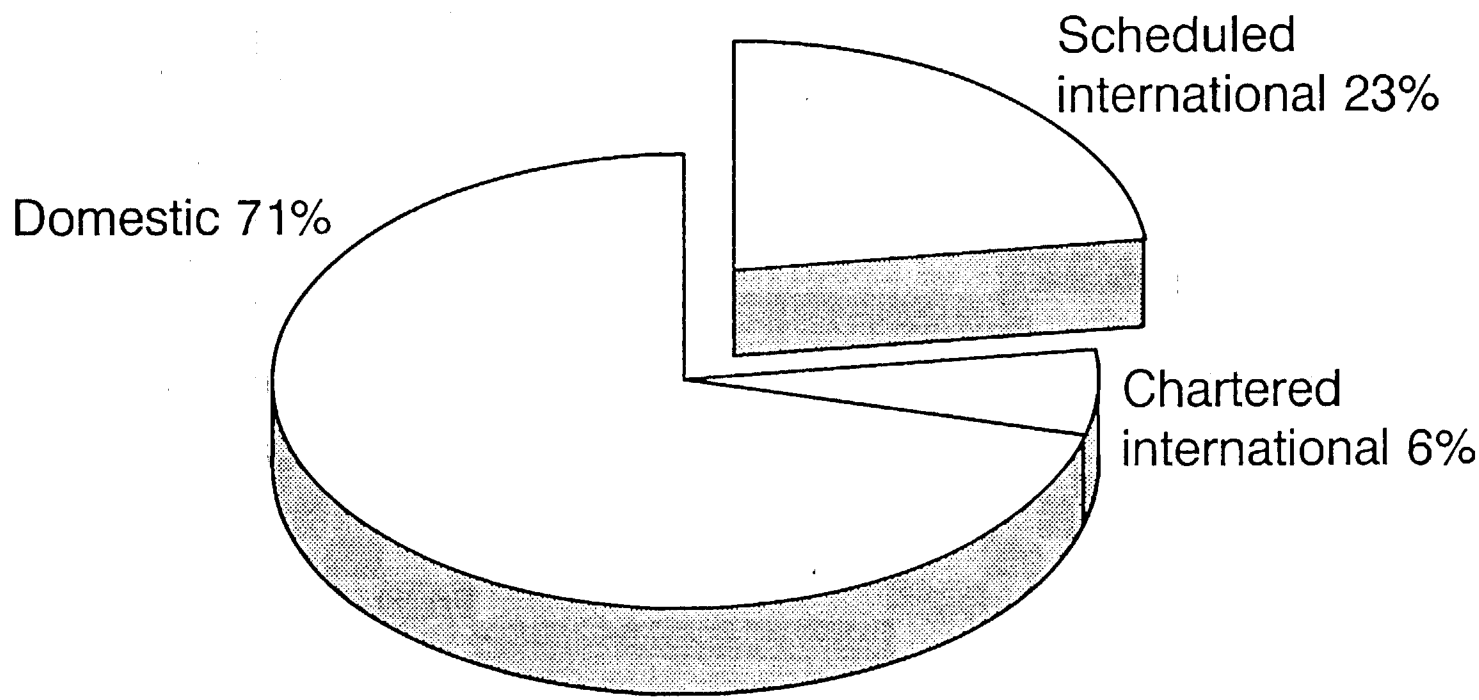


Note: Excludes U.S.S.R.

World Traffic Demand Forecast

Year 2000

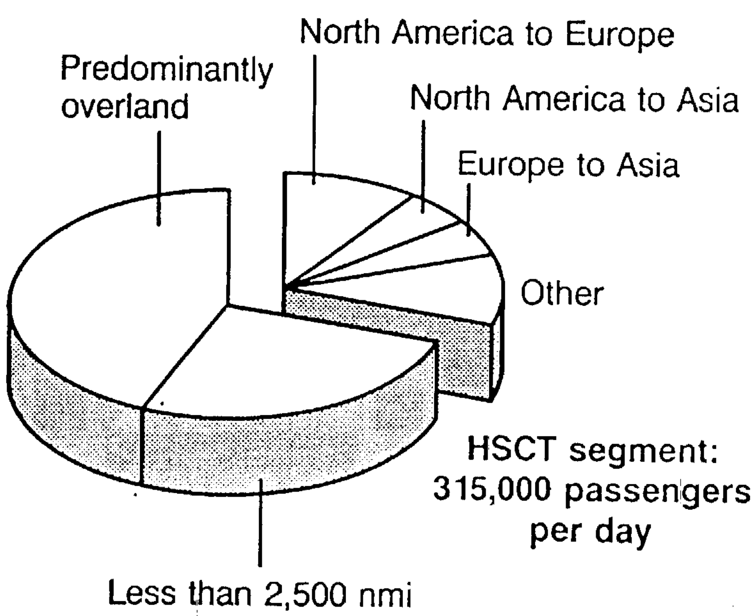
4.8 million passengers per day



HSCT Study Markets

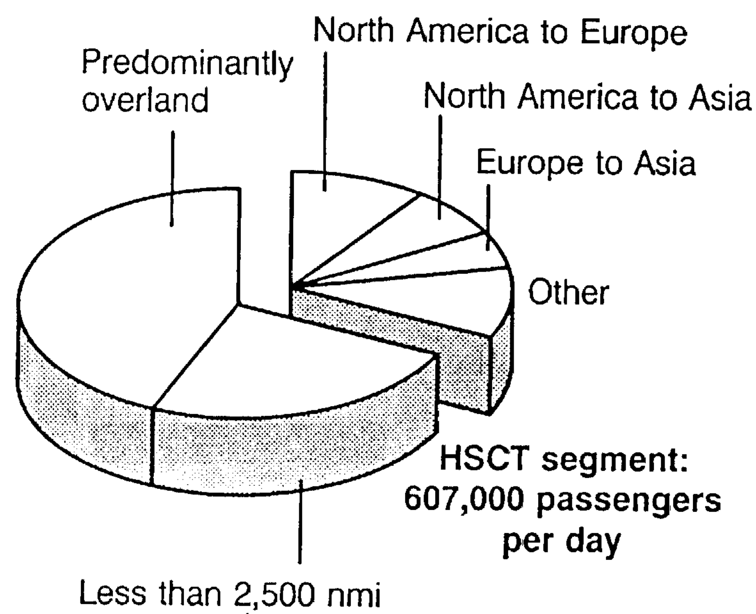
Year 2000

1.09 million passengers per day



Year 2015

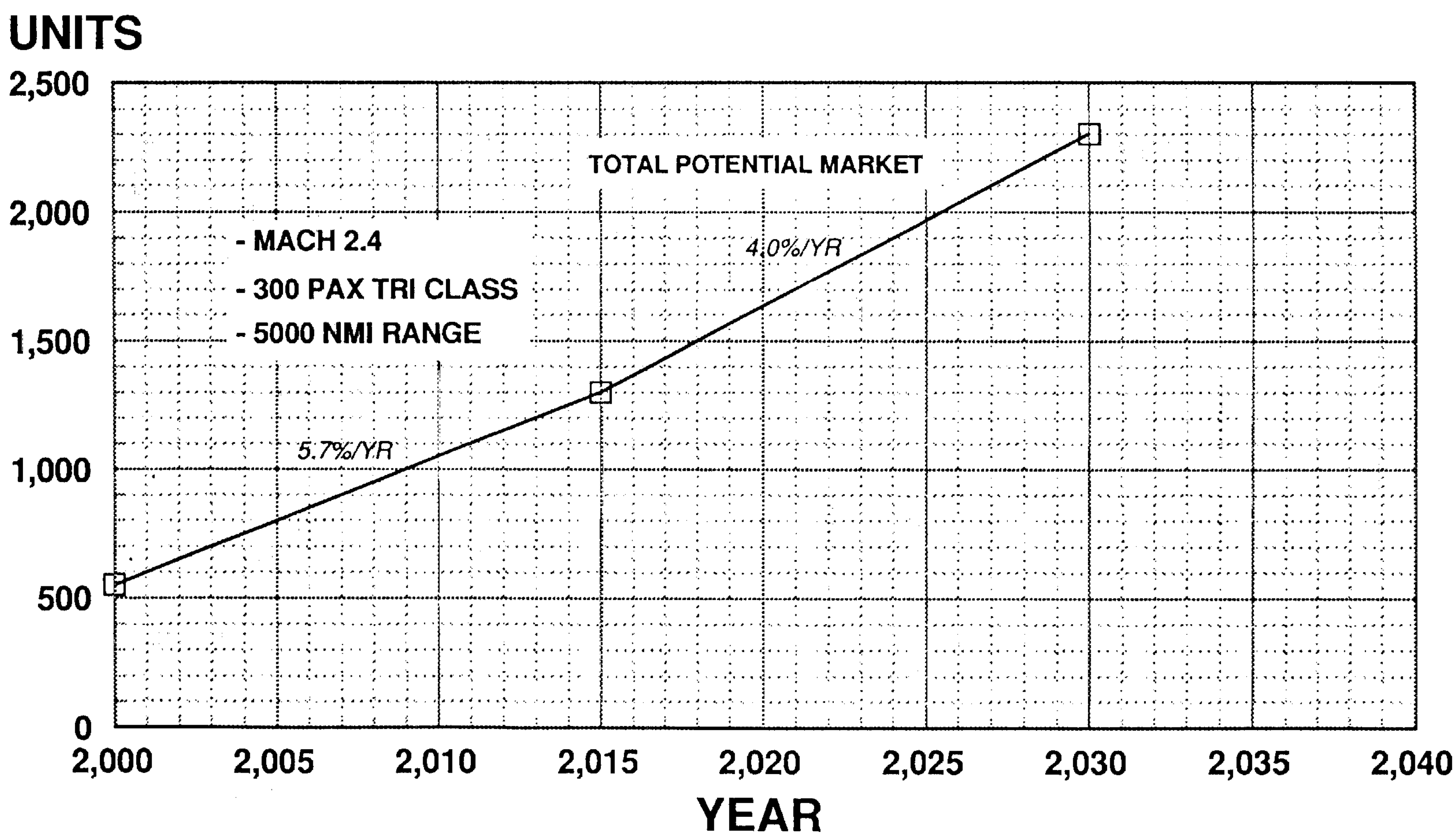
1.90 million passengers per day



Cities Used in the Study Route System

HSCT MARKET ESTIMATE

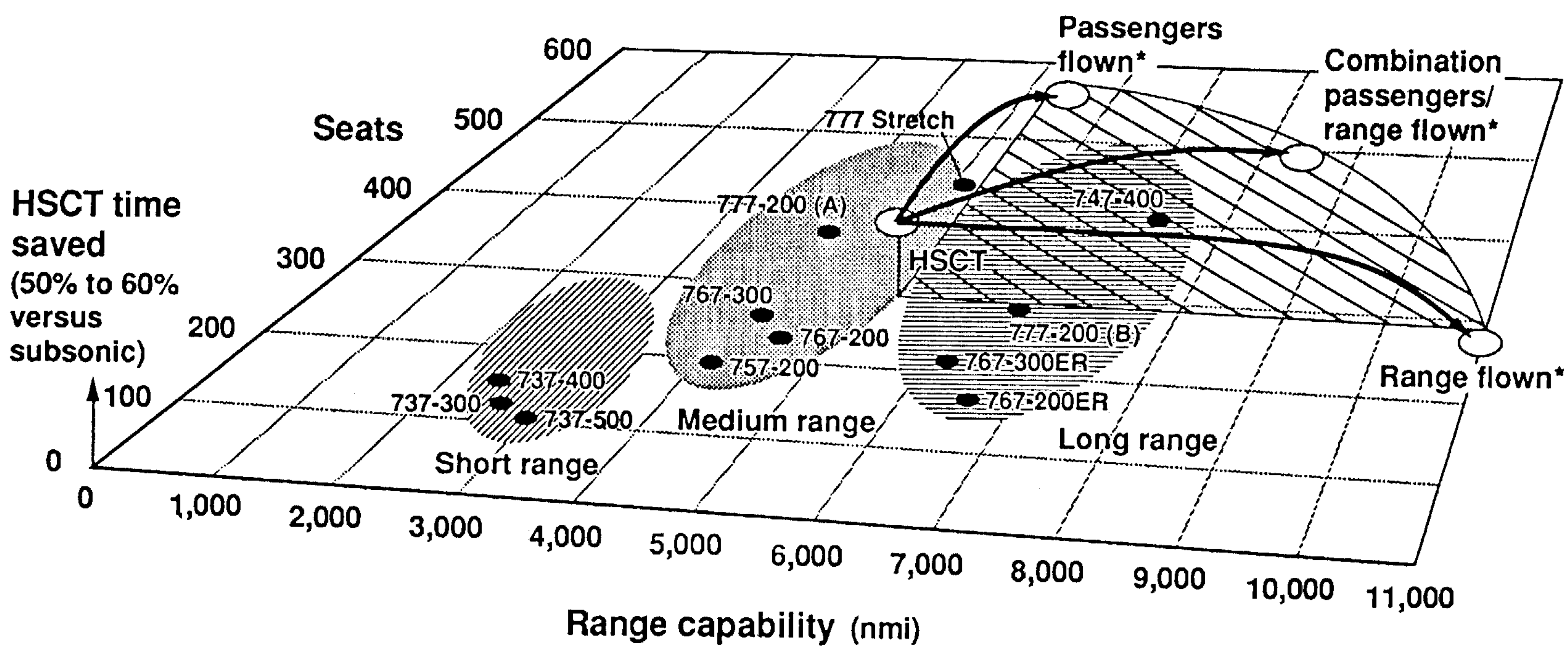
TOTAL POTENTIAL MARKET



Market Requirements

- Speed
  - Mach 2.4 provides a good balance in trip time benefit, technology risk, reducing environmental impact, and overall system scheduling efficiency.
- Design range
  - The initial range capability of 5000 nmi would provide non-stop service for city-pairs comprising approximately 80% of the forecast long range international scheduled passengers flown.
  - The airplane is projected to grow to 6,500 nmi range capability, expanding non-stop capabilities.
- Seat-size
  - The airplane is nominally 300 seats tri-class. This capacity provides a balance between reduced seat-mile costs and a size that is consistent with the increased frequencies of the HSCT.

HSCT Flexibility



* For equivalent subsonic trip time

Viable High Speed Civil Transport

Elements of success:

- Environmental acceptability
- Technical feasibility
- Economic viability

Environmental Goals

- Emissions:
  - No significant ozone depletion
- Airport noise:
  - As quiet as Stage III subsonic airplanes
- Sonic boom:
  - No perceptible boom over populated areas

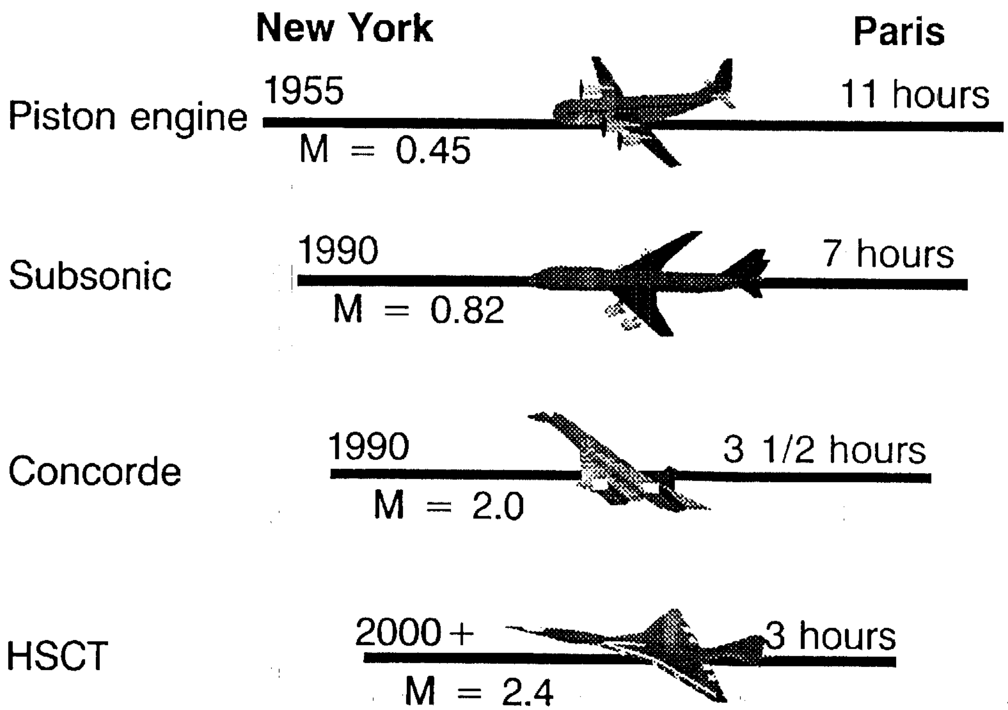
Economic Measures of Success for the HSCT

- The cost-price-market loop must close
  - Sufficient program (total units) to allow airframe and engine manufacturers to build and sell with a reasonable return on investment
  - Overall economics (operating plus ownership costs) that permit a reasonable return to the airline
- Passengers appear to be willing to pay relatively modest surcharges over competing subsonic fares for roughly a 50% time savings
  - Surcharge target is in the +10 to +20% range
  - Current indications are that technologies could be available to achieve the target surcharge level

Making the World Smaller

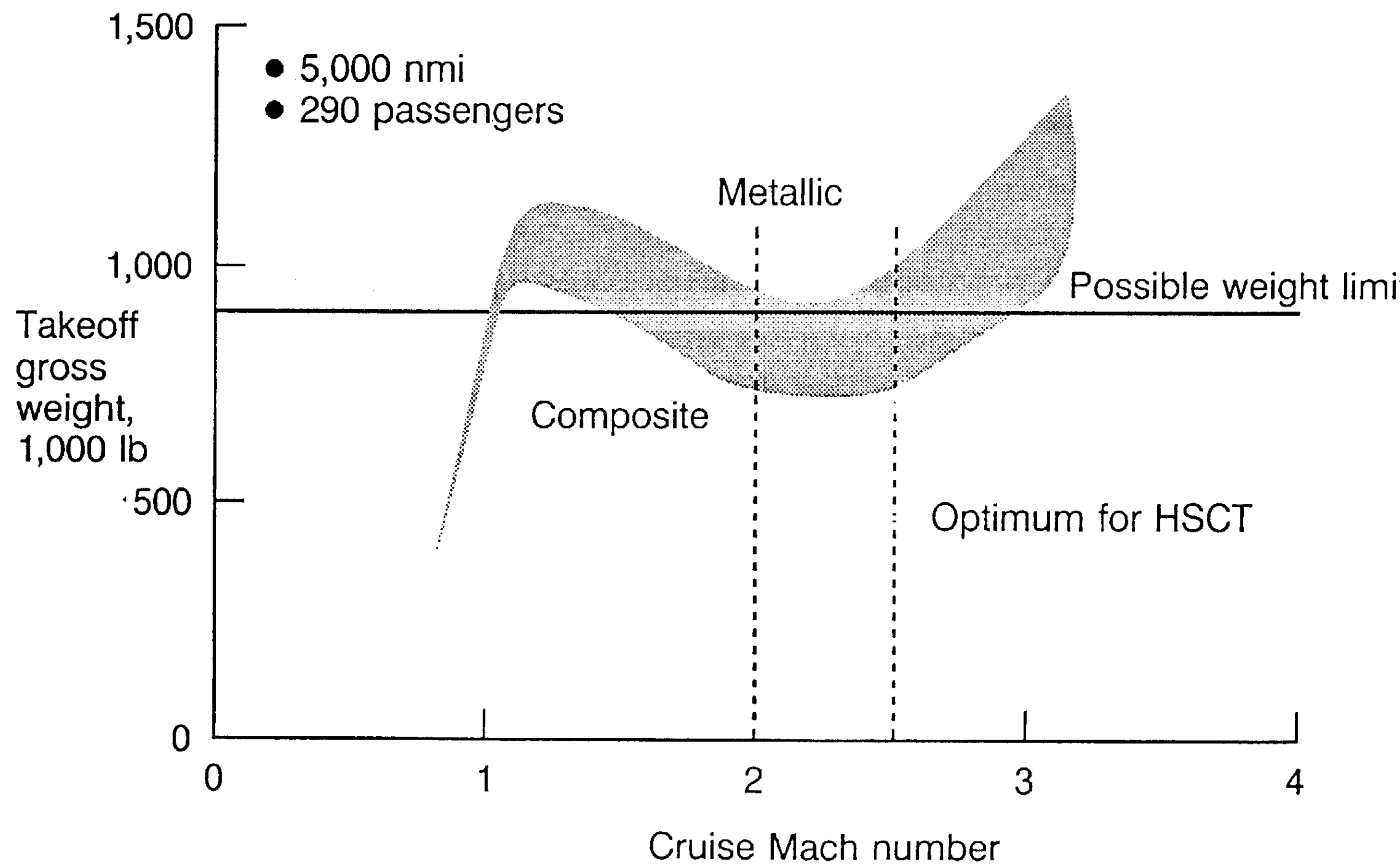
With High Speed Civil Transport

Economically and with positive environmental impact



Typical fares (1990 dollars)		
Full economy	Discount	Average
$1,800	--	--
$ 857	$ 250	$ 500
$2,700	$2,700	$2,700
$ 950	$ 290	$ 550

Effect of Cruise Mach Number on Maximum Takeoff Weight



High Speed Civil Transport

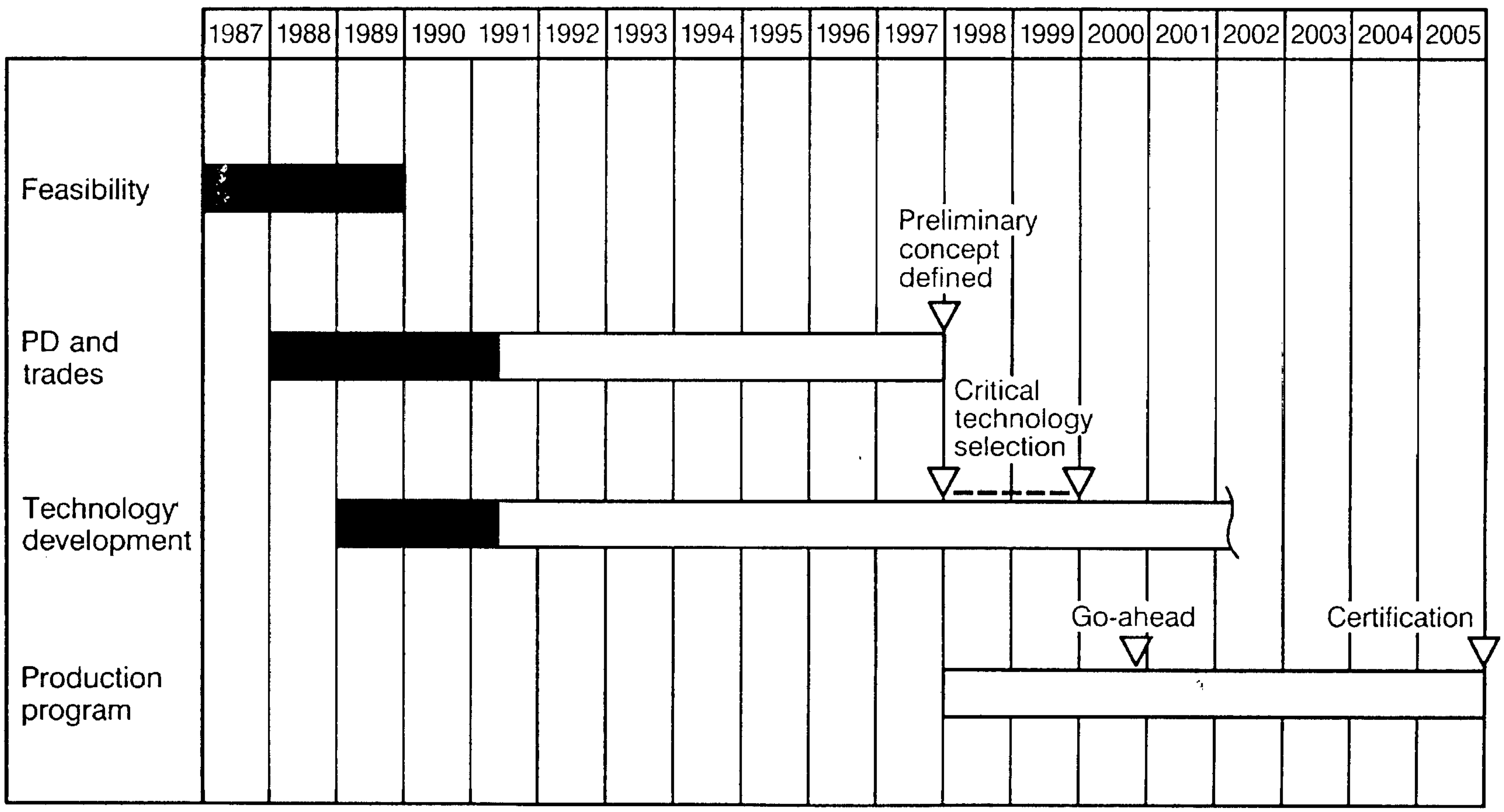
Product Development Study

- Boeing has a significant study effort directed at development of a viable High Speed (Supersonic) Civil Transport for introduction into service early in the next century

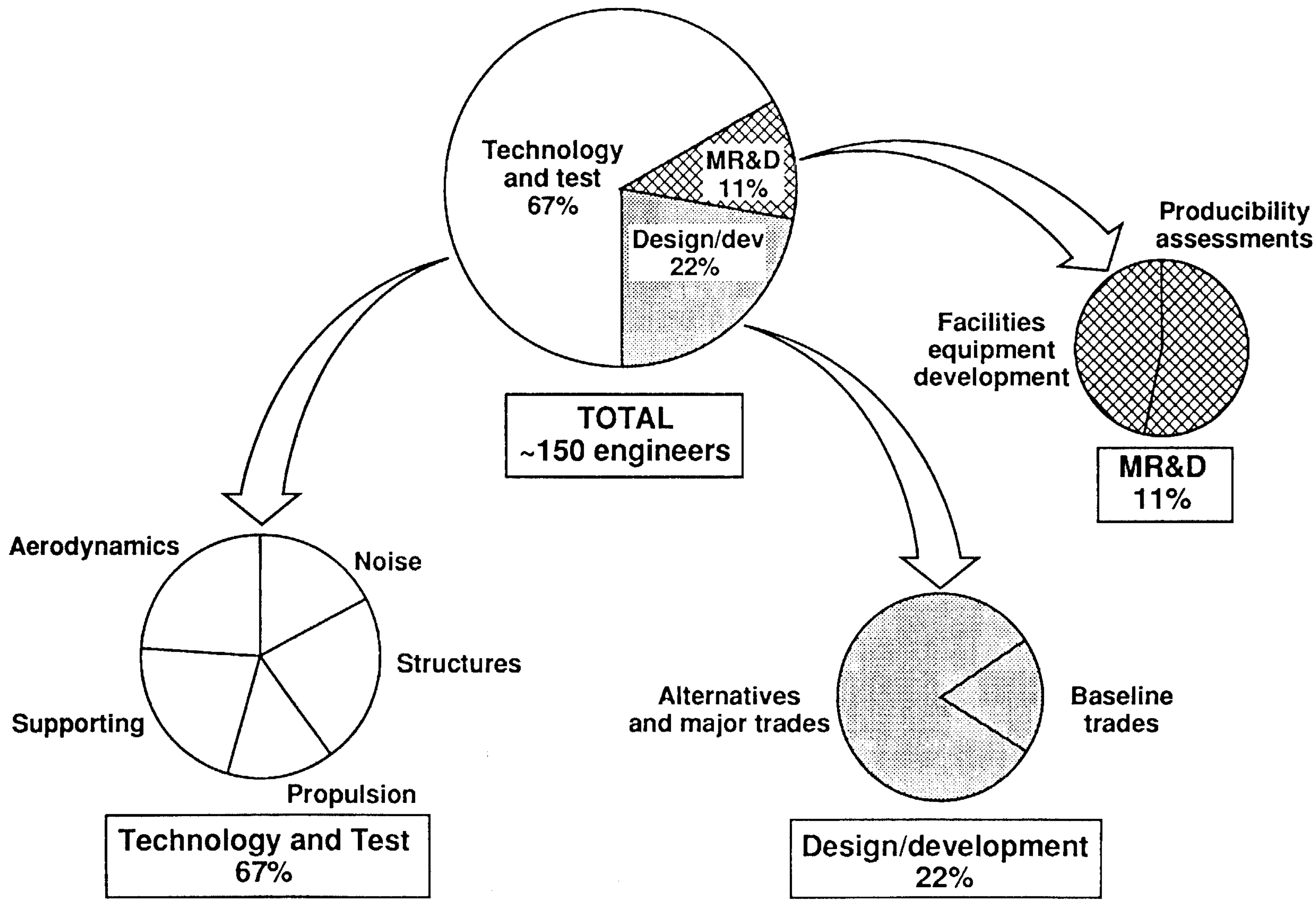
- The program integrates technology development, aircraft design, manufacturing research, and airline requirements

- While the results of studies to date are encouraging, it is also clear that early, focused technology development is vital to the timing and ultimate success of the HSCT

HSCT Planning Schedule

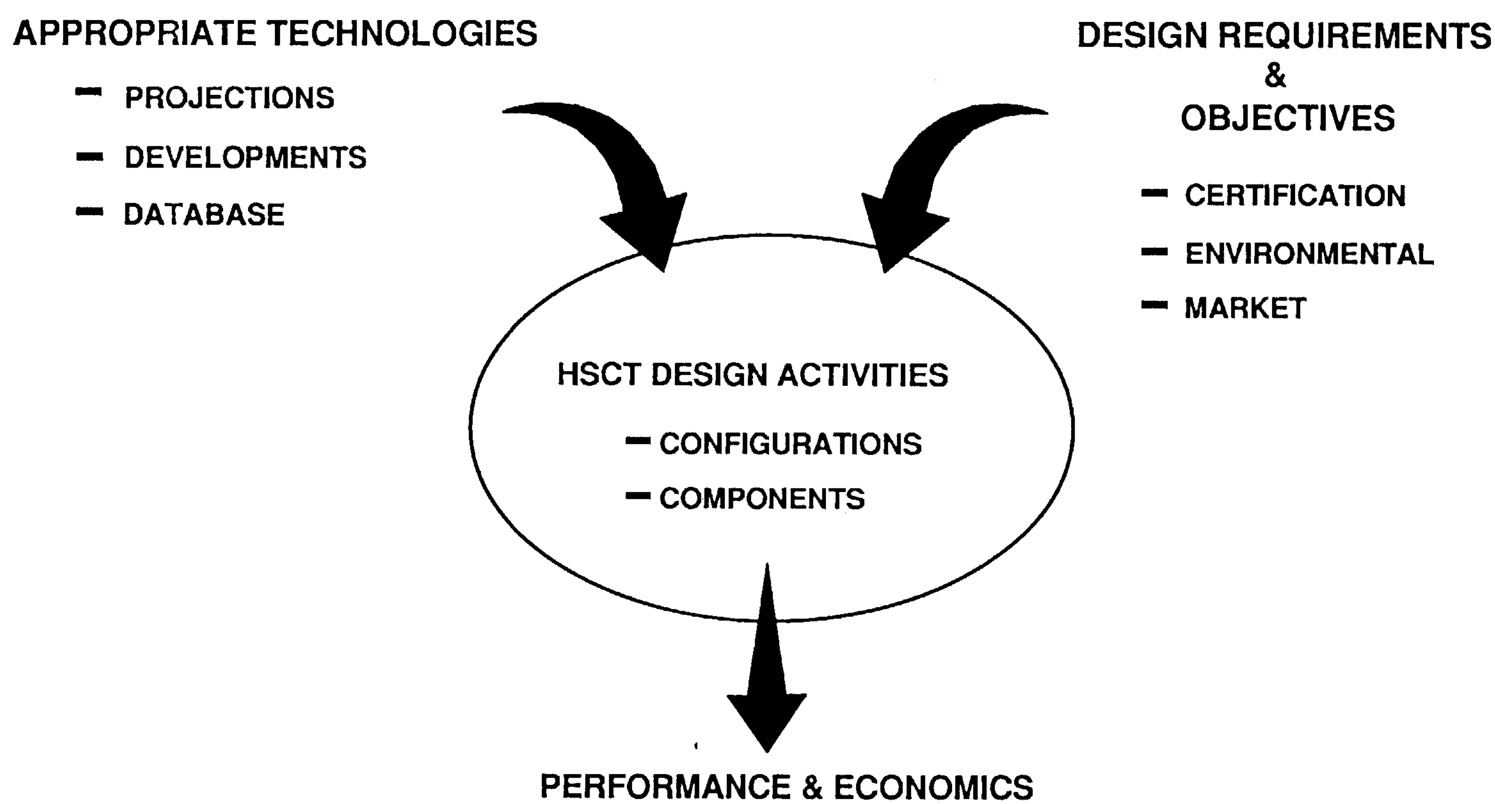


1991 HSCT Budget Breakdown



HSCT TECHNOLOGY PROJECTIONS AND PROGRESS

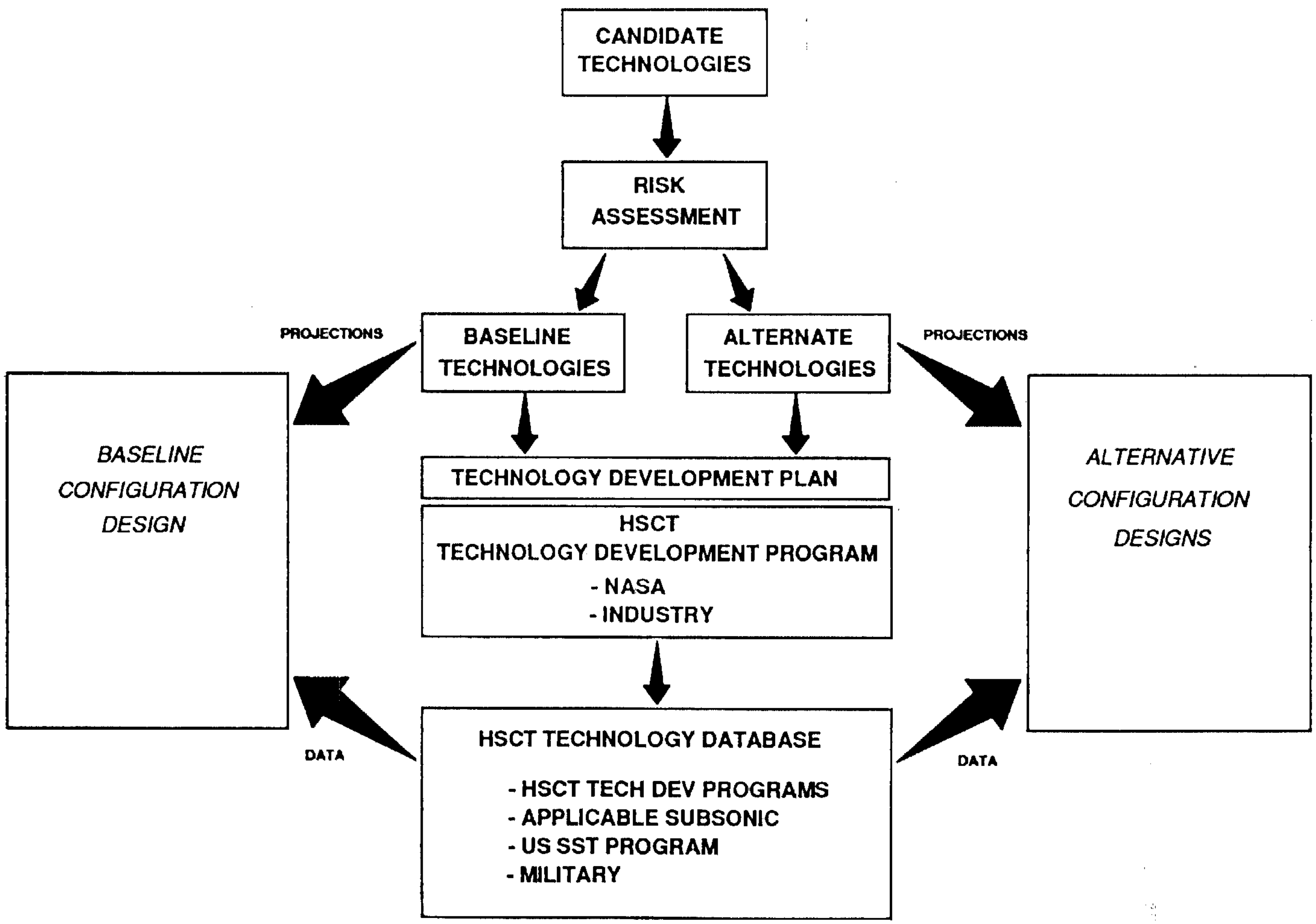
PERFORMANCE AND ECONOMICS DRIVERS



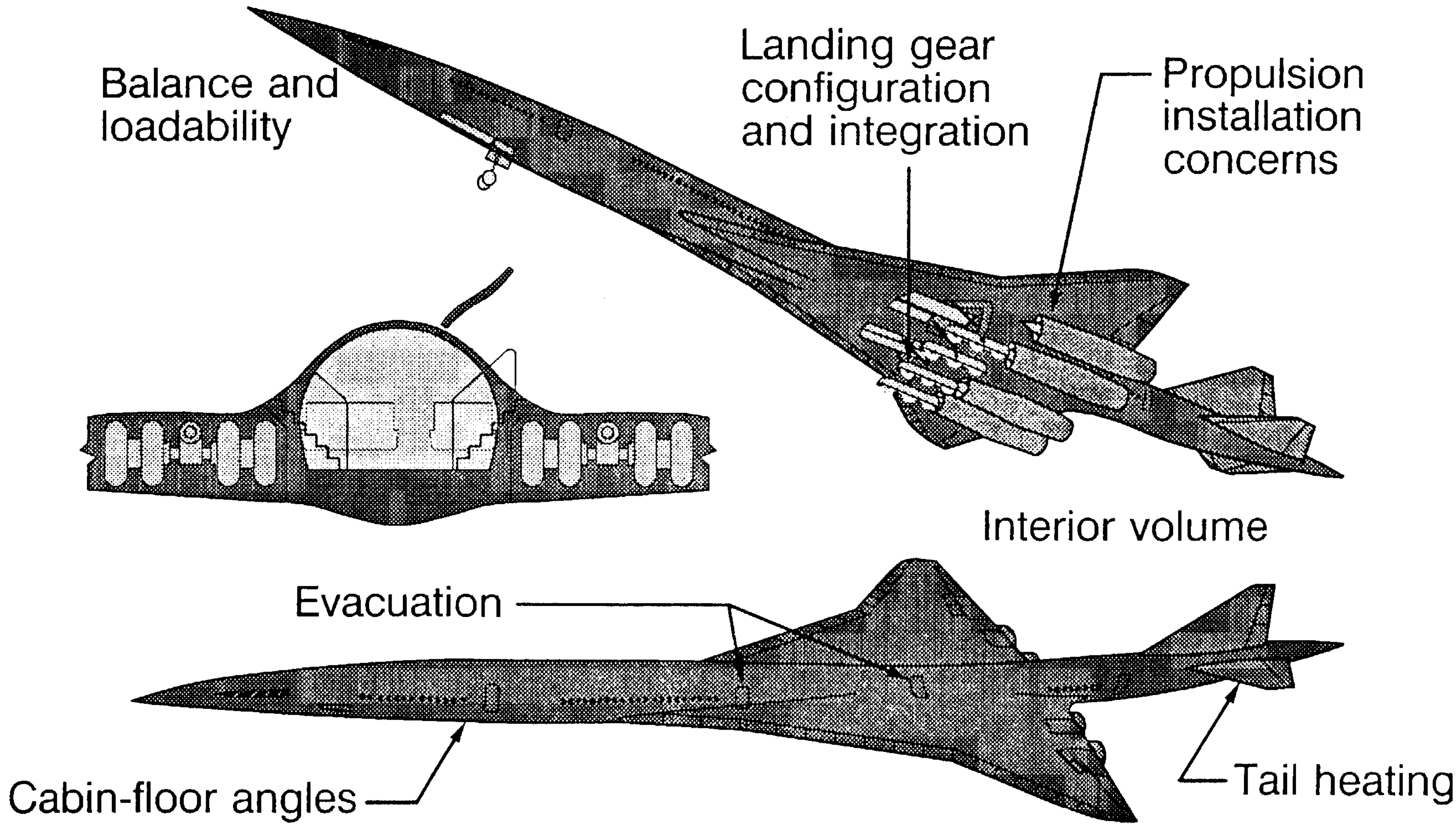
MSG: HSCT PERFORMANCE & ECONOMICS ARE DEPENDENT ON ACHIEVING HIGH CONFIDENCE LEVEL IN *KEY PROJECTED TECHNOLOGIES* BY GO AHEAD.

HSCT TECHNOLOGY PROJECTIONS AND PROGRESS

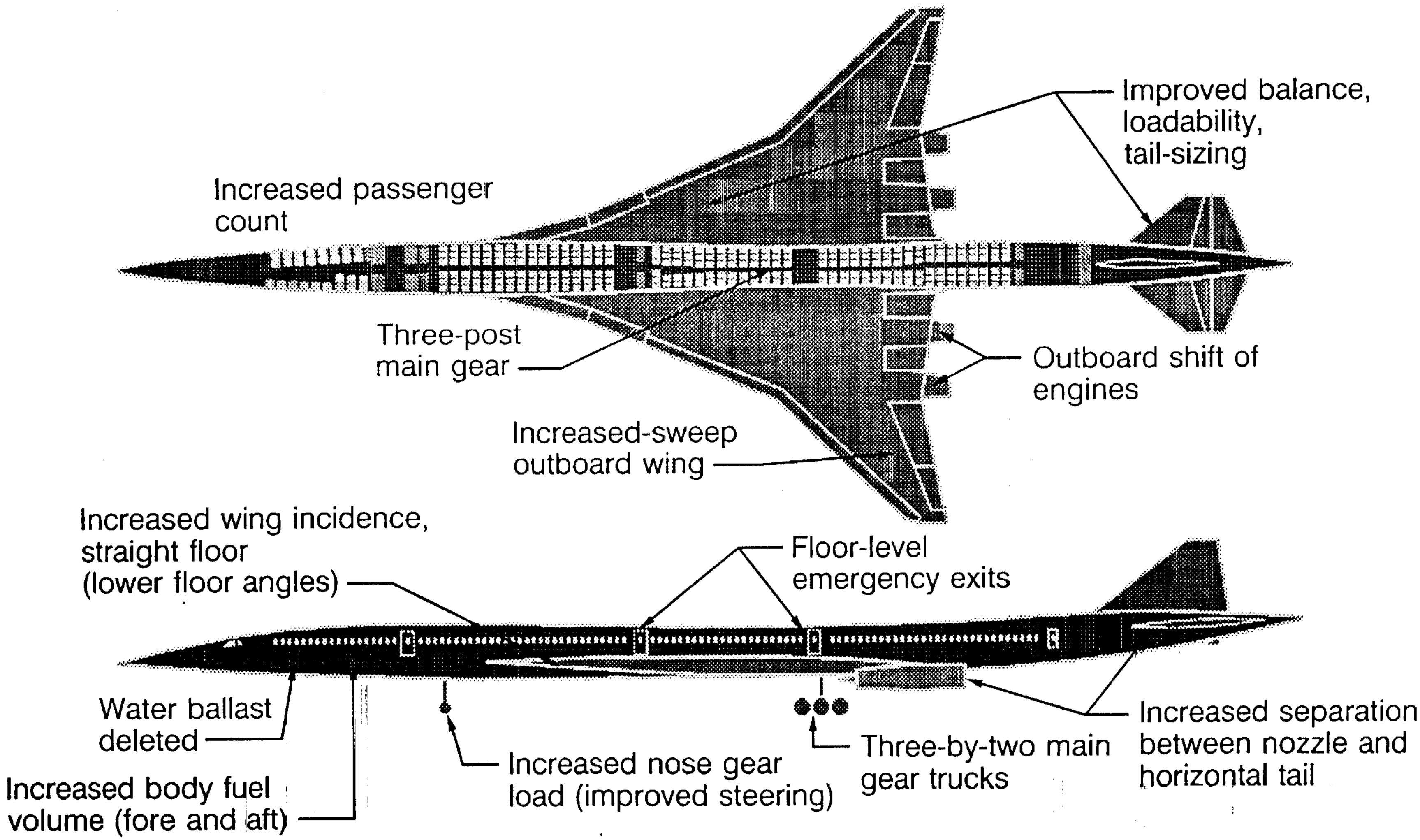
TECHNOLOGY PROJECTION AND DEVELOPMENT PROCESS



HSCT Blended Configuration Design Concerns

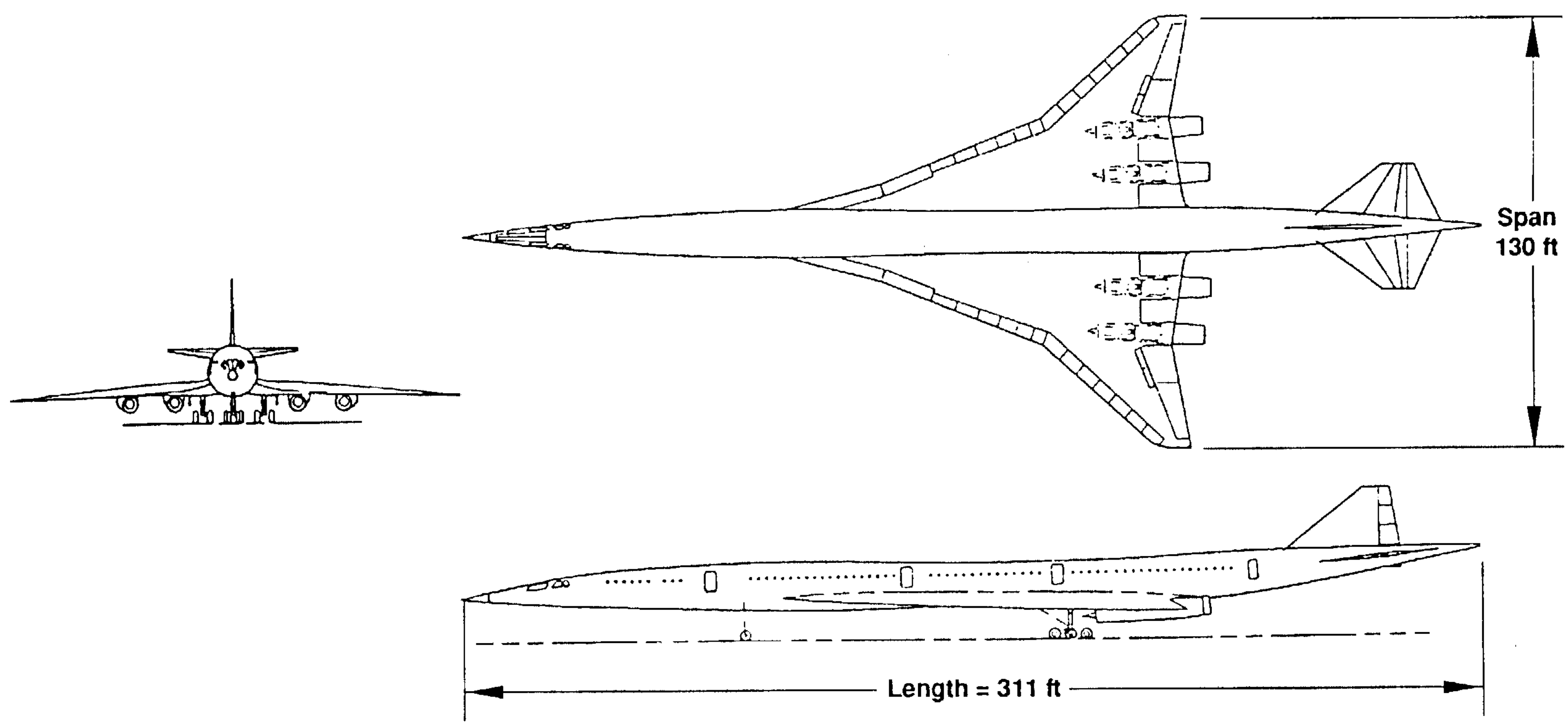


Unblended Configuration



High Speed Civil Transport

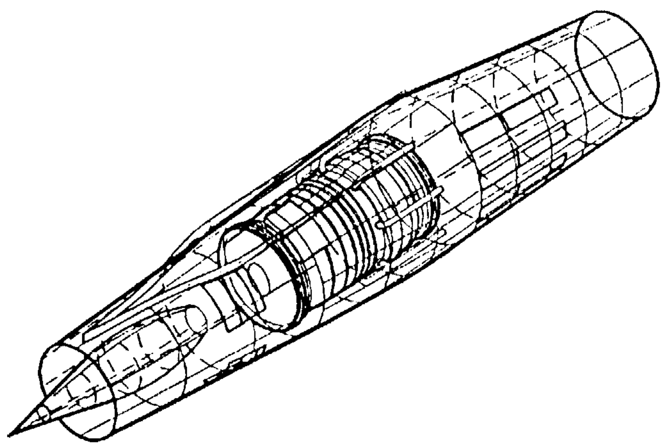
Baseline Configuration



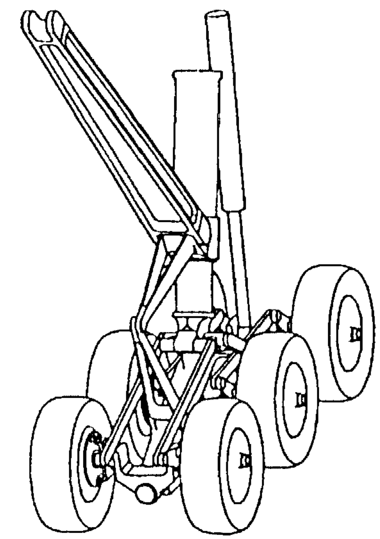
Range	5,000 nmi
Payload	302 passengers tri-class
MGW	705,000 lbs
OEW	275,000 lbs
Noise	FAR 36 stage III
Wing area	7,100 ft^2

High Speed Civil Transport

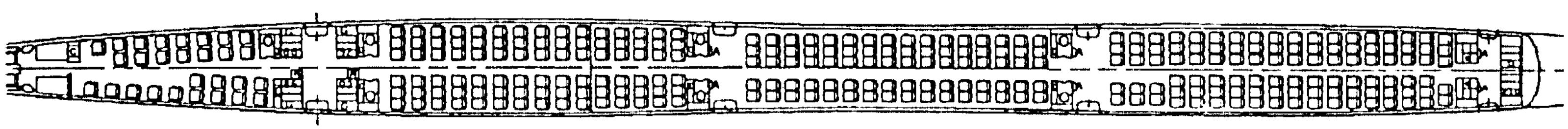
Baseline Features



Suppressed turbojet propulsion system



3-post 6-wheel steerable MLG



28 first class
38 In pitch

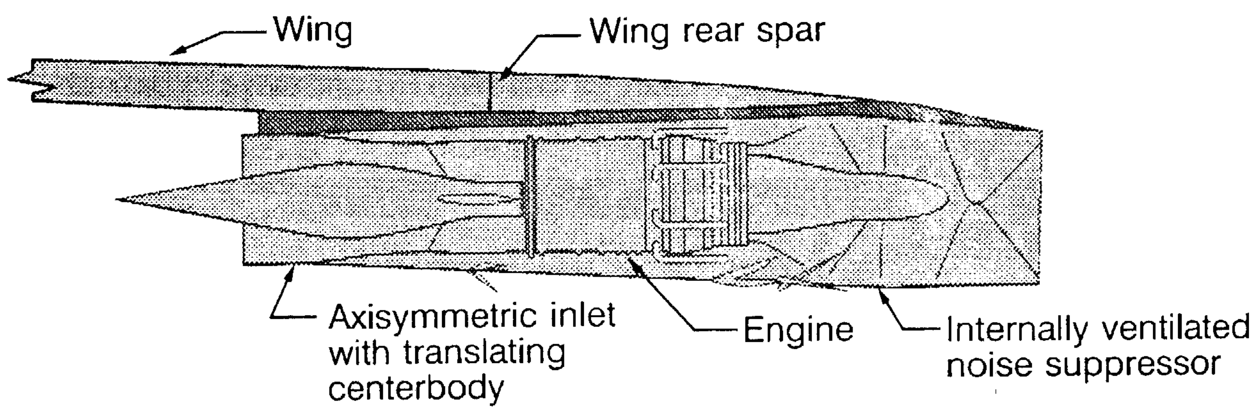
60 business class
36 In pitch

214 tourist class
33/34 In pitch

302 passengers

Interior arrangement

Baseline Engine Features



Engine	Turbine bypass turbojet
Nozzle	Internally ventilated noise suppressor
Inlet	Axisymmetric mixed-compression with translating centerbody
Combustor	Low emissions (5 to 8 lb NO_X/1,000 lb fuel)
Engine maximum airflow	460 lb/s
Takeoff thrust	62,200 lbs at $M = 0.2$
Pod length	345 in
Pod inlet diameter	53.9 in
Pod maximum diameter	73.8 in
Pod weight	14,100 lb

BRITISH AIRWAYS REVIEW

PURPOSE

" BEGIN A PROCESS THAT WILL LEAD TO AIRLINE PARTICIPATION IN THE ASSESSMENT AND DESIGN OF AN ECONOMICALLY VIABLE HSCT. "

TODAY'S MEETING

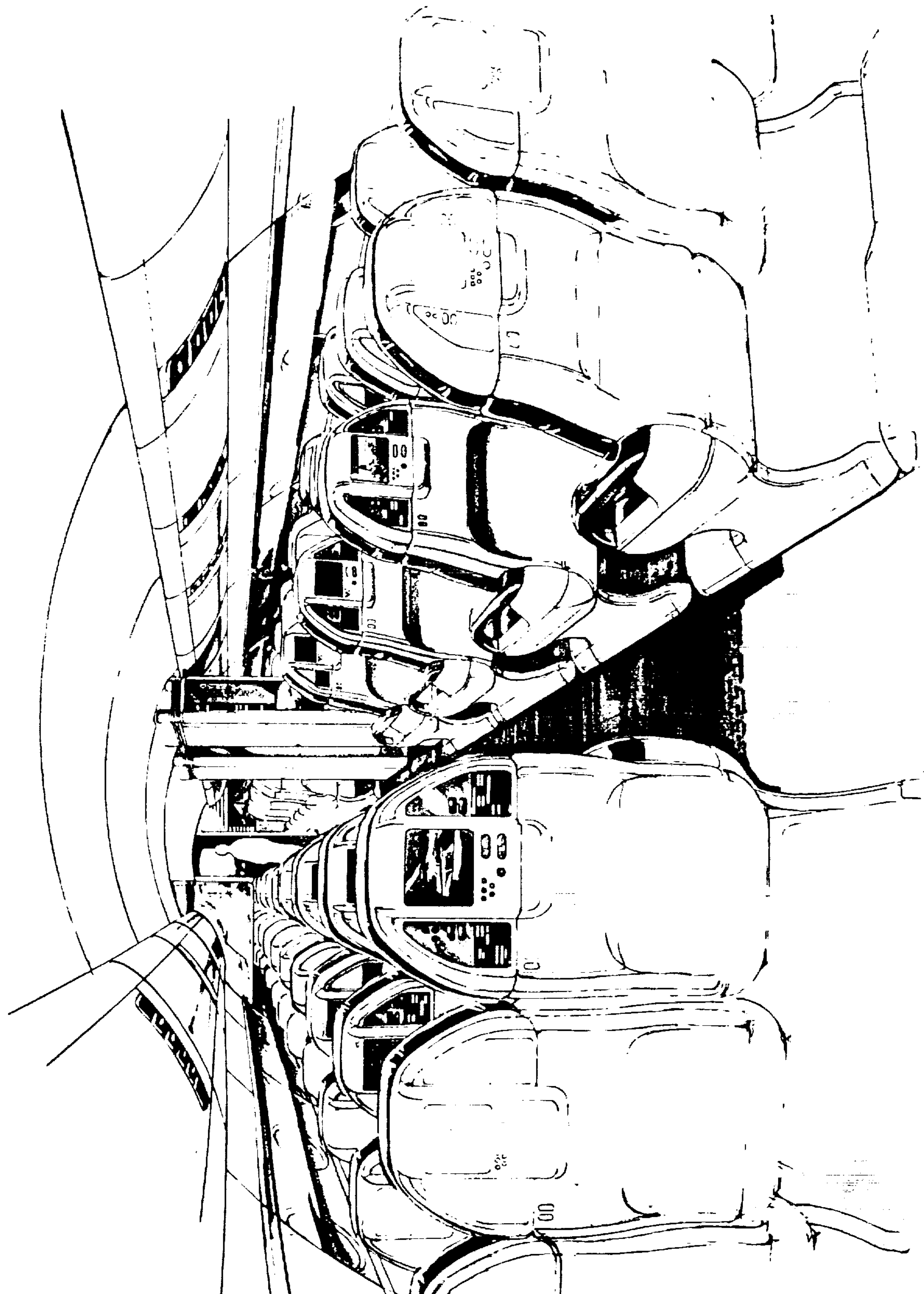
–SHARE WITH BRITISH AIRWAYS OUR ASSUMPTIONS AND STUDY RESULTS.

–LISTEN TO YOUR FEEDBACK.

–BEGIN TO PLAN FUTURE HSCT ACTIVITY WITH BRITISH AIRWAYS.

INTERIORS

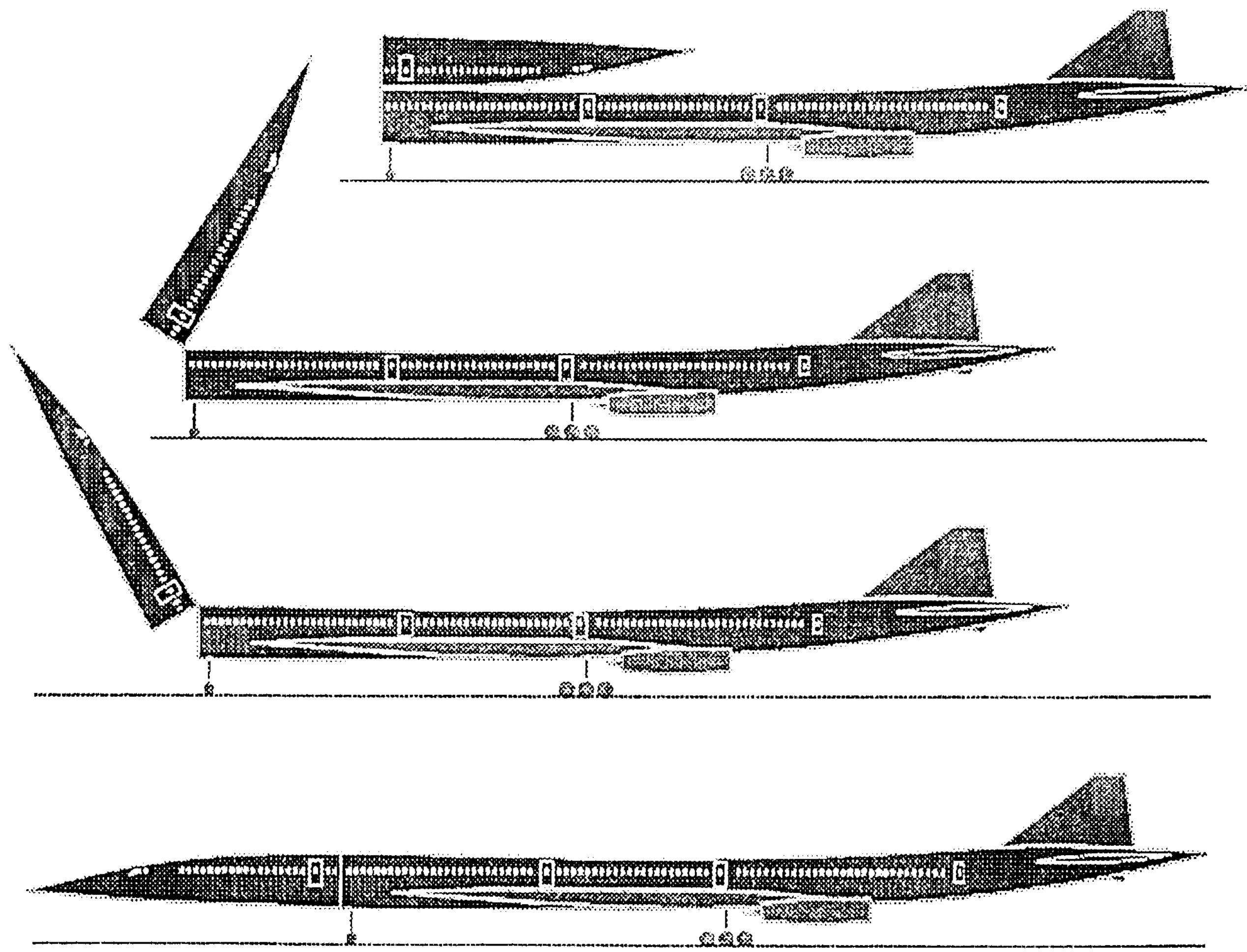
- DESIGN REQUIREMENTS & OBJECTIVES
- INTERIOR ARRANGEMENT
- CROSS-SECTIONS
- CARGO STUDIES
- EVACUATION ISSUES
- TEAGUE'S INTERIOR CONCEPTS



AIRPORT ISSUES

- DESIGN REQUIREMENTS & OBJECTIVES
- AIRPORT PARKING
- RUNWAY LOADING
- TAXIWAY TURNING
- TURN-AROUND
- GROUND HANDLING
- FLIGHT DECK OVERHANG

Preferred Airline Configuration



“Nonproblems”

- Field length requirements - same as large subsonic aircraft
- Runway separation - no more critical than large subsonic aircraft
- Turbulence impact on operations - less critical than large subsonic aircraft
- Fuels - jet A is satisfactory

HIGH SPEED CIVIL TRANSPORT

KEY PROGRAM ISSUES

TECHNICAL

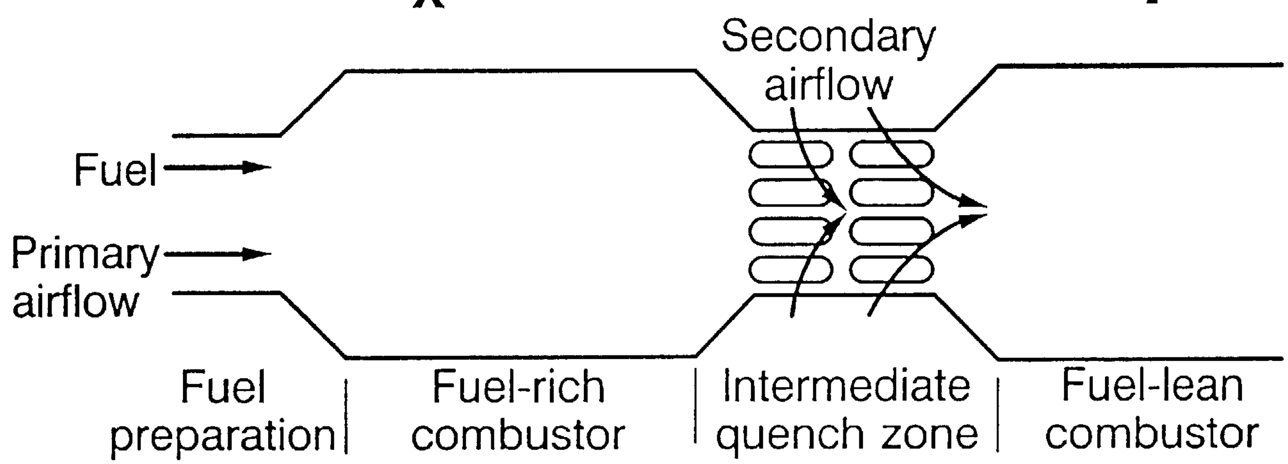
AIRFRAME

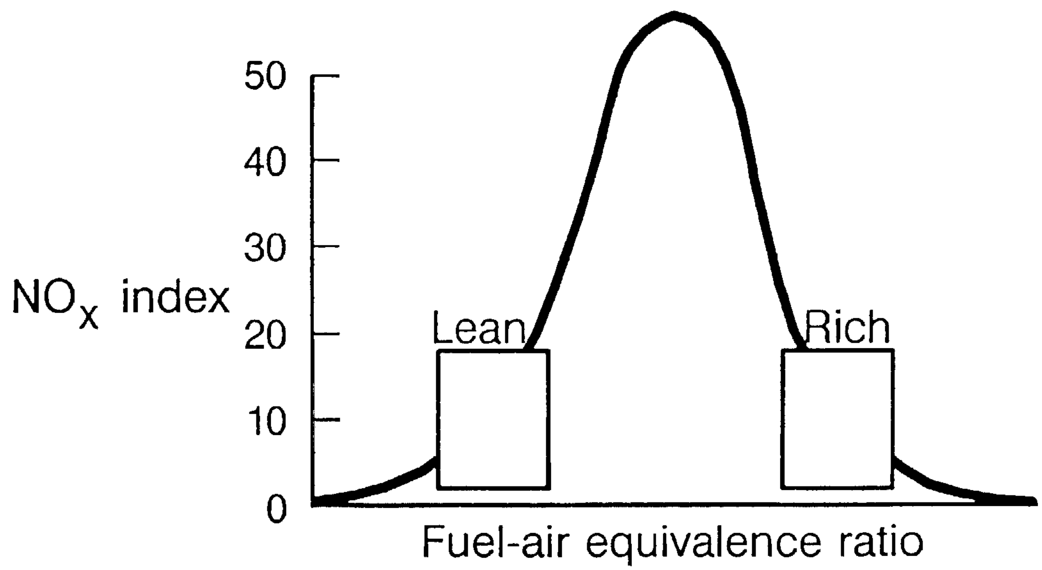
- HIGH TEMPERATURE COMPOSITE STRUCTURE
- JET NOISE SUPPRESSORS
- ENGINE INLET
- AERODYMANICS AND CONTROLS

ENGINE

- LOW EMISSIONS BURNERS
- VARIABLE CYCLE ENGINE CORE

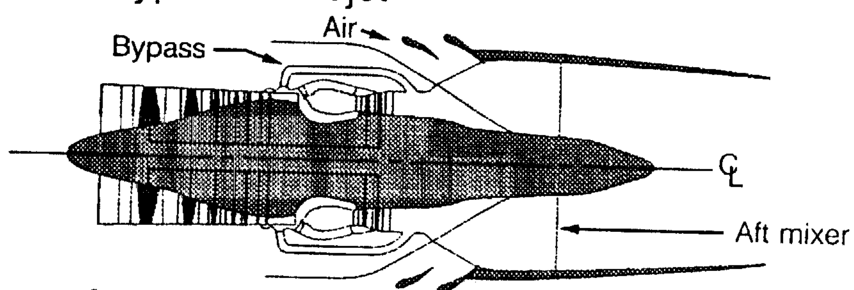
Low NO_X Combustor Concept





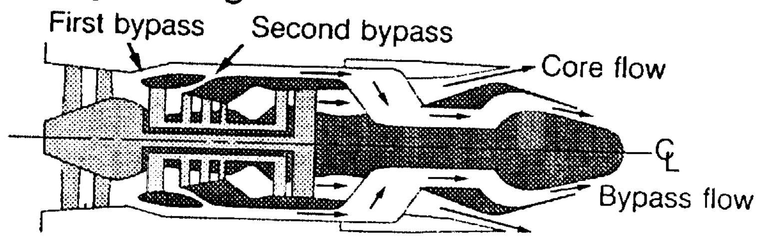
Engine Developments

Pratt & Whitney
Turbine bypass turbojet



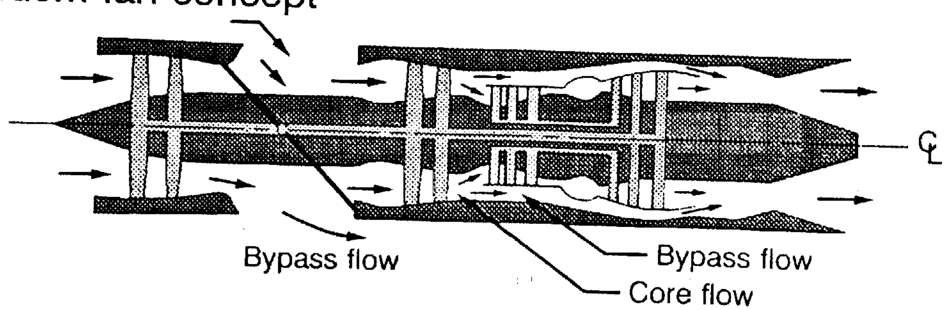
- Single spool
- Simple concept
- High-temperature materials
- Noise-suppression nozzle
- Low-emission combustor

General Electric
Variable cycle engine



- Dual spool
- Variable geometry
- High-temperature materials
- Low-emission combustors
- Noise-suppression nozzle

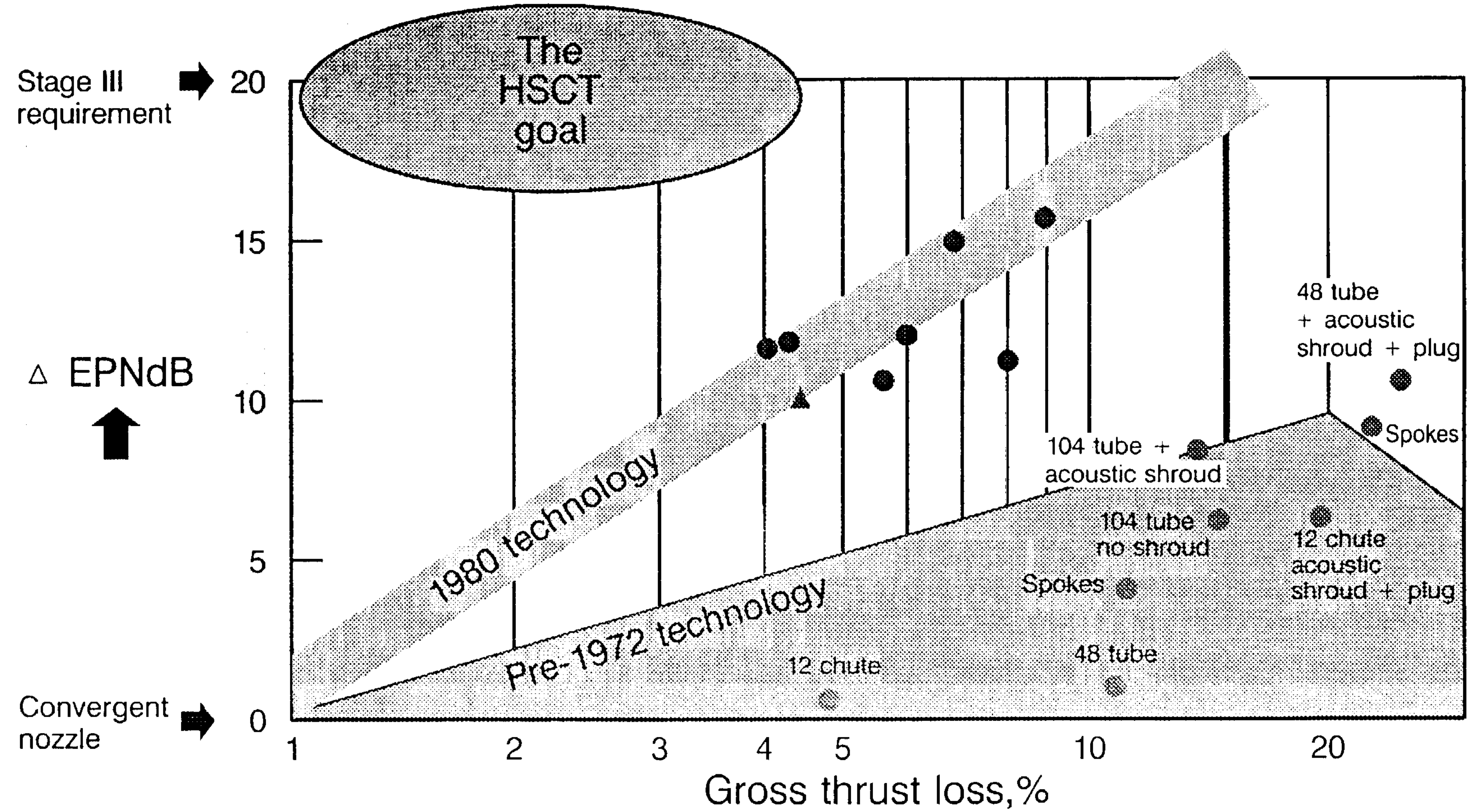
Rolls Royce/Snecma
Tandem fan concept



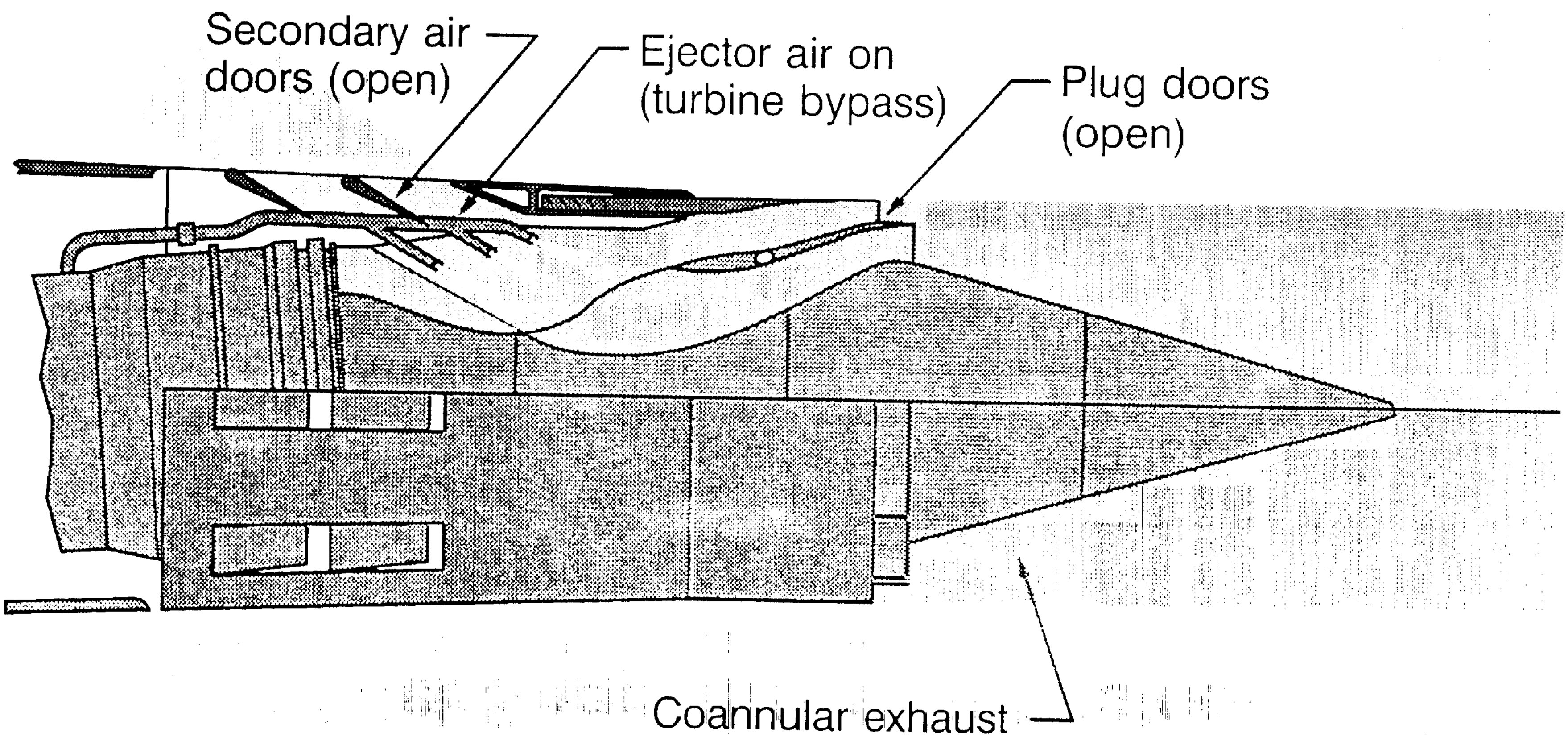
- Dual spool
- Big valve
- Heavier
- Longer
- Conceptual design

Jet Suppressor Technology

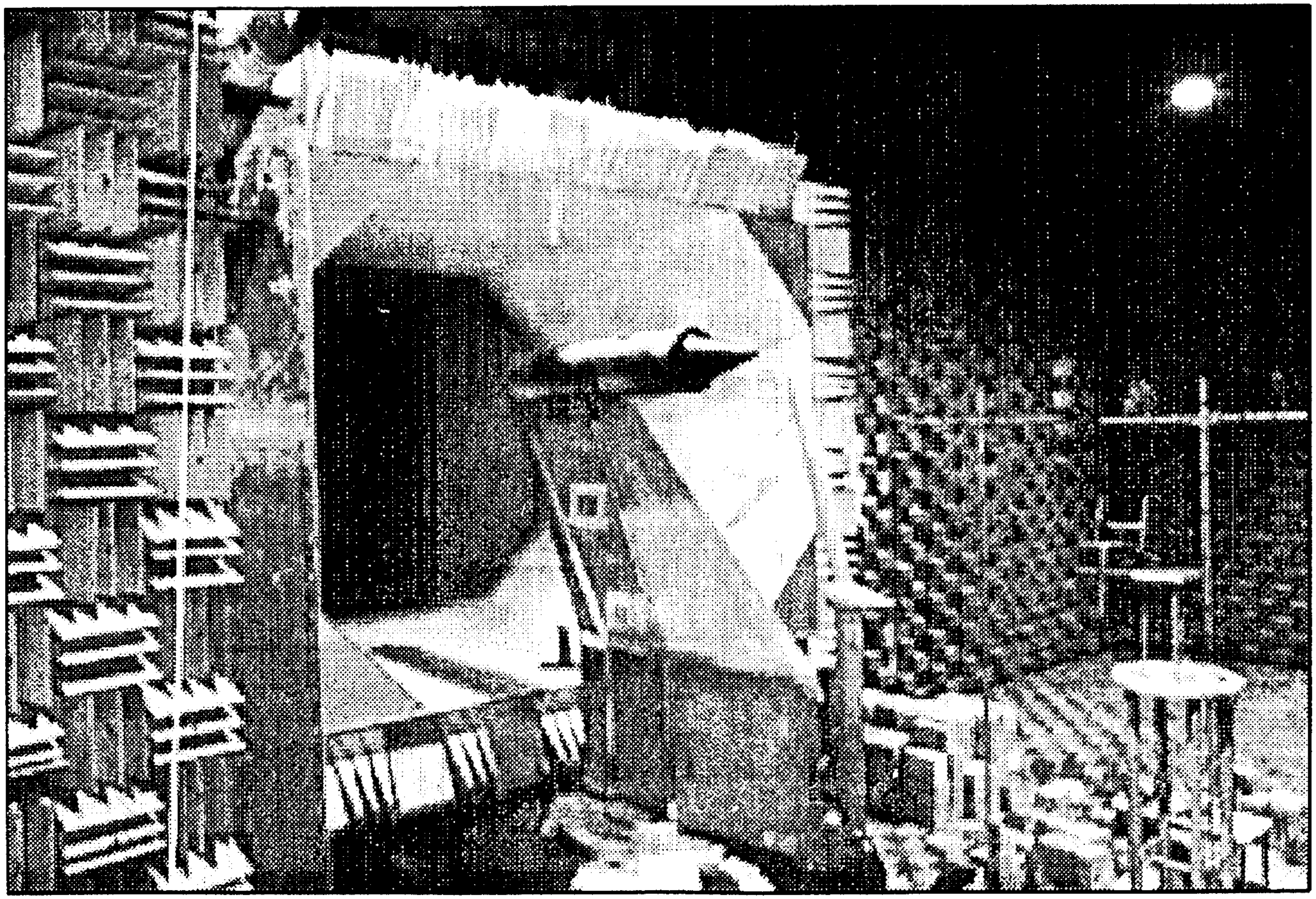
Late 1980s



1989 NACA Nozzle Concept



Large-Scale Aeroacoustic Facility (LSAF)



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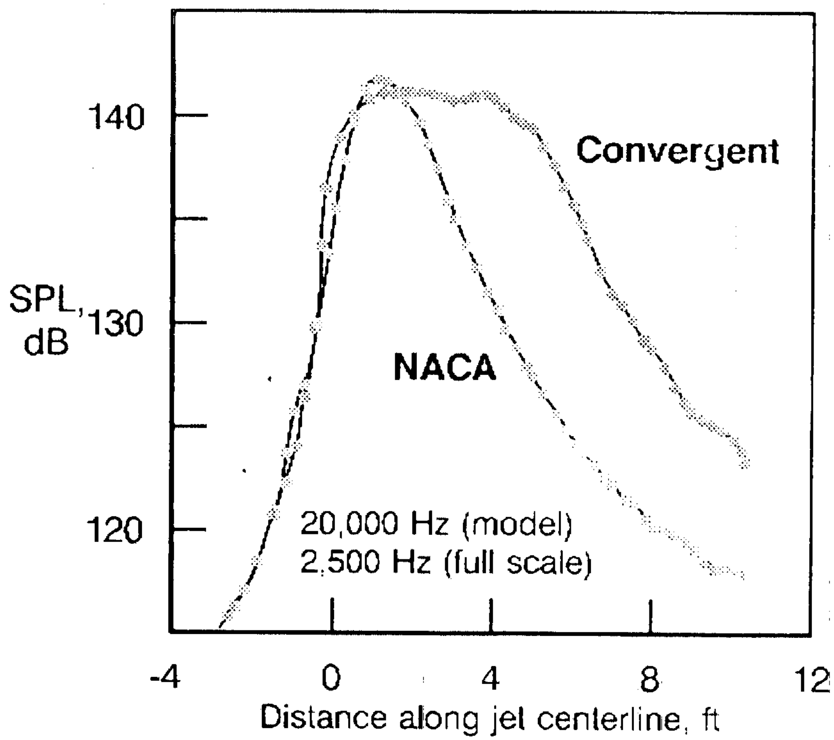
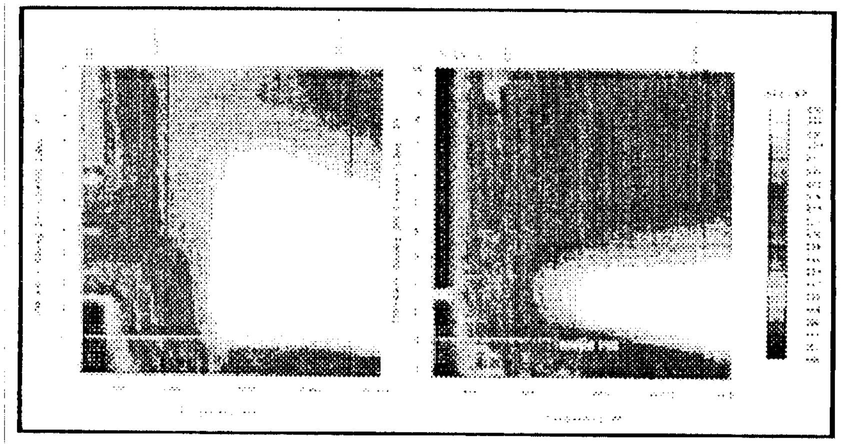
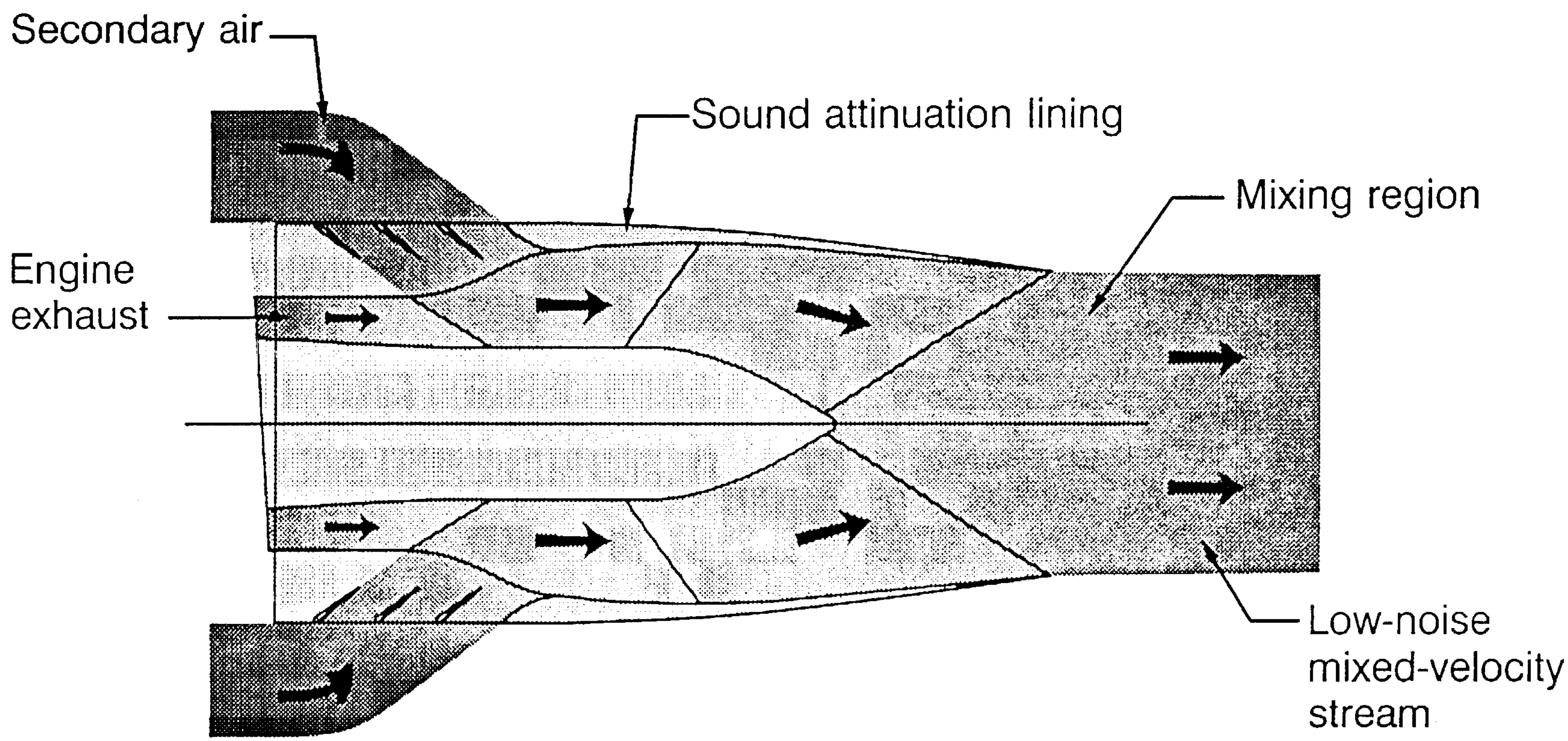
NACA Nozzle Results



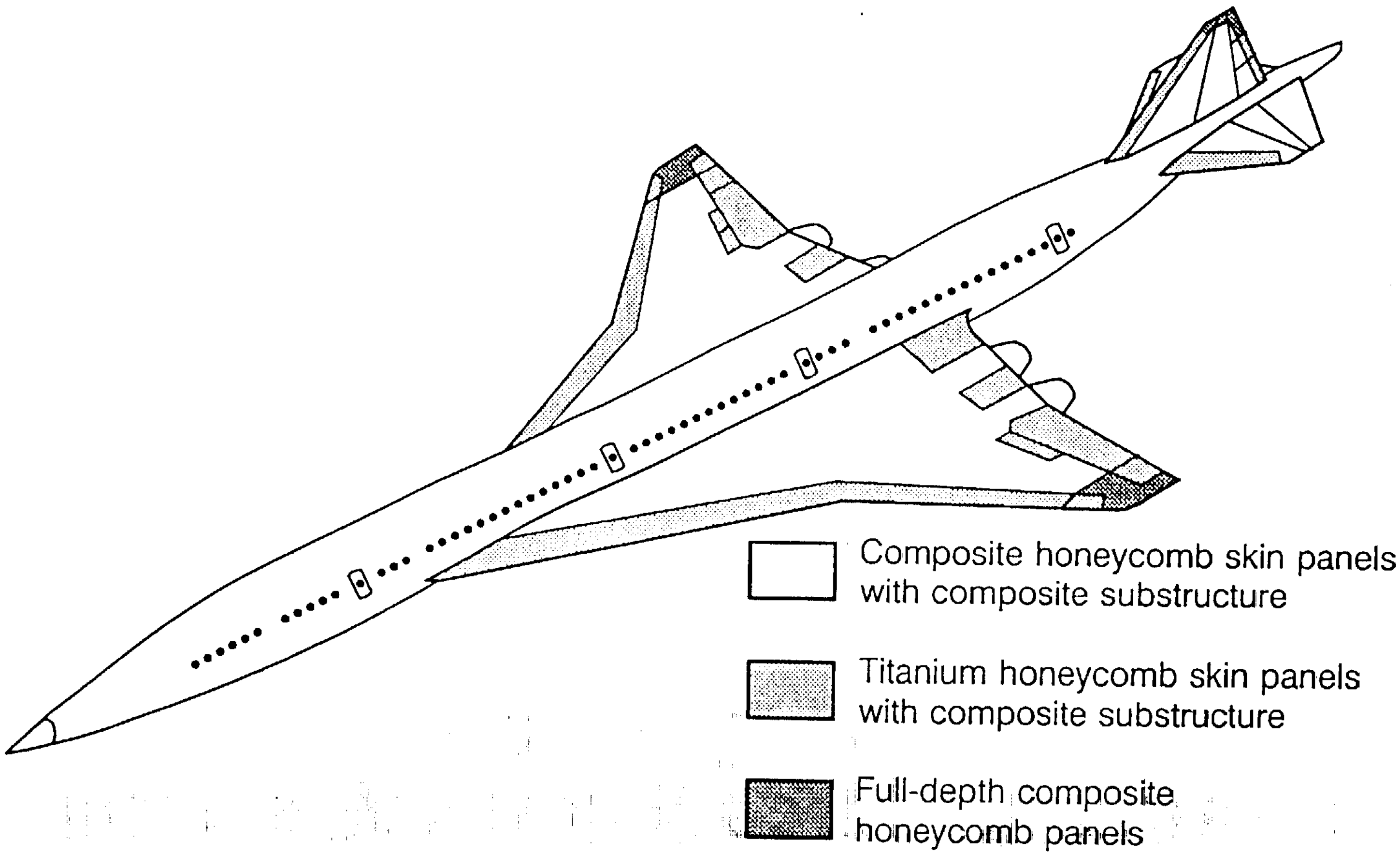


- Low-frequency jet noise reduced
- Low thrust loss
- Mixing noise remained high
- Concept fell short of expectations

Internally Mixed Ejector - Suppressor Nozzle Concept



Proposed Usage of Materials for the HSCT



Materials Technology Development Tasks

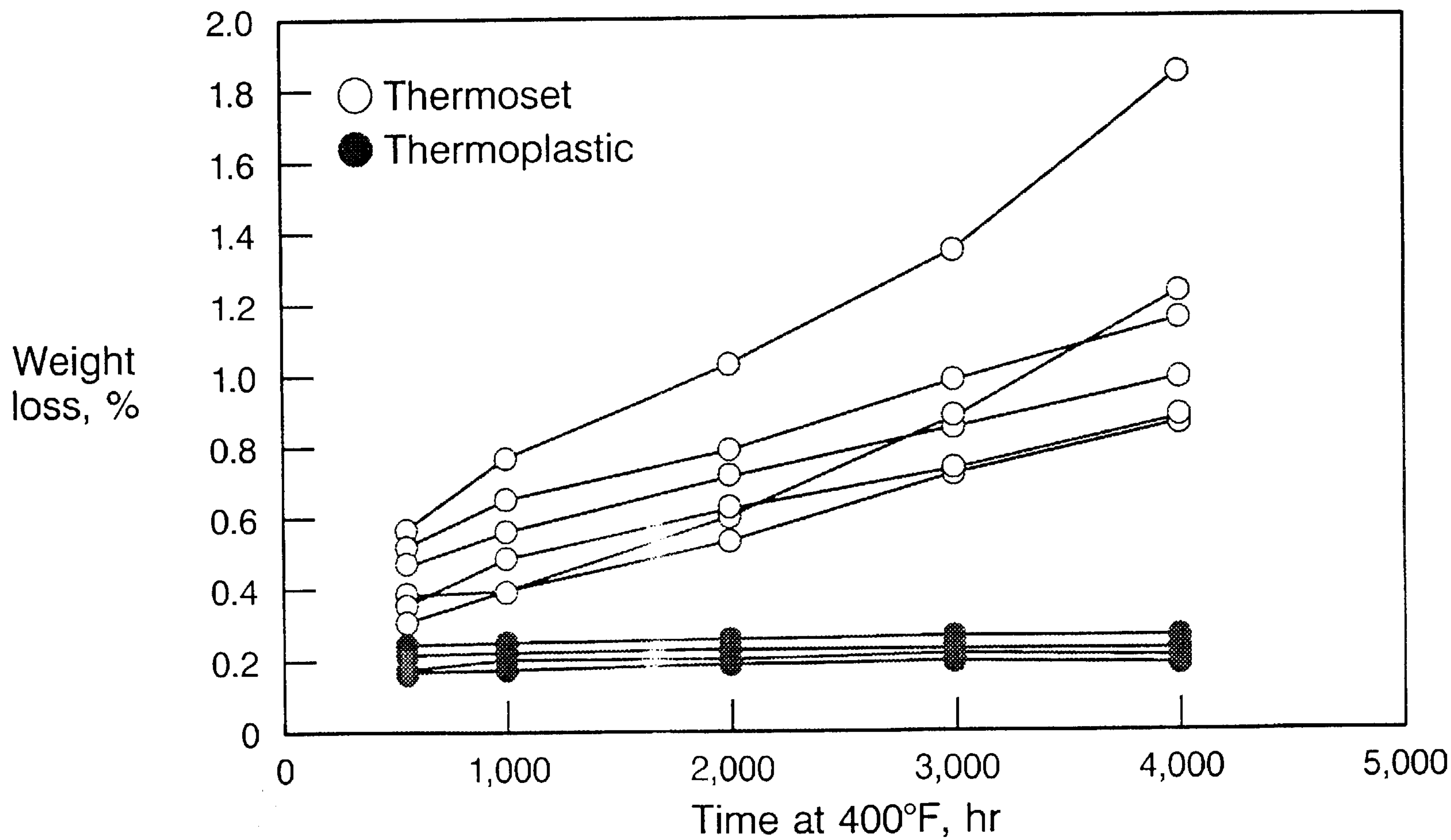
- Structural materials
  - Composites
  - Metals
- Adhesives
- High-temperature sealants
- Finishes
- Lubricants

Structural Composites Screening Matrix

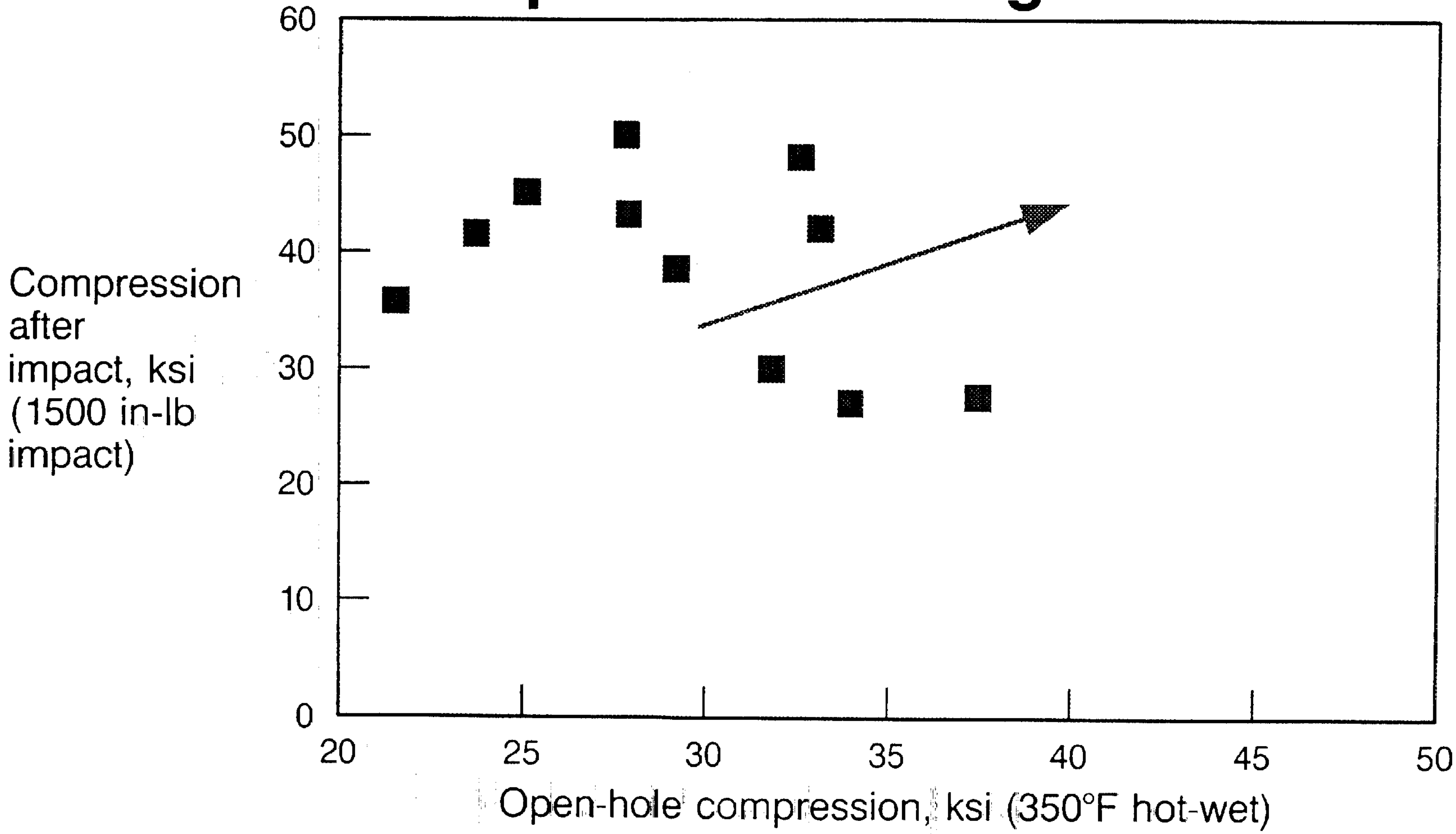
◐ Scheduled
○ In testing
● Complete

	Thermoplastics						Thermosets										
	1	2	3	4	5	6	1	2	3	4	5	6	7	8	9	10	11
Open-hole compression	●	●	●	●	●	◐	●	●	●	●	●	●	●	●	●	●	○
Open-hole tension	●	●	●	●	●	◐	●	●	●	●	–	●	●	●	●	●	○
Uni compression	●	●	●	–	–	◐	●	●	●	●	–	–	–	–	●	●	◐
Uni tension	●	●	●	–	–	◐	●	●	●	●	–	–	–	–	●	●	◐
CAI	●	●	●	●	●	◐	●	●	●	●	●	●	●	●	●	●	○
G_{IC}	●	–	●	–	–	◐	●	●	●	●	–	–	●	●	●	●	◐
G_{IIC}	●	–	●	–	–	◐	●	●	●	●	–	–	●	●	●	●	◐
Fluid sensitivity	●	●	●	●	●	●	●	●	●	●	–	●	●	●	●	●	○
Compressive interlaminar shear	◐	●	●	●	●	●	●	●	●	●	●	–	–	●	●	●	◐

Isothermal Aging

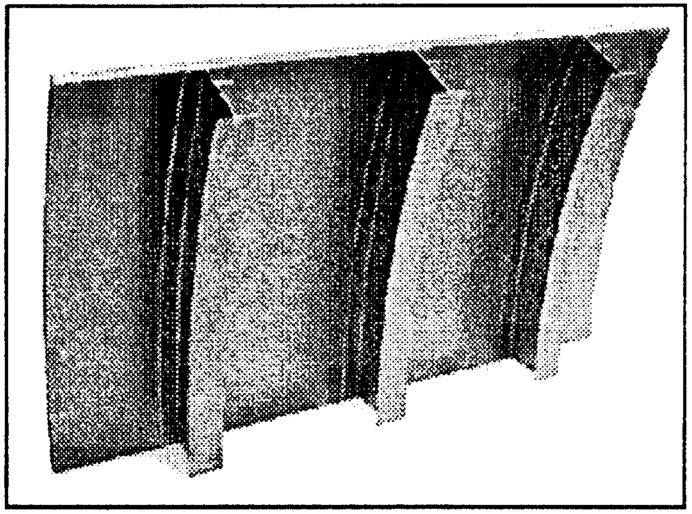


Damage Tolerance Versus Compression Strength

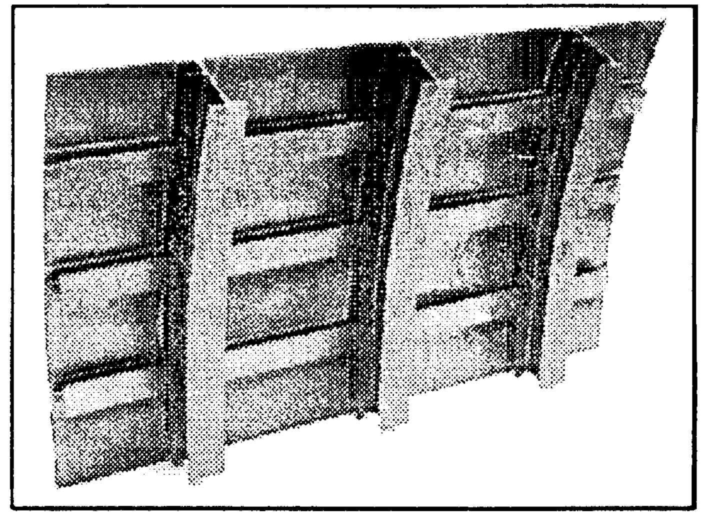


Manufacturing Research and Development

3- by 5-ft Body Panels



Honeycomb panel

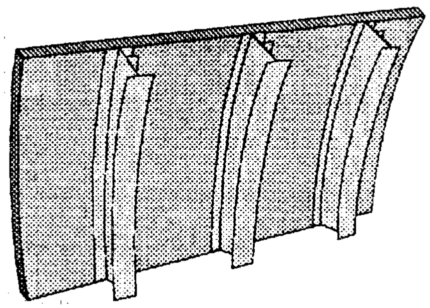


Skin stringer panel

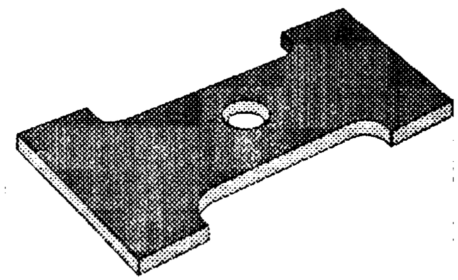
Producibility issues

- Cure cycle optimization
- Layup properties
- Titanium-core bonding
- Laminate thickness over core
- Bagging requirements

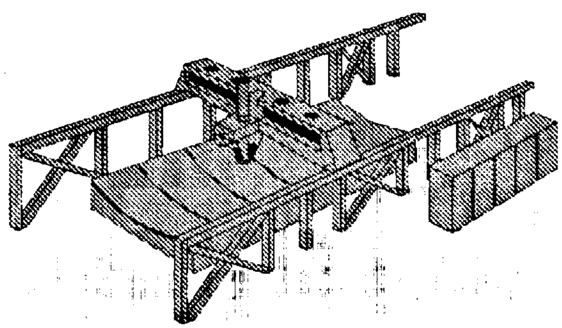
Composite Structure Development



Structural
design concepts
- Weight
- Durability
- Cost

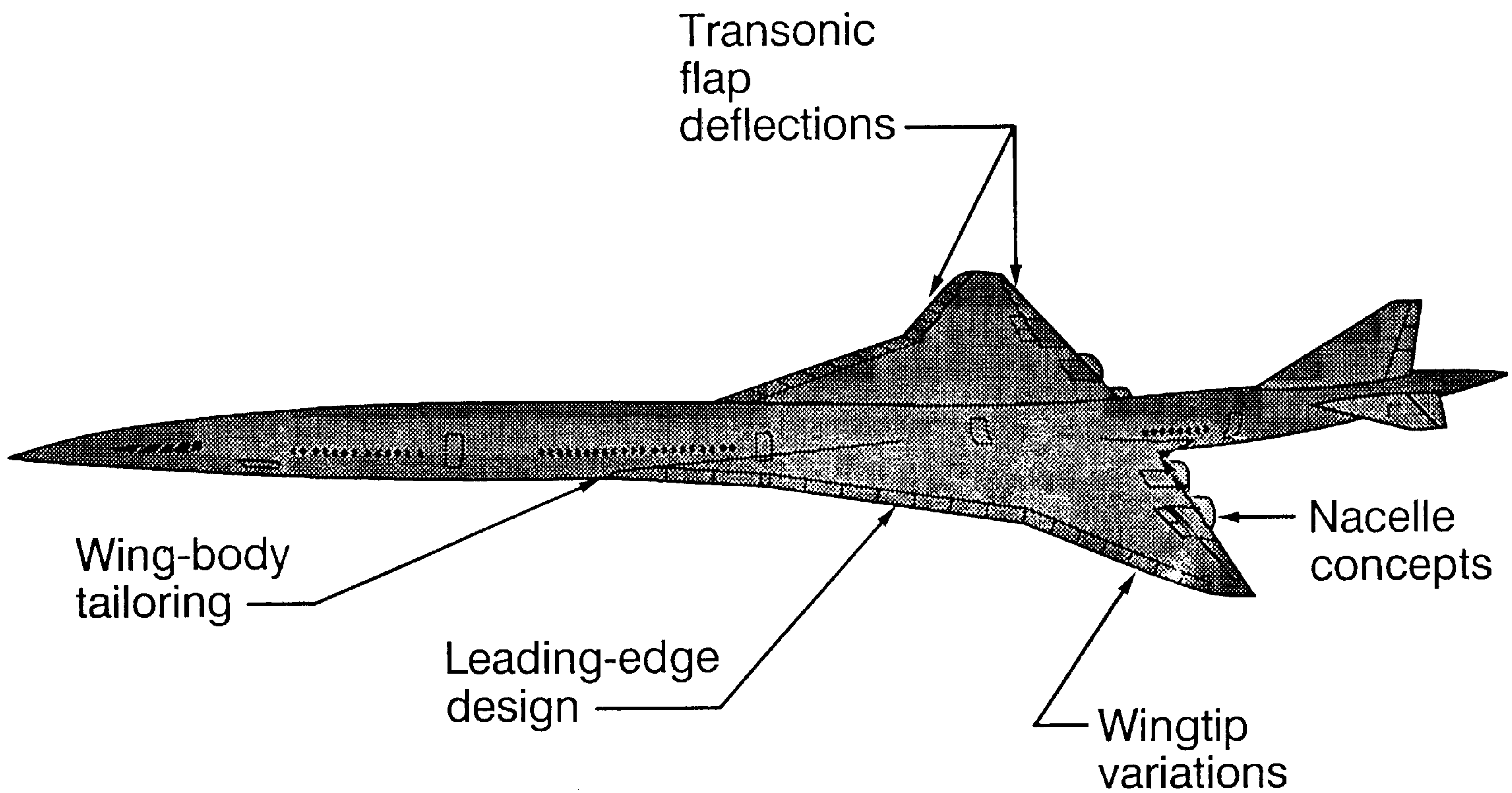


Materials development
- Properties
- Temperature capability
- Durability
- Cost

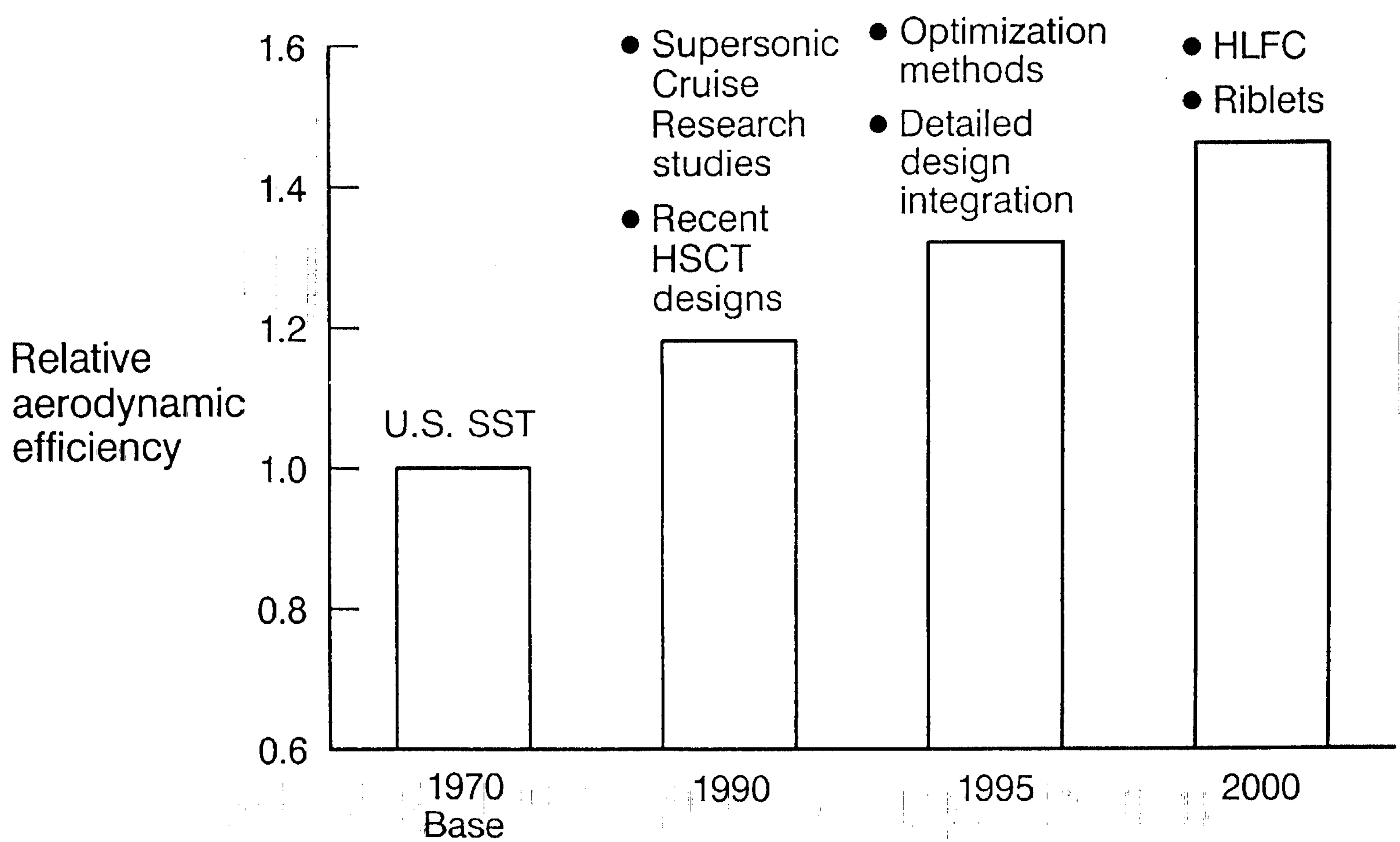


Manufacturing
development
- Producibility
- Tooling and capital
- Quality
- Cost

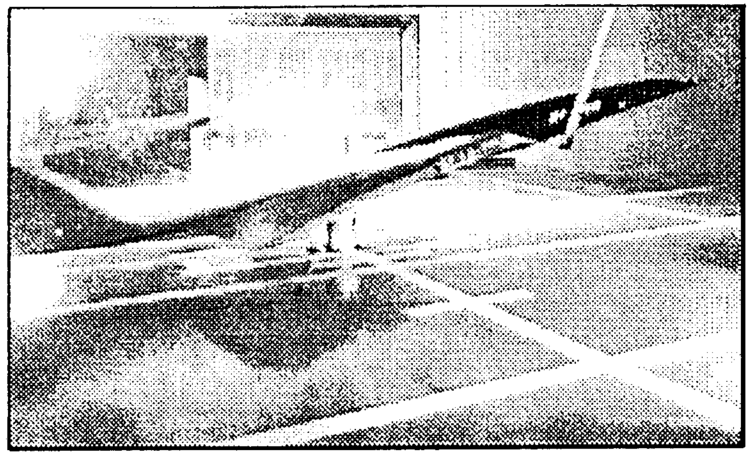
High-Speed Aero Optimization

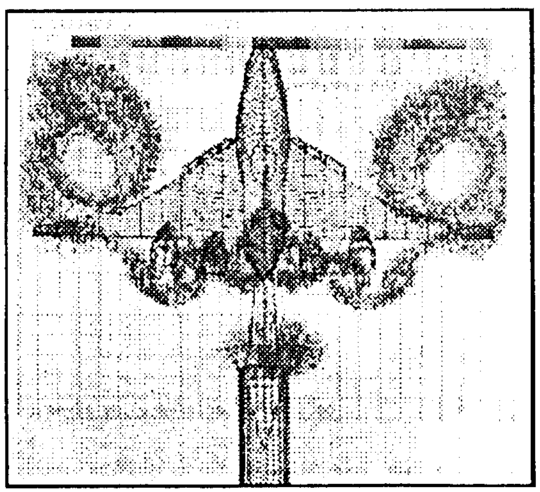


Aerodynamic Efficiency Improvement Projections



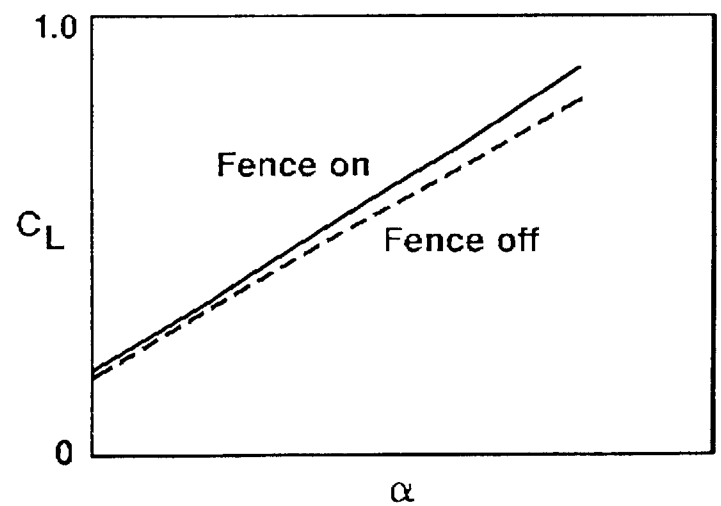
Vortex Fence





High-lift Vortex Amplification

Effect of Vortex Fence in Ground Effect



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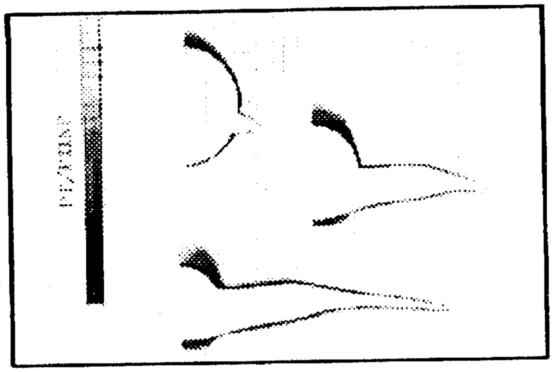
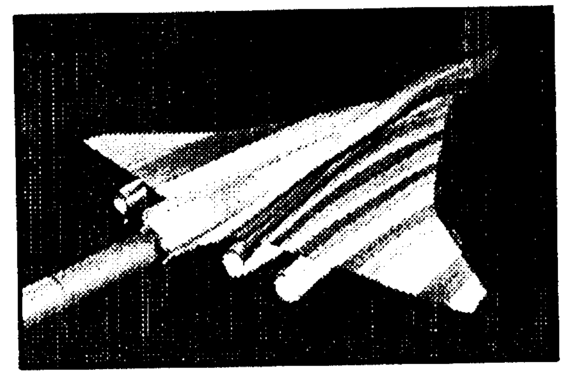
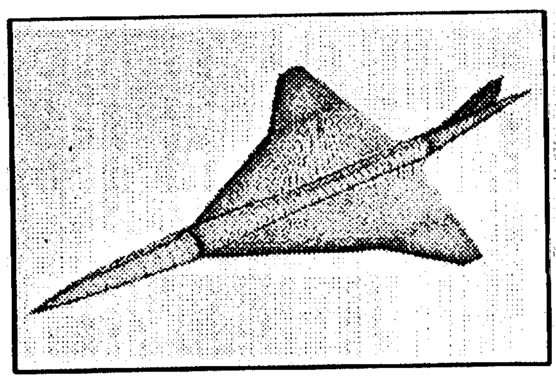
High-Speed Aerodynamics



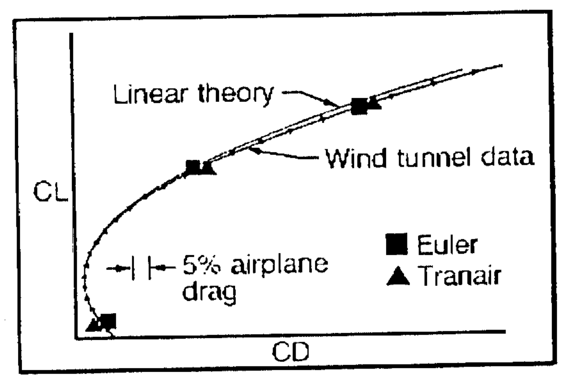
Flow quality
Parabolized Navier-Stokes
(Total pressure)



Boeing supersonic wind tunnel

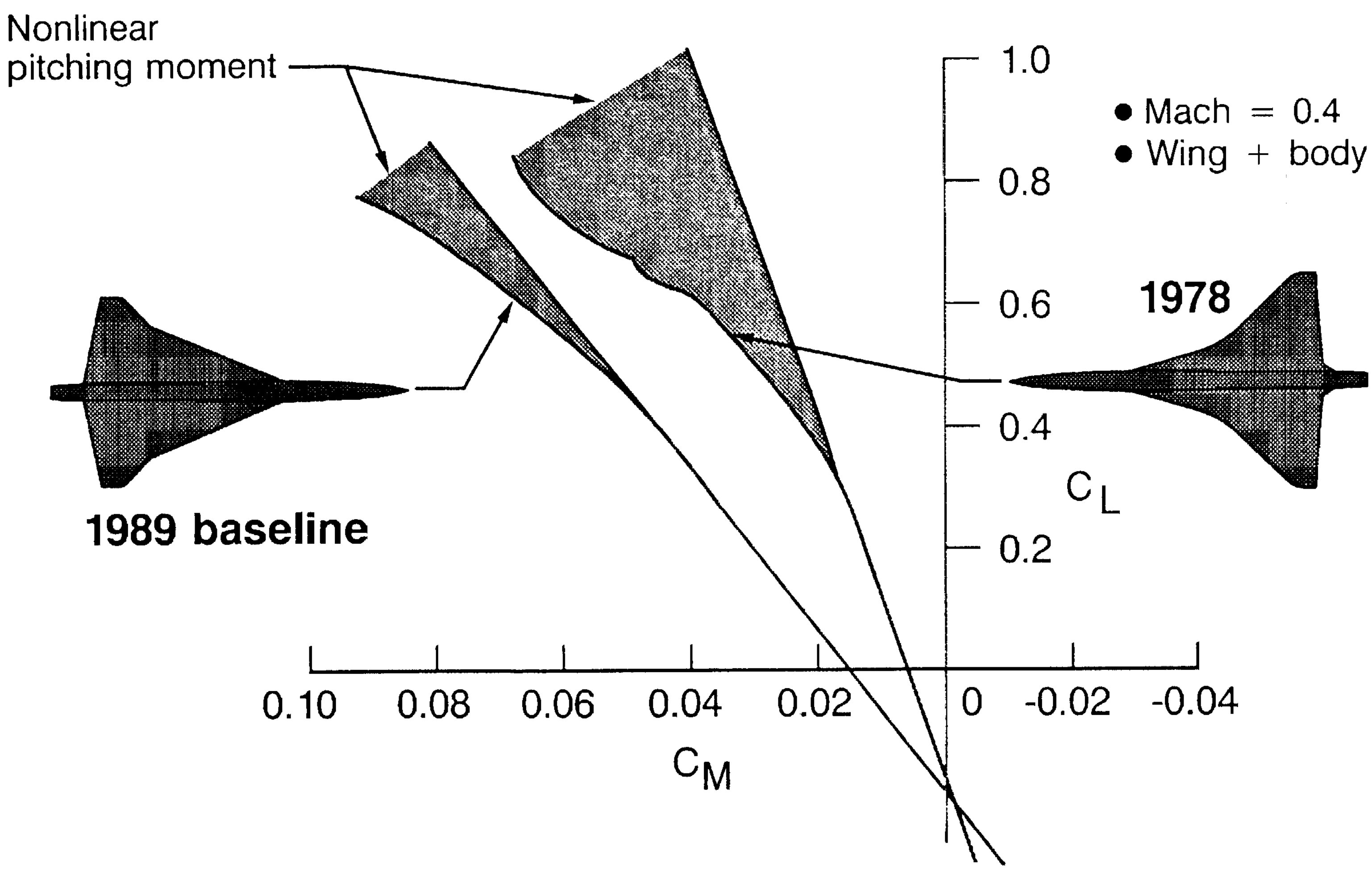


Drag prediction
Euler
Full potential (Tranair)
Linear potential

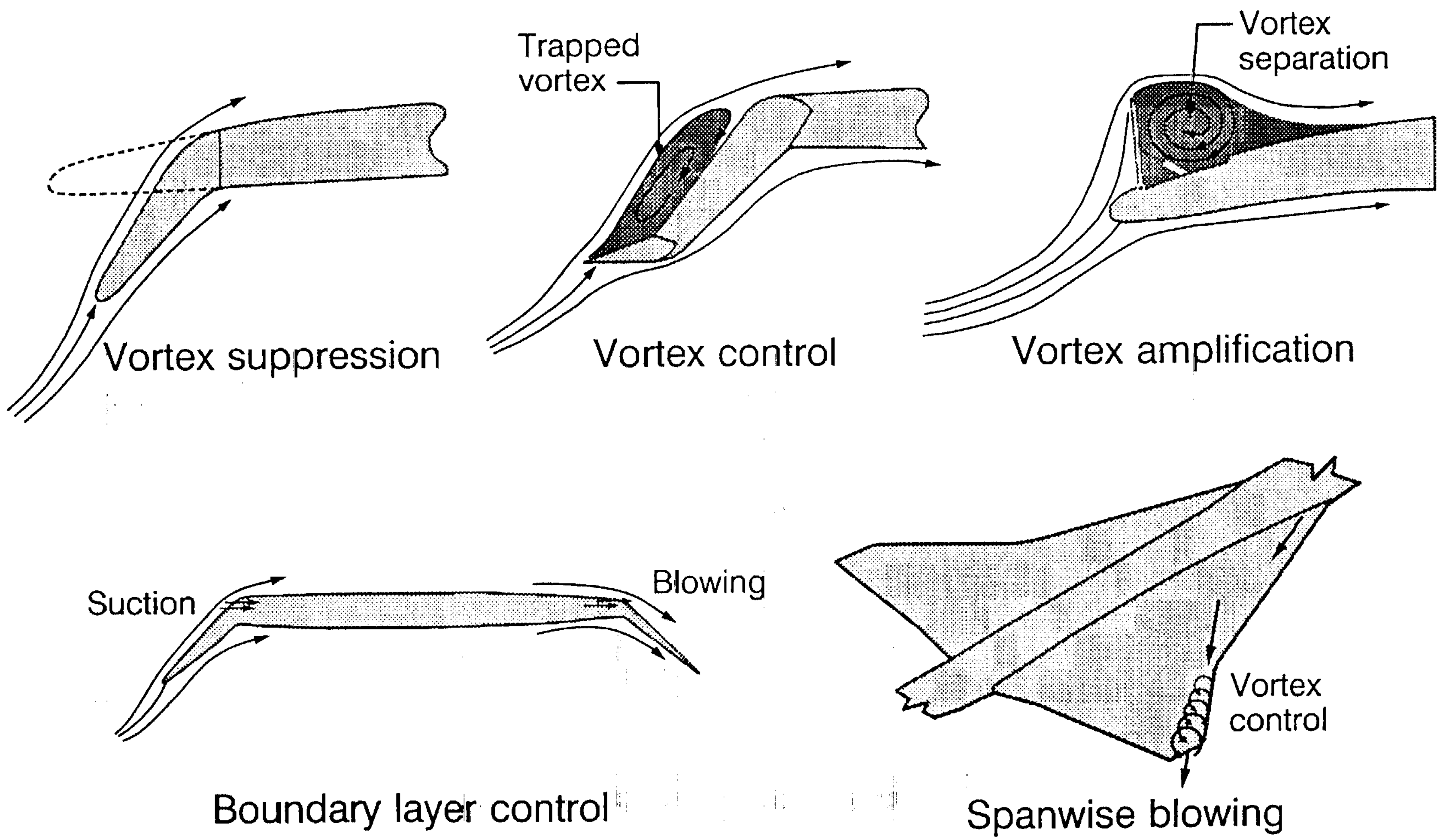


Test versus theory comparison

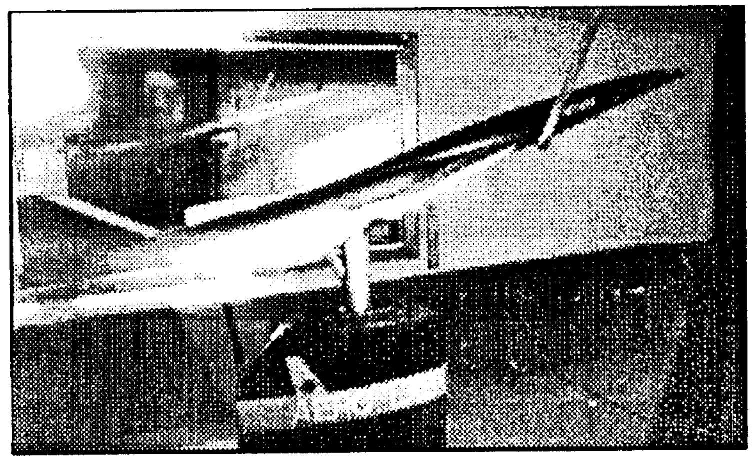
Pitching Moment



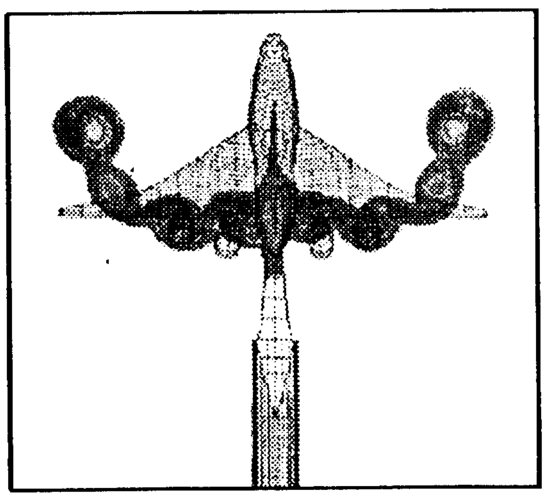
High-Lift System Concepts



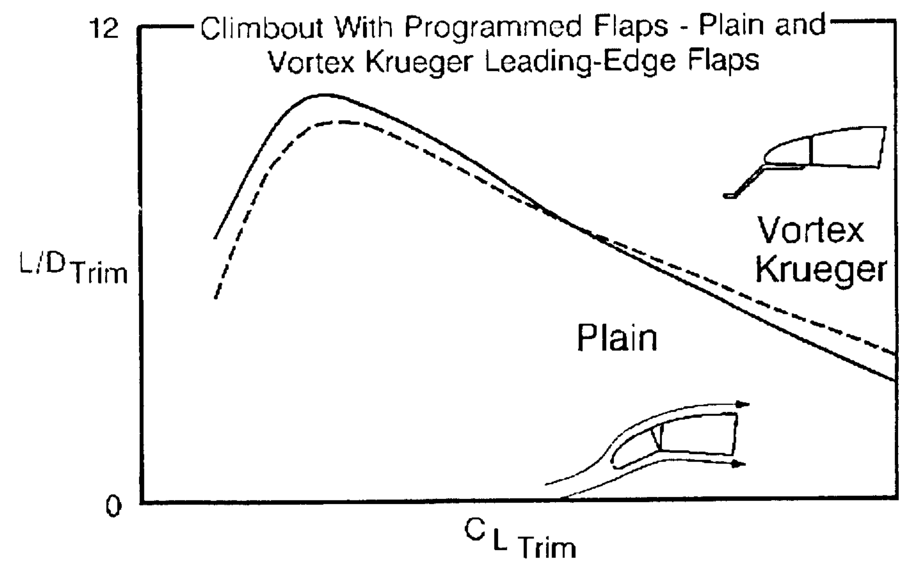
Vortex Krueger Flaps



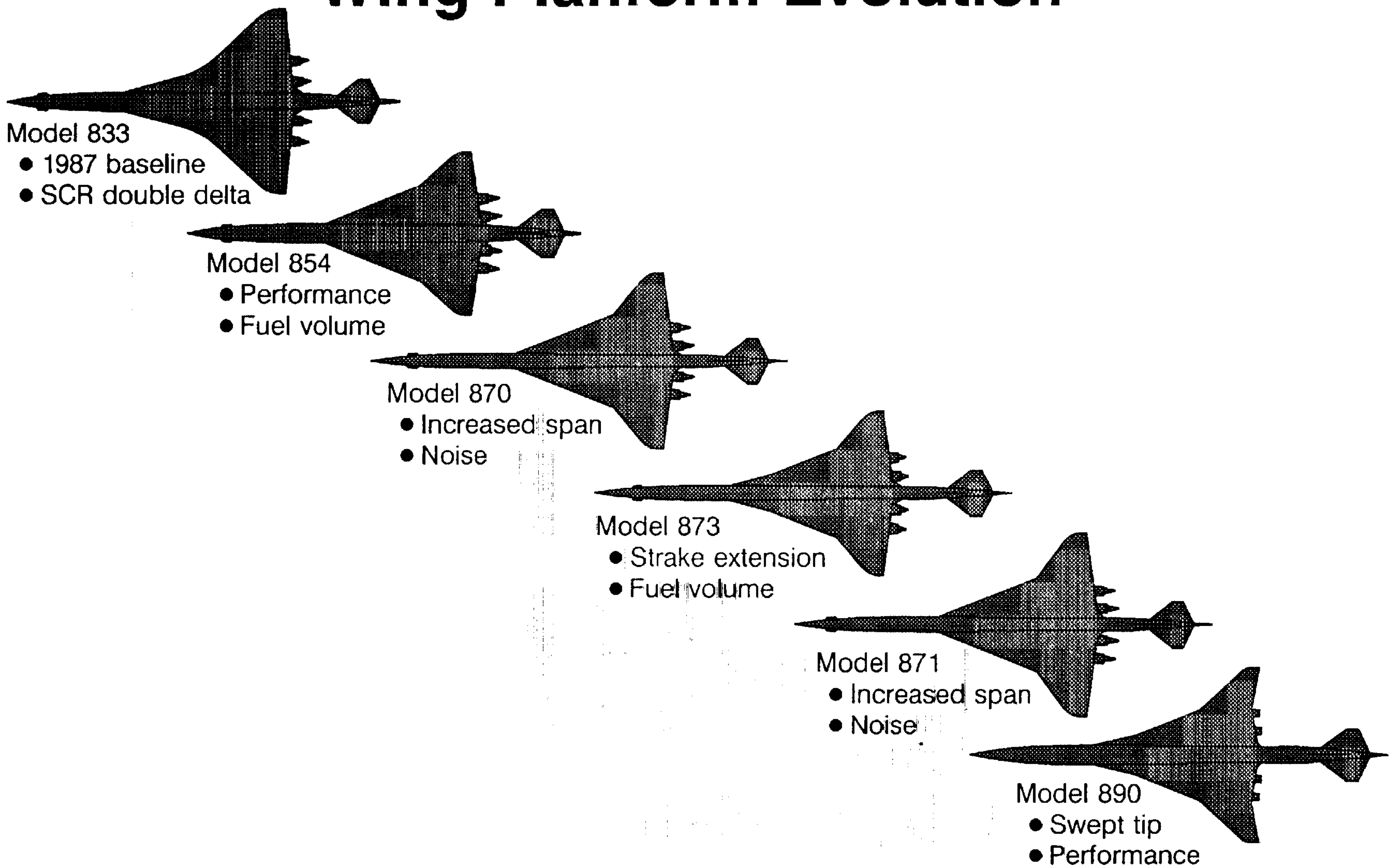
Vortex Krueger
Trapped Vortex



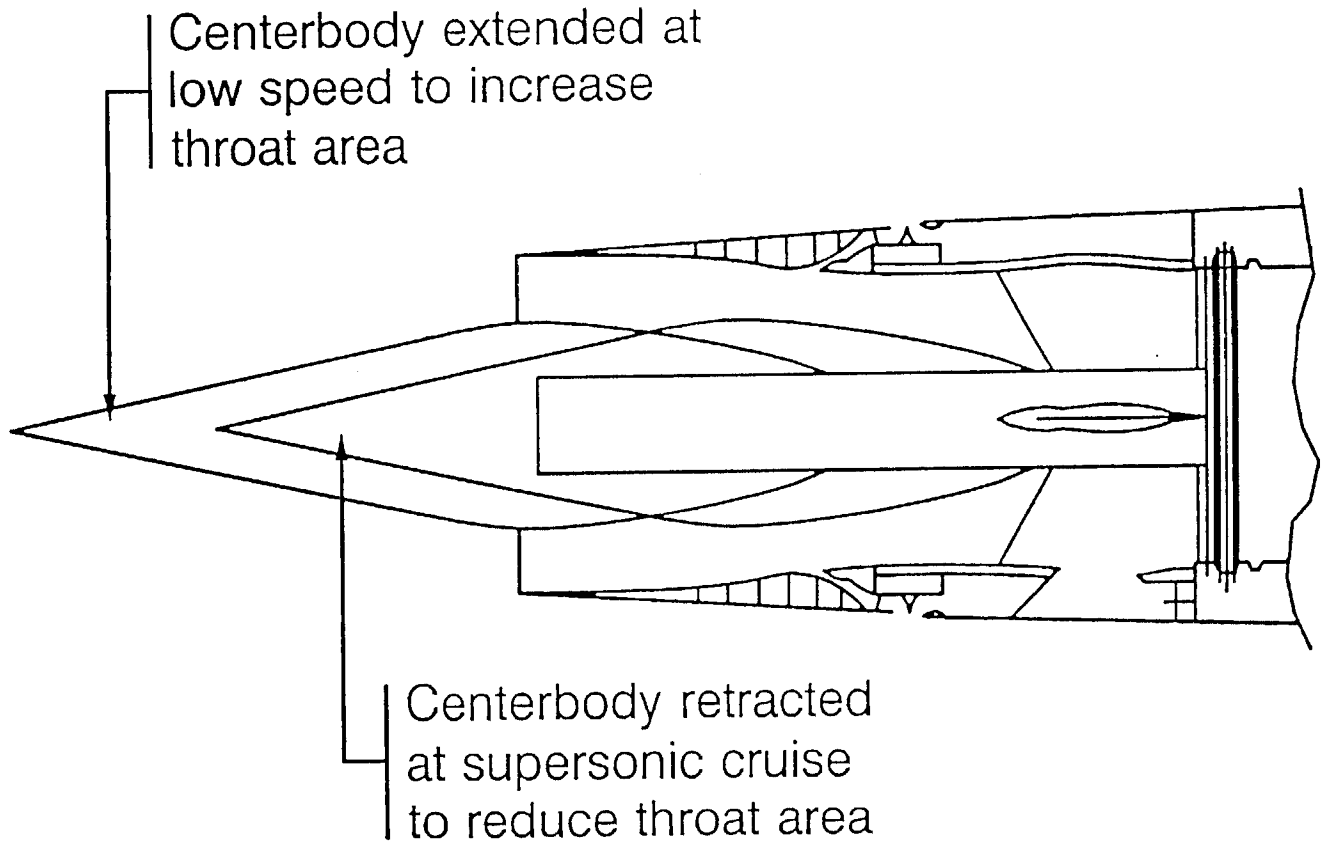
High L/D - Attached Flow



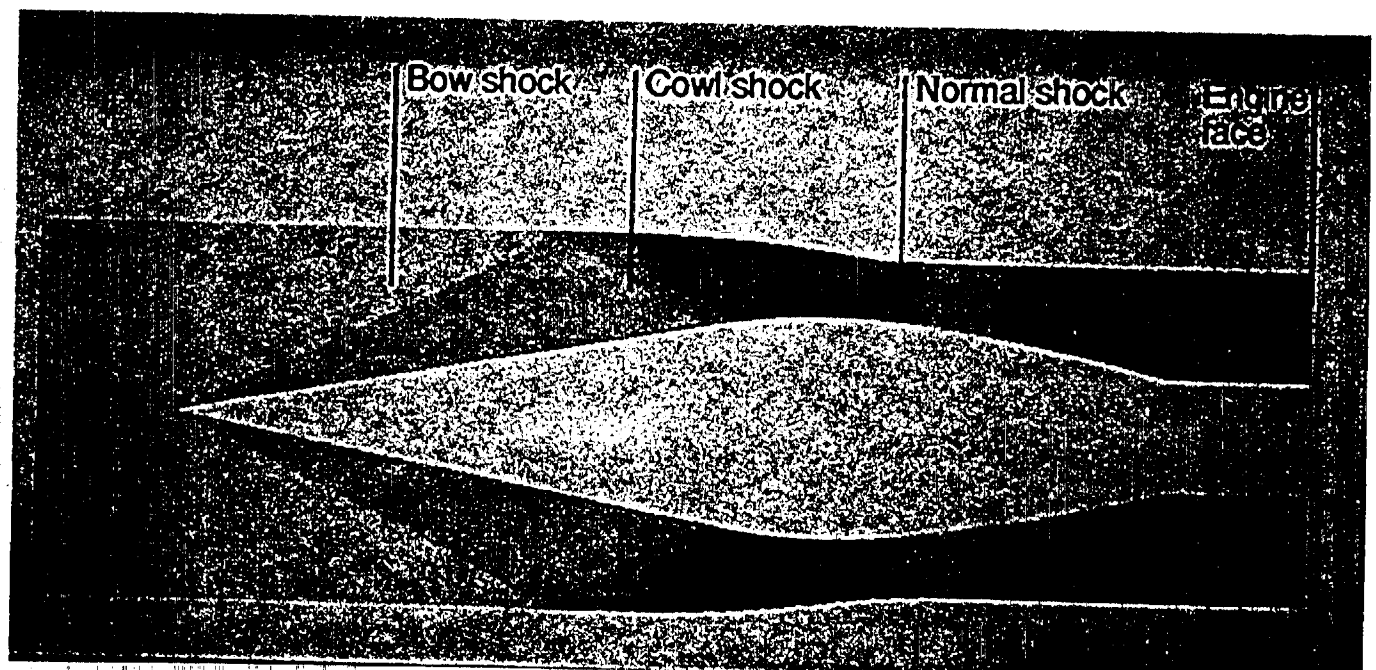
Wing Planform Evolution

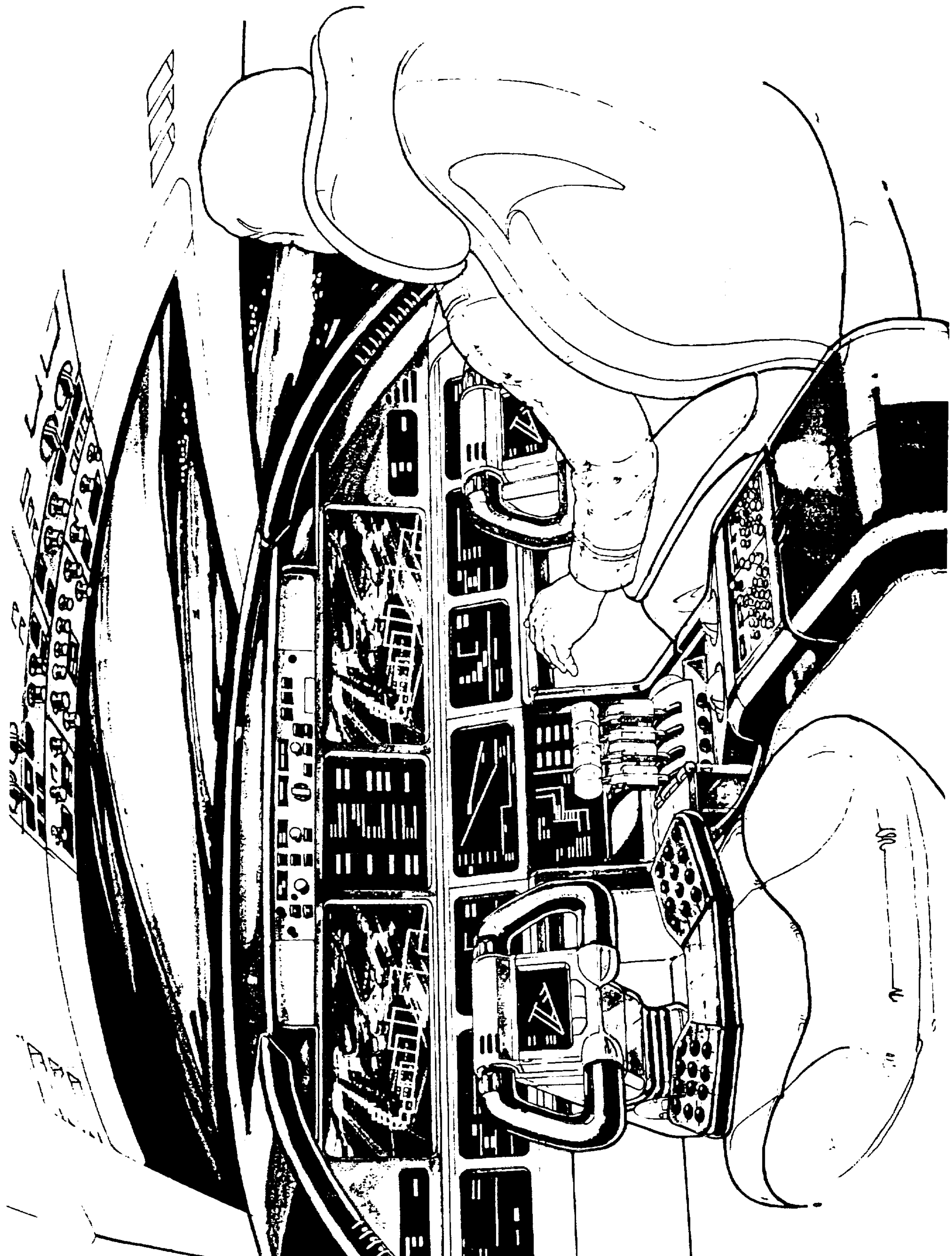


Variable Geometry Inlet Concept



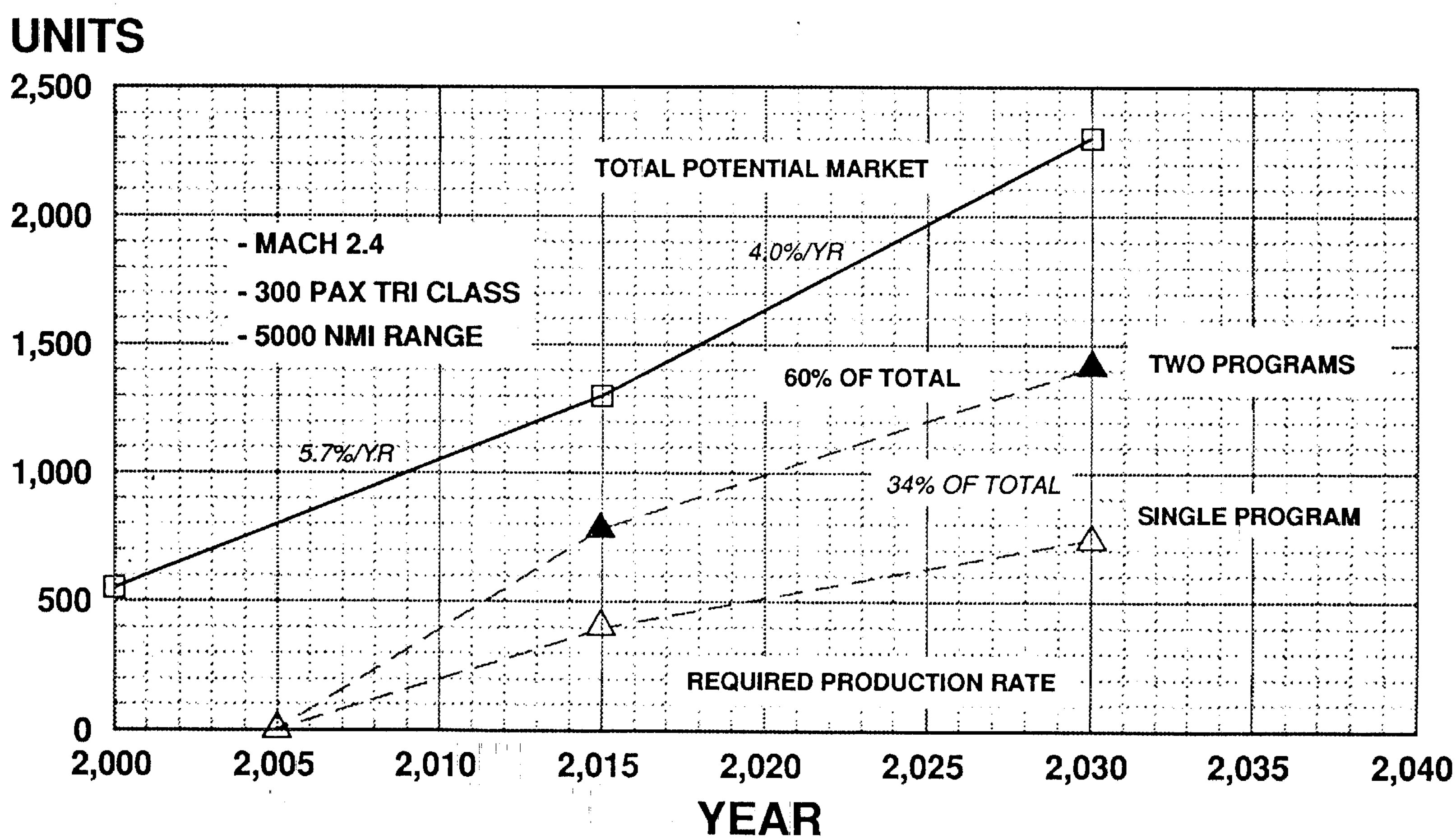
CFD Representation of the Inlet Operating at Mach 2.4



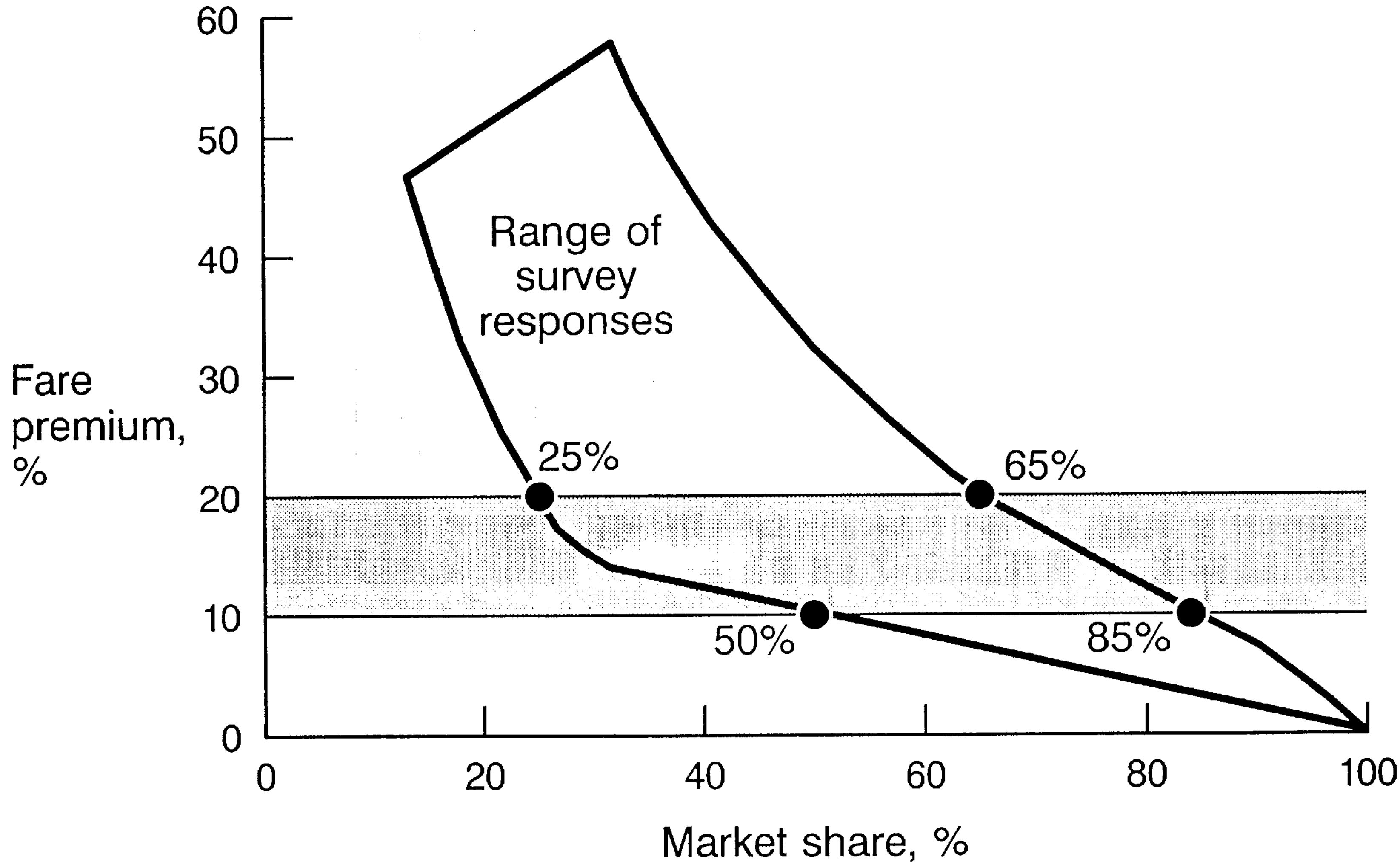


HSCT MARKET ESTIMATE

MINIMUM MARKET - SINGLE AND TWO SUCCESSFUL PROGRAMS

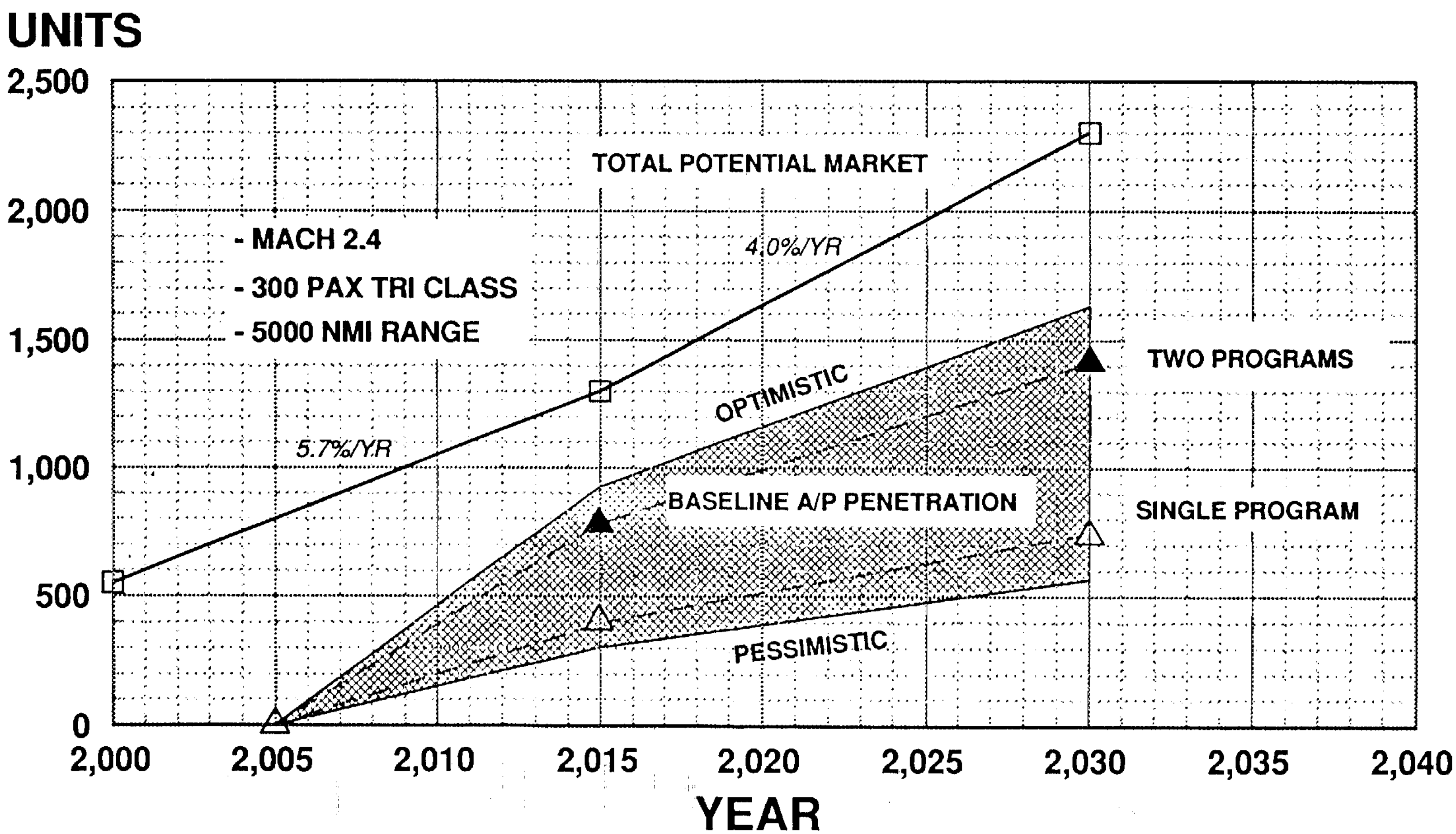


Passenger Willingness to Pay a Fare Premium

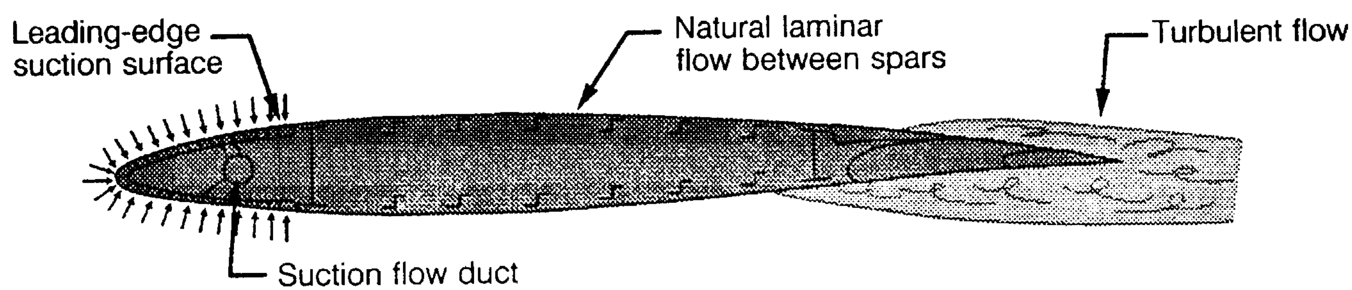


HSCT MARKET ESTIMATE

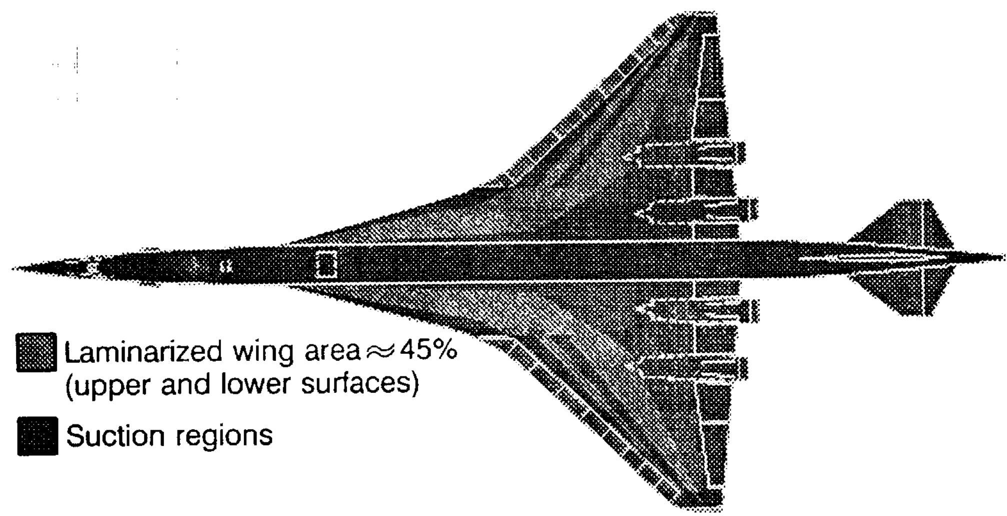
BASELINE HSCT MARKET PENETRATION



HSCT Laminar Flow Control Studies

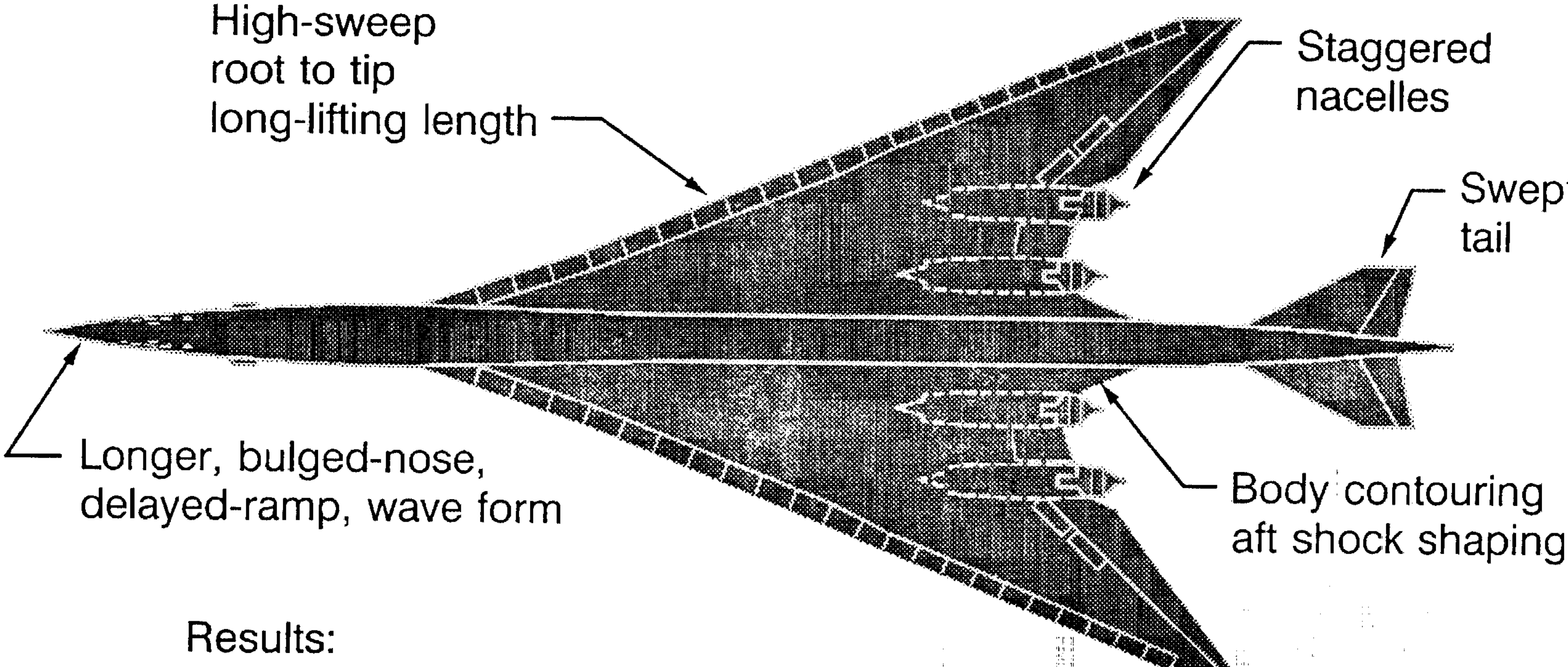


Airfoil section showing laminar flow control details



HSCT laminar flow control concept

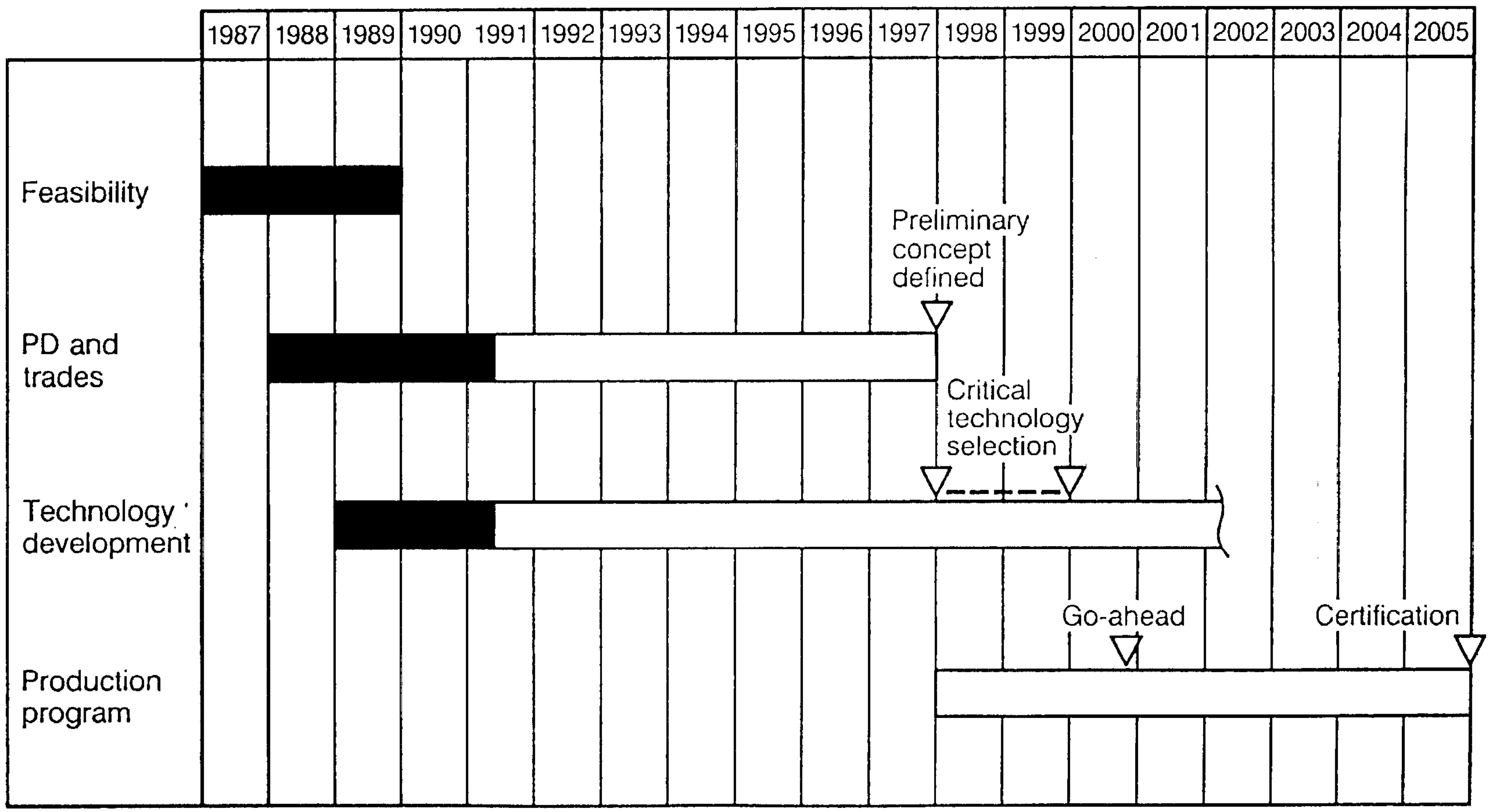
Low-Sonic-Boom Design Results



Results:

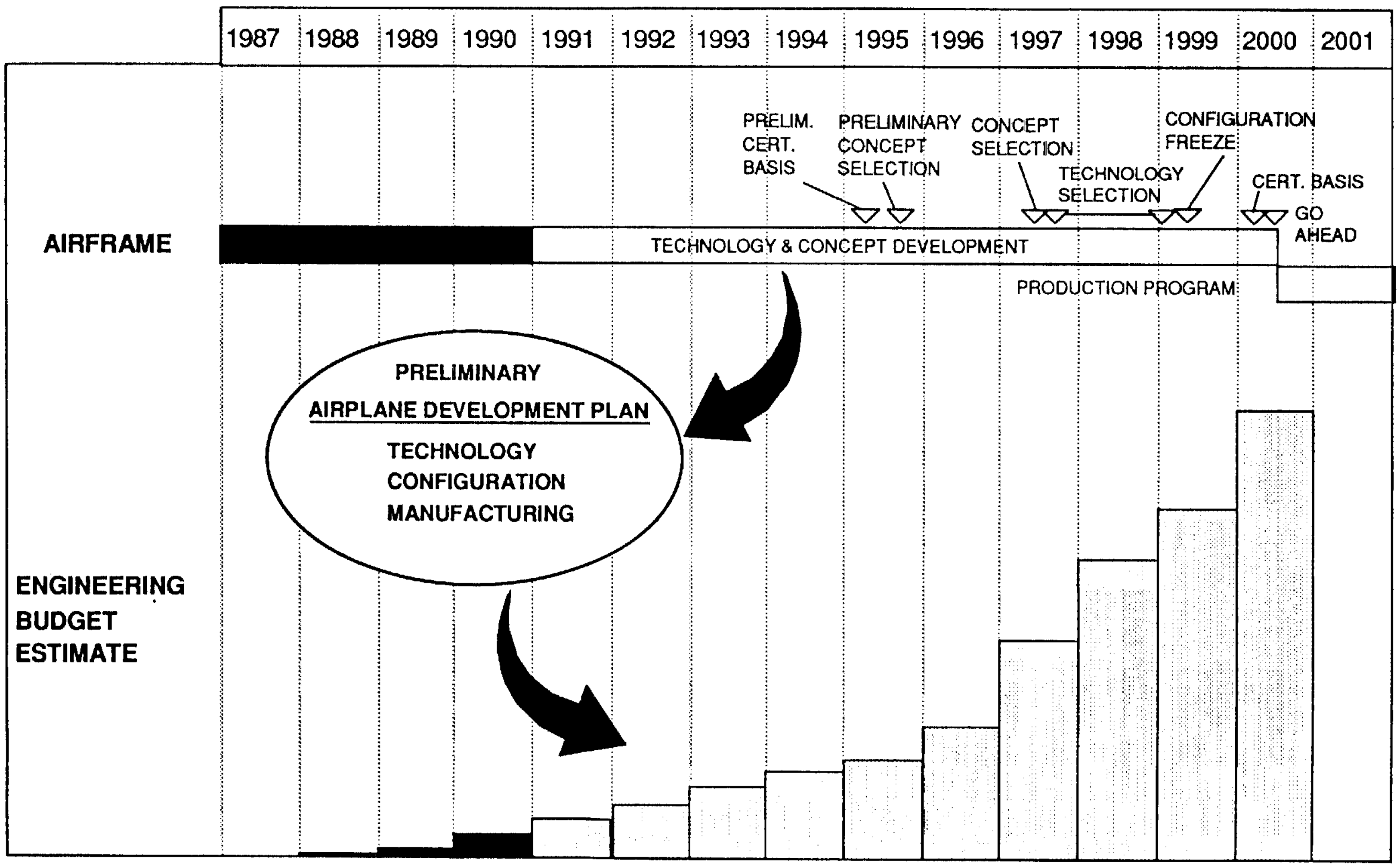
- Boom over pressure - 0.75 psf (base is 2.5 psf)
- Boom loudness - 71 dBA (base is 88 dBA)
- Gross weight penalty - +2%
- Payload penalty - -42 passenger (-15%)

HSCT Planning Schedule



HSCT TECHNOLOGY DEVELOPMENT PLAN

TECHNOLOGY AND CONFIGURATION DEVELOPMENT MILESTONES



BOEING VIEW OF HSR PHASE I

- NASA HSR PHASE I PROGRAM ON TARGET
  - GOALS, OBJECTIVES & TECHNICAL PLAN FORMULATED VERY WELL
  - EXCELLENT START TOWARD PROGRAM GOALS
- NEED TO MAINTAIN FOCUS
- KEY TO SUCCESS OF PHASE I WILL BE TIMELY DELIVERABLES

a-2.

BOEING VIEW OF HSR PHASE II

- HSR PHASE II PROGRAM ESSENTIAL FOR DEVELOPMENT OF ENABLING AND HIGH RISK, HIGH PAYOFF EMERGING TECHNOLOGIES
- AGREE WITH PRIORITIES AND RELATIVE FUNDING LEVELS
- A MORE DETAILED PHASE II NASA HSR TECHNOLOGY DEVELOPMENT PLAN NEEDS TO BE DEVELOPED WHICH:
  - USES PRESENT HSR PHASE II PLAN AS A BASE
  - IS INTEGRATED WITH INDUSTRY PRODUCT & TECHNOLOGY DEVELOPMENT PLANS
  - IS CENTRALLY MANAGED WITH BUY-IN BY THE NASA CENTERS
  - IS NOT CONSTRAINED BY NASA MANPOWER