BASELINE HSR INLET AND ENGINE BAY COWL SEAL REQUIREMENTS

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The two dimensional bifurcated inlet, down selected for the HSR program, and the engine bay cowling consist of many sealing interfaces. The variable geometry characteristics of this inlet and the size of the propulsion system impose new sealing requirements for commercial transport aircraft. Major inlet systems requiring seal development and testing include the ramp system, the bypass/ take-off system, and the inlet/ engine interface. Engine bay cowling seal interfaces include the inlet/ cowling interface, the keel split line, the hinge beam/ engine bay cowling, and the nozzle/ cowling interface. These seals have to withstand supersonic flight operating temperatures and pressures with typical commercial aircraft reliability and lives. The operating conditions and expected seal lives will be identified for the various interfaces. Boeing's SST seal development program will also be discussed.

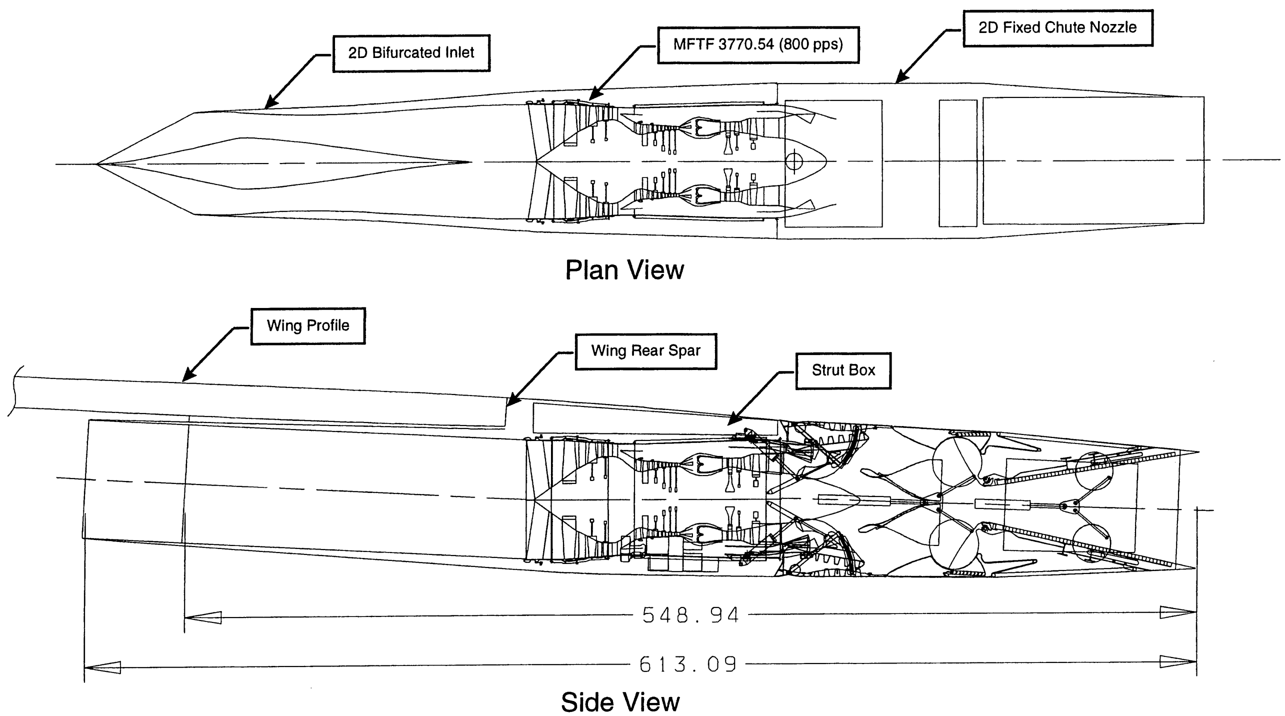
The High Speed Civil Transport's (HSCT) propulsion system requires significant technological advancements to become an economically viable product. Indifferent to the more severe operating conditions and variable geometry features, the HSCT propulsion system needs to operate with the same reliability as current subsonic systems. One area beginning to be addressed to meet these requirements is the inlet and engine bay cowl sealing systems.

Agenda

- Propulsion System Installation
- 2D Bifurcated Inlet
- Engine Bay Cowl
- Boeing's SST Seal Development Program (History)
- Conclusion

To illustrate the scale of the HSCT propulsion design an overview of the baseline propulsion system is shown installed on the HSCT airframe. Preliminary sealing interface requirements are presented for the two dimensional bifurcated inlet and the engine bay cowl. A historical perspective of the seal development program is given to show the starting point of the current seal development program. The proposed direction that this project is taking concludes this discussion.

Propulsion System Installation

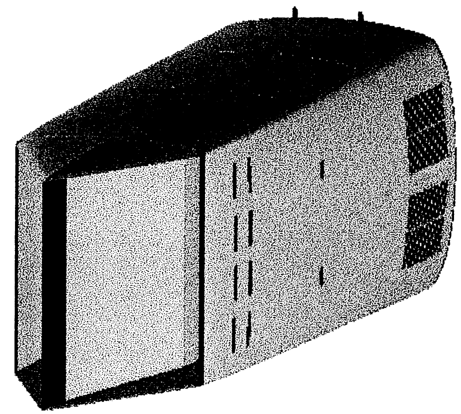


HSCT Outboard Nacelle Installation

The current baseline propulsion system installation includes a two dimensional bifurcated inlet mounted directly to the airframe. Down stream of the inlet are the 3770.54 mixed flow turbofan and fixed chute nozzle. The engine and nozzle are mounted to a strut which attaches to the rear spar of the wing. The overall propulsion system is over 613 inches (51 feet) long. The propulsion system is being designed to operate in an acoustically suppressed takeoff mode, a subsonic cruise mode, a supersonic mode, and a reverse mode.

2D Bifurcated Inlet

- Inlet Sealing Systems
    - Ramp System
    - Bypass/ Takeoff System
    - Inlet/ Engine Interface



Two Dimensional Bifurcated (2DB) Inlet

The two dimensional bifurcated inlet utilizes a centrally located ramp to compress incoming flow. The cowl captures this flow and creates a duct further compressing this flow until it enters the engine. Inlet systems requiring seal development include the ramp system, the bypass/ takeoff system, and the inlet engine interface. To match throat area requirement throughout the subsonic and supersonic flight envelope the internal ramp must translate. During the takeoff and landing modes, when the forward velocity of the aircraft is low, takeoff doors open to allow addition air into the propulsion system. Located in the same area as the takeoff doors, bypass doors bleed excess air overboard to match engine requirement during higher velocities. The inlet and engine are mounted separately to the airframe and require a sealing system at their interface.

2D Bifurcated Inlet

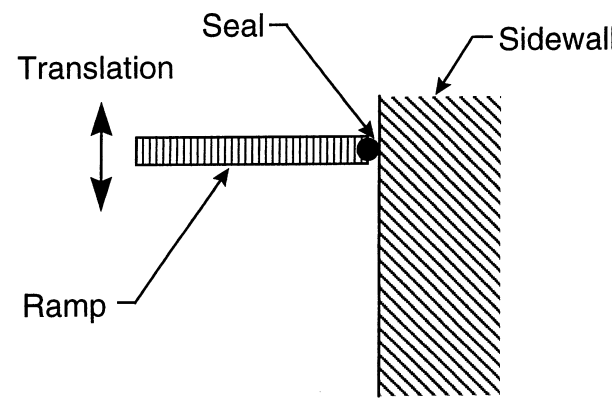
Ramp System

Ramp to Sidewall

• Cross Section:	TBD
• Size:	TBD
• Air temperature:	370 deg. F
• Pressure :	+ 15.18/ - 3 psi delta
• Metal temp.:	350 deg. F
• Time at temp.:	TBD
• Deflection:	TBD
• Sliding distance:	TBD
• Sliding Rates:	TBD
• Actuator loading : (drag force)	TBD

- Technology Gaps:

Operating temperature	Actuator Loading
Time at temperature	Seal/ Seal Interface



Inlet Station Cut

To accommodate the require variable geometry shapes, a single side of the ramp assembly is made up of three ramps connected by two hinges and supported by a trailing edge support beam. The ramps interface the the cowl along the horizontal crown and keel of the cowl. As this figure shows the interface between the sidewall and the translating ramp will need to be sealed. These seals will have to operate in an elevated temperature environment of supersonic flight with an overall operating life of 60,000 hours (similar to the life requirement of the inlet structure). The ends of these seals will have to be designed to interface with the ramp hinge seals.

2D Bifurcated Inlet

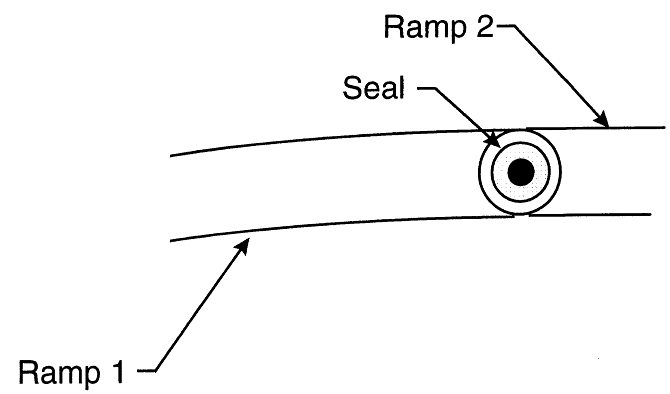
Ramp System

Ramp to Ramp Hinges

- Cross Section: TBD
- Size: TBD
- Air temperature: 370 deg. F
- Pressure : + 15.18/ - 3 psi delta
- Metal temp.: 350 deg. F
- Time at temp.: TBD
- Deflection: TBD
- Sliding distance: TBD
- Sliding Rates: TBD
- Actuator loading : (drag force) TBD
- Technology Gaps:

  Operating temperature — Actuator Loading

  Time at temperature — Seal/ Seal Interface



Inlet Bulk Line Cut

The interfaces between the ramps and the hinges will also require sealing. These seals will seal against a surface rotating about the hinge line. These ramp hinge seal ends will have to interface with the ramp sidewall seals.

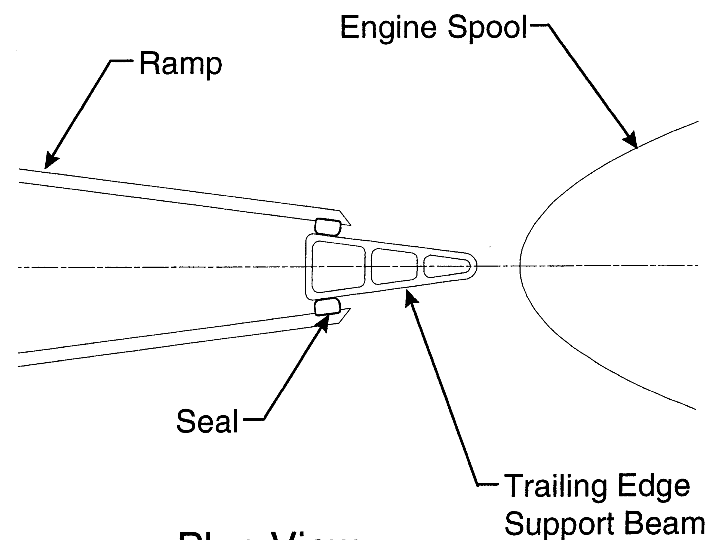
2D Bifurcated Inlet

Ramp System

Ramp Trailing Edge to Support Beam

- Cross Section: TBD
- Size: TBD
- Air temperature: 370 deg. F
- Pressure : + 15.18/ - 3 psi delta
- Metal temp.: 350 deg. F
- Time at temp.: TBD
- Deflection: TBD
- Sliding distance: TBD
- Sliding Rates: TBD
- Actuator loading : (drag force) TBD
- Technology Gaps:

Operating temperature	Actuator loading
Time at temperature	Seal/ Seal Interface



Plan View

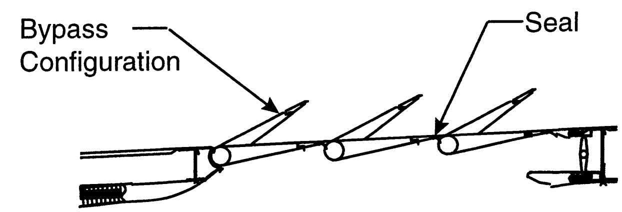
A trailing edge support beam will close out the ramps. The aft ramps will be guided with tracks and rollers to translate along the surface of this support beam. This interface will also require a sealing system. Again these seal ends will have to interface with the ramp sidewall seals.

2D Bifurcated Inlet

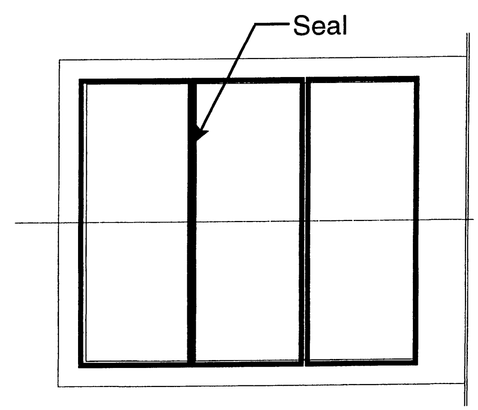
Bypass/ Takeoff System

Bypass Door - (current)

- Cross Section: TBD
- Size: TBD
- Air temperature: 370 deg. F
- Pressure: TBD
  TBD
- Metal temp.: TBD
- Time at temp.: TBD
- Deflection: TBD
- Sliding distance: TBD
- Sliding Rates: TBD
- Actuator loading : TBD
  (drag force)
- Technology Gaps:
  - Operating temperature
  - Time at temperature
  - Relative deflection
  - Seal Corners



Plan View



Side View

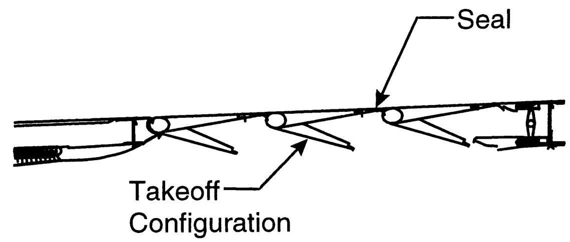
Each inlet consists of two bypass door assemblies located in the subsonic diffuser section of the inlet on both of the vertical sides of the cowl. The current bypass door assemble consists of three louver doors that rotate outward to allow excess flow overboard. The bypass doors are currently actively controlled to maintain the correct overflow of air. When closed these three door will need to be sealed around each door's circumference, requiring three rectangular seals per assembly. The current design shows a small land for compressing the seal.

2D Bifurcated Inlet

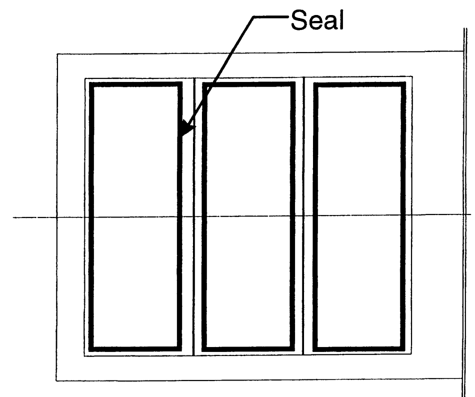
Bypass/ Takeoff System

Take-off Door - (current)

- Cross Section: TBD
- Size: TBD
- Air temperature: 370 deg F
- Pressure: TBD
  TBD
- Metal temp.: TBD
- Time at temp.: TBD
- Deflection: TBD
- Sliding distance: TBD
- Sliding Rates: TBD
- Actuator loading : TBD
  (drag force)
- Technology Gaps:
  - Operating temperature
  - Time at temperature
  - Relative deflection
  - Seal Corners



Plan View



Side View

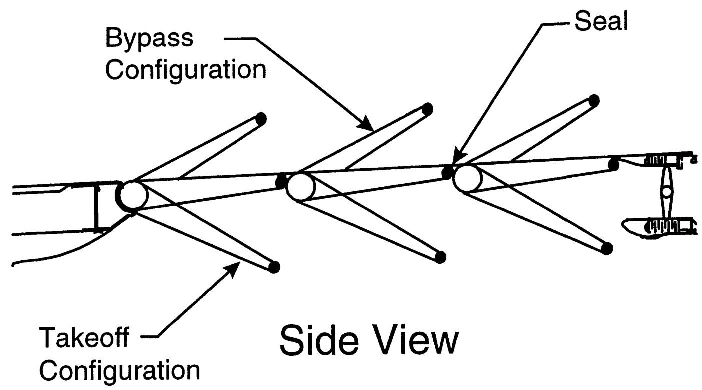
The takeoff door system also consists of three doors per assembly. These doors will be housed within the bypass doors, creating a door within a door. These doors are floating and will open only when the static pressure inside the diffuser is less than the external static pressure. When the diffuser pressure is higher than the external pressure, the doors are closed and sealed, again around the circumference. The door within a door design allows for a “hard stop” for the door and a land for sealing. The takeoff door seals will also be rectangular.

2D Bifurcated Inlet

Bypass/ Takeoff System

Bypass/ Take-off Door - (option)

- Cross Section: TBD
- Size: TBD
- Air temperature: 370 deg. F
- Pressure: TBD
  TBD
- Metal temp.: TBD
- Time at temp.: TBD
- Deflection: TBD
- Sliding distance: TBD
- Sliding Rates: TBD
- Actuator loading : TBD
  (drag force)
- Technology Gaps:
  - Operating temperature
  - Time at temperature
  - No Hard Sealing Surface
  - Relative deflection
  - Seal Corners



Side View

- No Hard Stop -

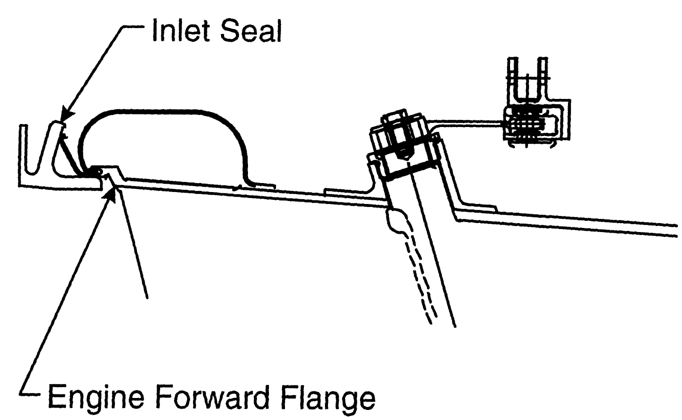
An alternate integrated bypass/ takeoff door design has been proposed. This design utilizes one actively controlled door for both the bypass and takeoff configurations. This design would not have a hard stop for locating the door. It would also not have a compressive seal land. While being a simpler design, this concept would still require the same leakage performance and controllability as the current design.

2D Bifurcated Inlet

Inlet/ Engine Interface

Subsonic Diffuser

- Cross Section: TBD
- Size: TBD
- Air temperature: 370 deg. F
- Pressure: TBD
  TBD
- Metal temp.: TBD
- Time at temp.: TBD
- Deflection: TBD
- Sliding distance: TBD
- Sliding Rates: TBD
- Actuator loading : N/A
  (drag force)
- Technology Gaps:
  Relative deflection - Inlet/ Engine

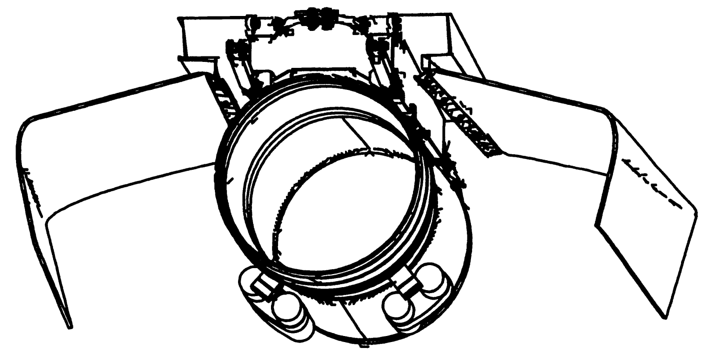


Typical Fighter Inlet Seal Interface

The final inlet seal system discussed here is located inlet/ engine interface. The interface shown is an example of a typical fighter inlet seal interface. The seal required for the HSCT application will maintain a seal with significant relative motion between the inlet and the engine which are mounted separately. Preliminary finite element models predict a relative axial motion of 0.8 inches and verical motion of 0.02 inches between the inboard inlet and engine. The outboard installation should see larger magnitudes.

Engine Bay Cowl

- Engine Bay Sealing Systems
  - Inlet Aft Cowl
  - Keel Split Line
  - Hinge Beam
  - Nozzle Cowling



The engine bay cowling will be mounted off of the strut. It forms the aerodynamic fairing around the engine. The two cowls are attached to the strut by way of a hinge beam. Latches are located at the bottom of the cowlings to secure the cowling in a closed position. The engine bay cowling allows access to the engine for maintenance. The HSCT engine bay will contain free flowing air used to cool ECS bleed. This air is from the primary inlet flow taken

at the engine face. The engine bay cowling will require sealing at the inlet aft cowl interface, the keel split line, the hinge beam, and the nozzle cowl interface.

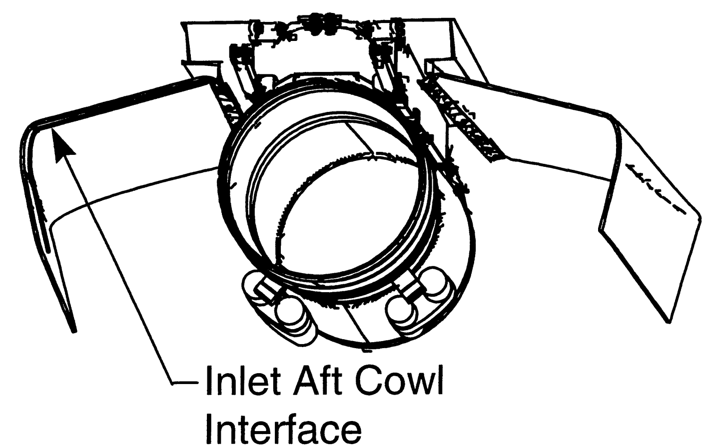
Engine Bay Cowl

Inlet Aft Cowl

- Cross Section: TBD
- Size: TBD
- Air temperature: 370 deg. F
- Pressure: TBD
- Metal temp.: TBD
- Time at temp.: TBD
- Deflection: TBD
- Sliding distance: Static
- Sliding Rates: Static
- Actuator loading : Static
  (drag force)
- Technology Gaps:

  Operating temperature   Time at temperature

  Relative deflection - Inlet/ Engine Bay Cowl



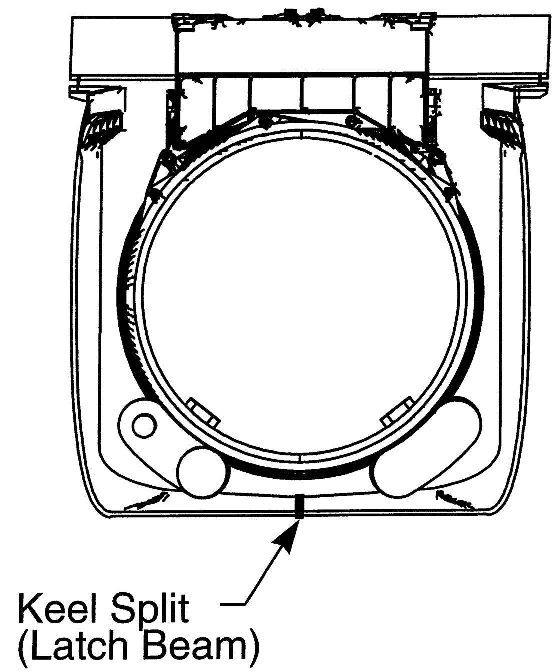
The first seal system shown for the engine bay cowl seals between the inlet aft cowl and the engine bay cowl. This seal will need to accommodate significant relative deflection between the inlet and the engine bay cowling. Sealing this interface is made more complicated by the tight aero contours required on the exterior of the cowling and the flexibility inherent in the its flat panels.

Engine Bay Cowl

Keel Split Line

• Cross Section:	TBD
• Size:	TBD
• Air temperature:	370 deg. F
• Pressure:	TBD
	TBD
• Metal temp.:	TBD
• Time at temp.:	TBD
• Deflection:	TBD
• Sliding distance:	Static
• Sliding Rates:	Static
• Actuator loading : (drag force)	Static

- Technology Gaps:
  - Operating temperature
  - Time at Temperature



The keel split line will need to be sealed in the closed position. This seal should be similar to current subsonic latch beam seals except for the elevated temperature requirements.

Engine Bay Cowl

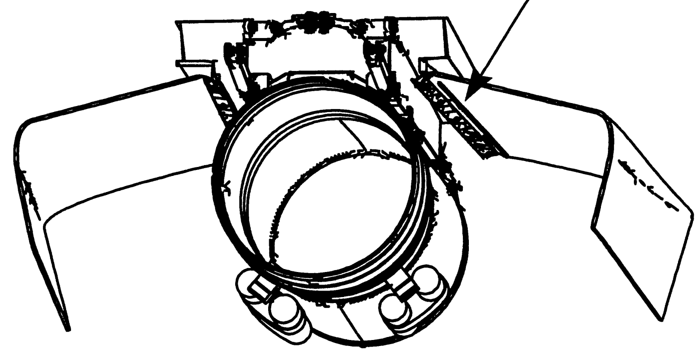
Hinge Beam

• Cross Section:	TBD
• Size:	TBD
• Air temperature:	370 deg. F
• Pressure:	TBD
• Metal temp.:	TBD
• Time at temp.:	TBD
• Deflection:	TBD
• Sliding distance:	Static
• Sliding Rates:	Static
• Actuator loading : (drag force)	Static

- Technology Gaps:

  Operating temperature

  Time at Temperature



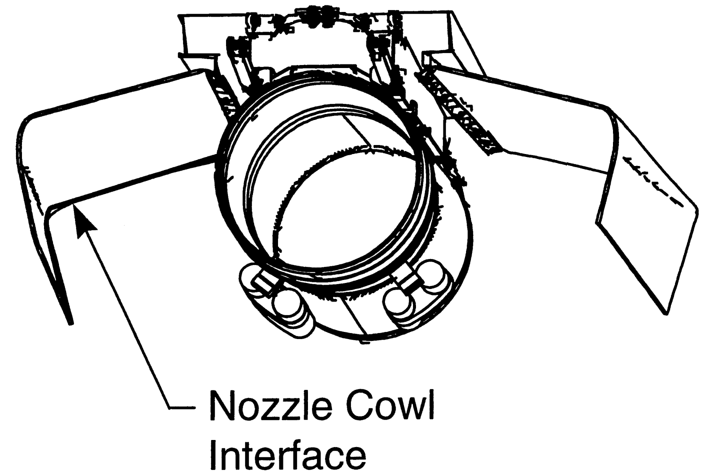
The hinge beam also requires sealing in the closed position. Again this seal should be similar to current subsonic hinge beam seals except for the elevated temperature requirements.

Engine Bay Cowling

Nozzle Cowling

• Cross Section:	TBD
• Size:	TBD
• Air temperature:	370 deg. F
• Pressure:	TBD
• Metal temp.:	TBD
• Time at temp.:	TBD
• Deflection:	TBD
• Sliding distance:	Static
• Sliding Rates:	Static
• Actuator loading : (drag force)	Static

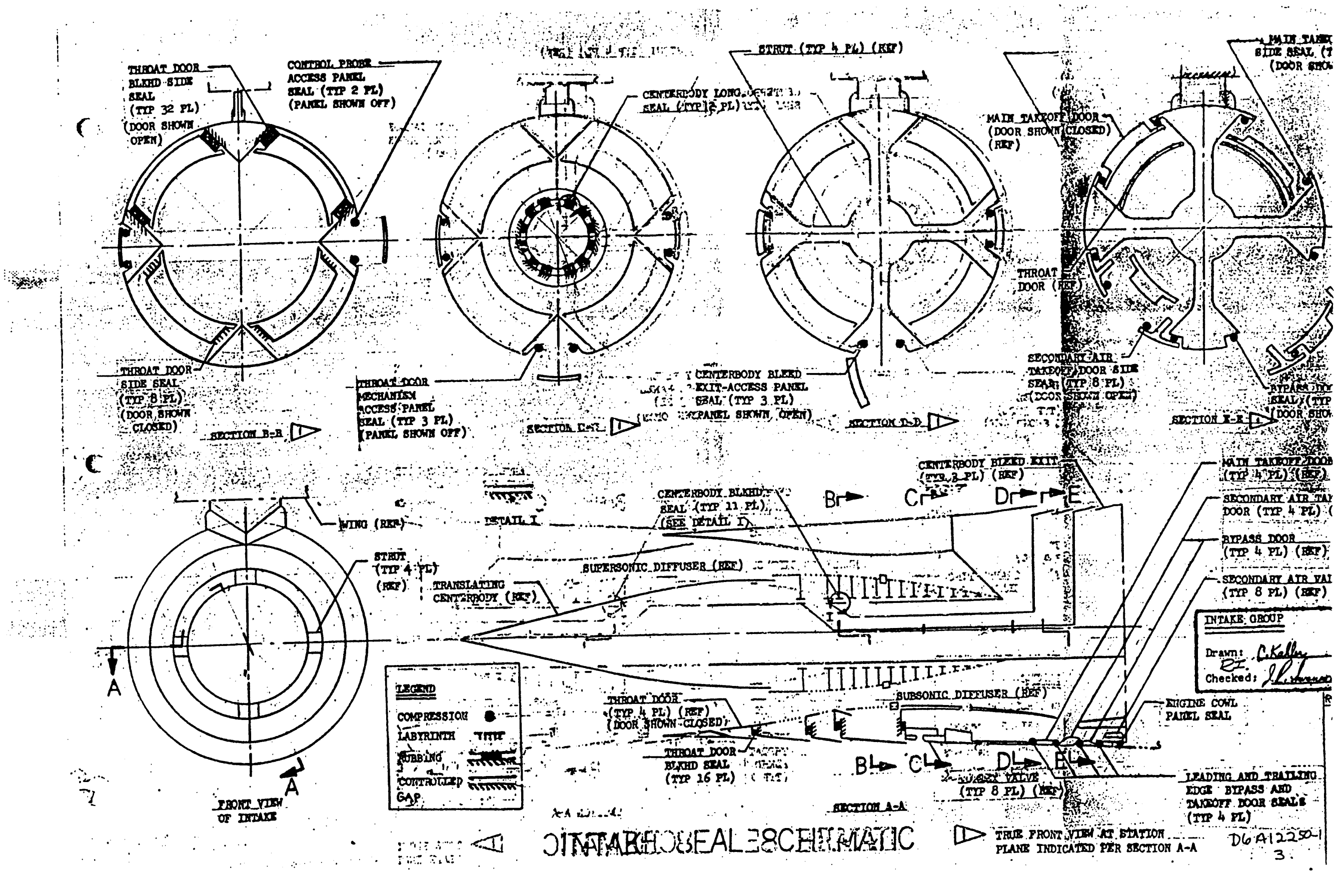
- Technology Gaps:
    - Operating temperature
    - Time at Temperature



Finally the engine bay/ nozzle cowling interface will require a sealing system. This seal will need to accommodate fairly large displacements between the cowling and the nozzle while maintaining tight aero contours. This seal system will need to withstand significantly higher temperatures due to its proximity to the nozzle.

SST Seal Development

Mixed Compression Translating Centerbody



During Boeing's original SST development program, the propose inlet was a Mixed Compression Translating Centerbody inlet. This variable geometry inlet used a translating centerbody to control the throat. It also had various low pressure and high pressure bleed regions. This figure shows the location of various seals and the general type of proposed seals. While the sealing requirement for this design are significantly different than those of the 2DB inlet, this data gathered from the SST program is being used as a starting point for the current design.

SST Seal Development

Testing

- Test Conditions

Seal Intake Pressure:	35 - 5 psia
Seal Exit Pressure:	31.5 - 0.5 psia
Seal Inlet Air Temp:	Ambient, -75 deg. F, 500 deg. F
Seal Gap:	0.002, 0.01, 0.03, 0.06, 0.09 inches
Seal Compression:	0.00, 0.03, 0.06, 0.09, 0.12,0.18 inches

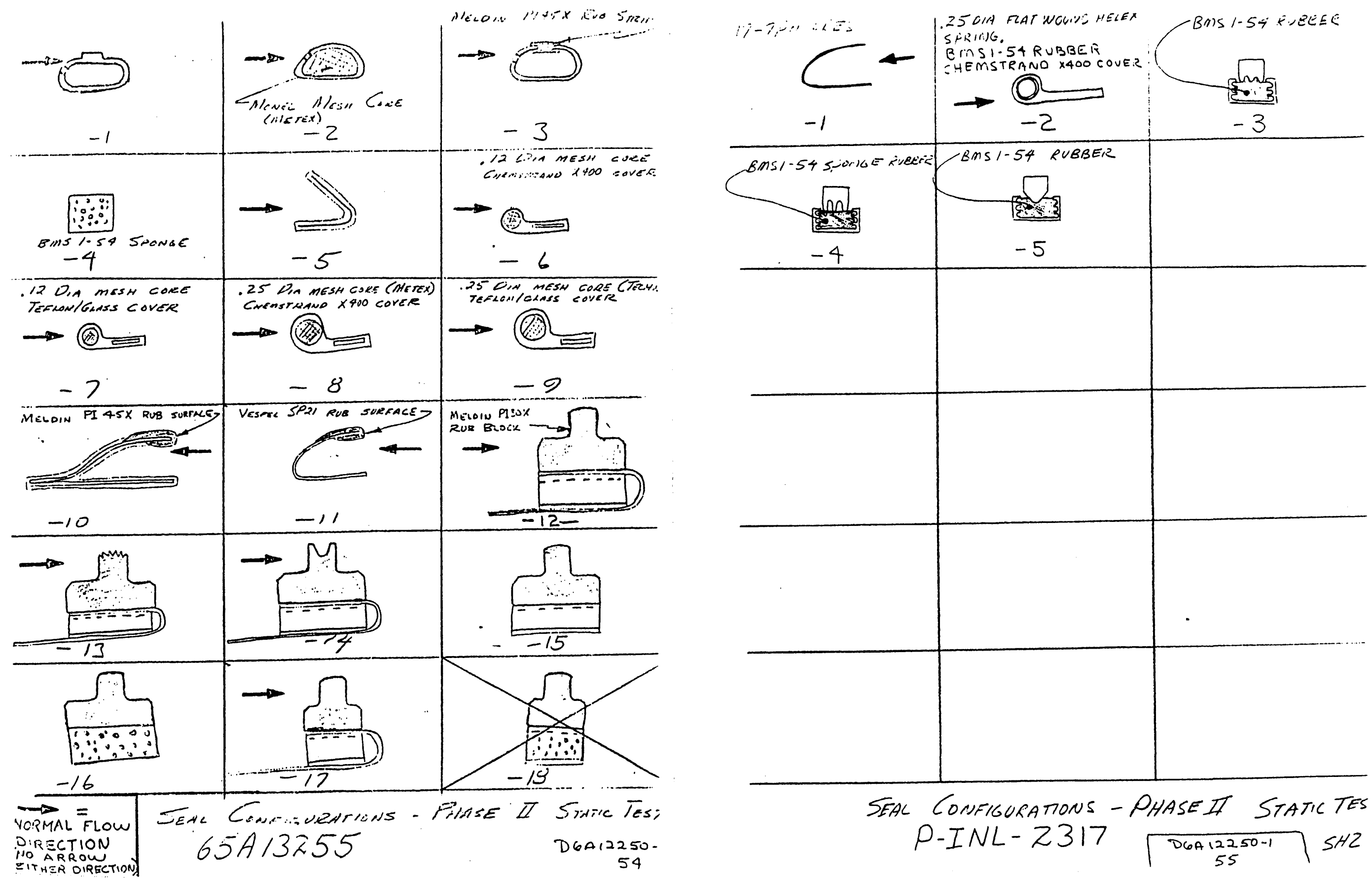
- Testing Duration

Inches of Travel:	5,000 inches @ 70 deg. F
(5 inch stroke)	5,000 inches @500 deg. F
	1100 inches @ -75 deg. F
Compression Cycles:	500 @ 70 deg. F
(close/ open/ close)	500 @ 500 deg. F
	110 @ -75 deg. F

In addition, the test condition used for the SST development program will be similar to the conditions required for the HSCT inlet seal test program. The SST development varied pressure, temperature, seal gap, and compression. The program also looked at how wear and cycles effected the seals performance.

SST Seal Development

Tested Seal Configurations - Geometry



The cross section geometries looked at in this program are specific to the TCB inlet being design.

SST Development

Tested Seal Configurations - Materials

- 17-7 Cress (Sheet)

- Meldin P145X Rub Strip
- Meldin PI30X Rub Block
- Vespel SP21 Rub Strip

- Chemstrand X400 Cover
- Teflon/ Glass Cover

- Monel mesh Core (Metrex)

- BMS 1-54 Sponge
- BMS 1-54 Rubber

Materials used for the SST program are also dated. Both new materials and cross sectional shape will evaluated for the 2DB inlet seal development program. Experience from the VDC inlet development, the F15, F18, and B1B programs will be gathered.

Conclusion

- Where do we go from here? (HSR Task 1.3.11.5)

    Fill in the TBDs

    Incorporate VDC Inlet Seal Work, F15, & F18 Experience

    HSR Task 1.3.6 - Ramp Actuation Slew Rates & Forces

    Work with Inlet Control to iterate actuation force requirements.

    Work with Inlet & Engine Bay Cowl Mechanical Designs to define sealing interface deflections.

- Innovative seal design for Bypass/ Take-off Door System would significantly impact inlet design.

The presentation shows the preliminary status of the inlet and engine bay cowl seal development program. The initial goal of this project will be to fill in all of the “to be determines.” The next objective of this task will be to gather concepts and lessons from recently accessible military programs. Sealing systems are a significant part of the inlet and engine bay design. Innovative seal designs will be required for the engine bay/ inlet and nozzle interfaces.