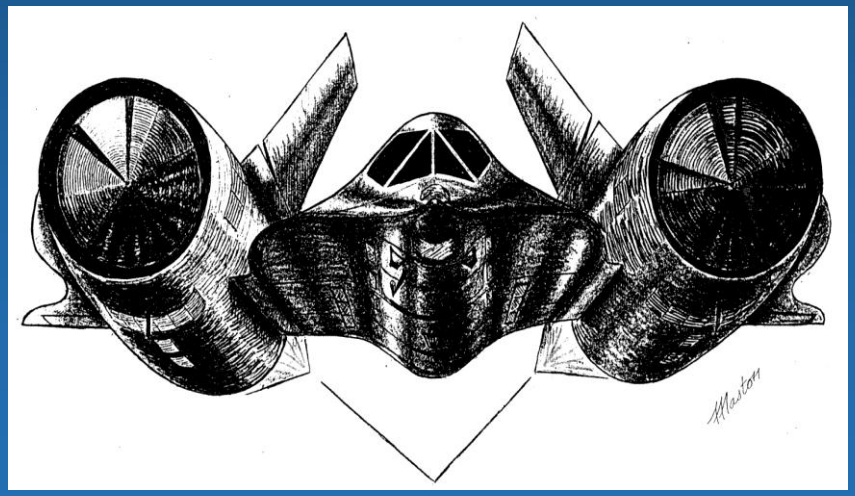
SR-71 Inlet Design Issues And Solutions

Dealing With Behaviorally Challenged Supersonic Flow Systems

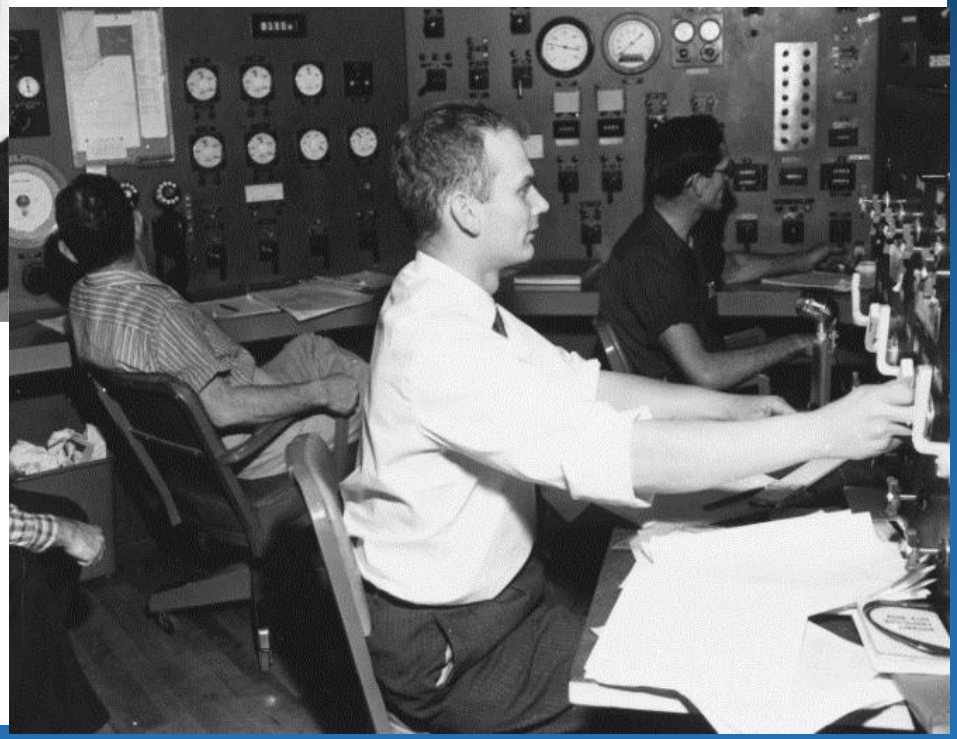


Tom Anderson

A-12, SR-71 Inlet Designers

Ben Rich
SR-71 Vehicle and Inlet Preliminary Design
Propulsion Boss
ADP President

Dave Campbell
SR-71 Inlet Designer
Propulsion Boss



SR-71 Inlet Document

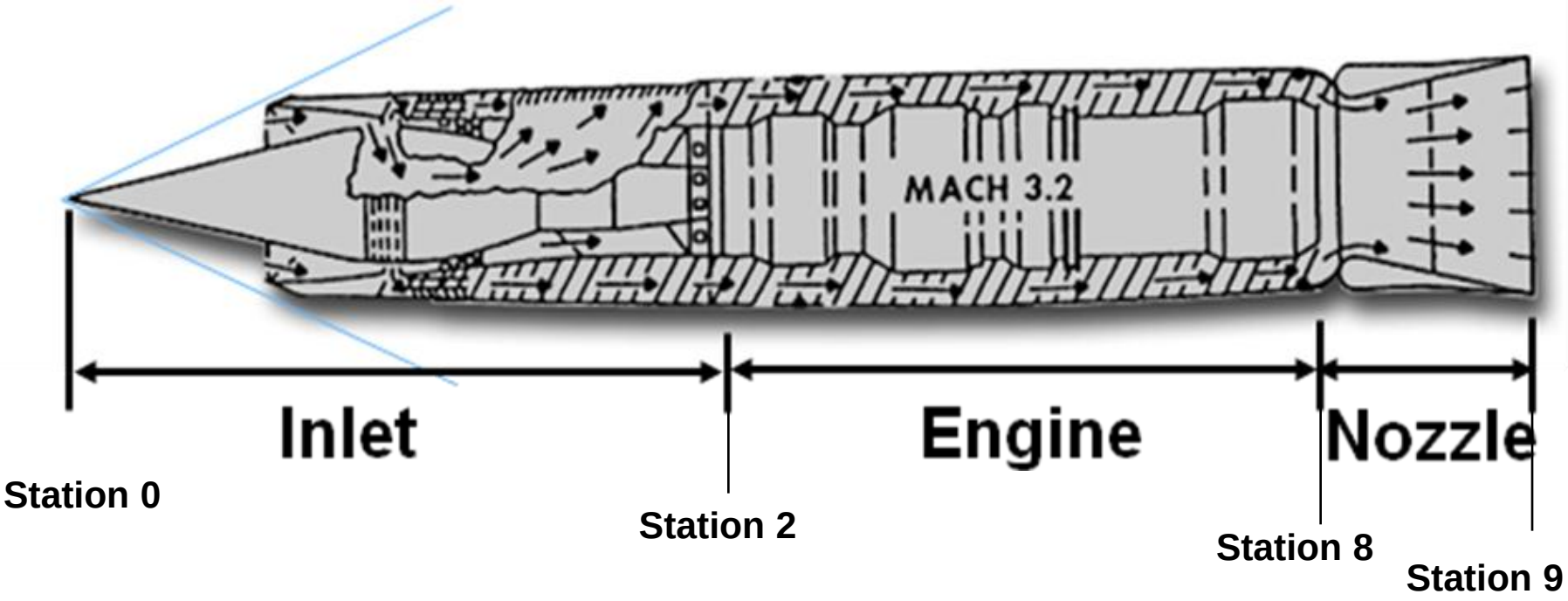
8/19/13

How Supersonic Inlets Work

Details Of The Geometry And Operation Of The SR-71 Mixed Compression Inlet

By J. Thomas Anderson
Technical Fellow Emeritus
Lockheed Martin Skunk Works

SR-71 Nacelle



Inlet Needed To Capture Ram Pressure

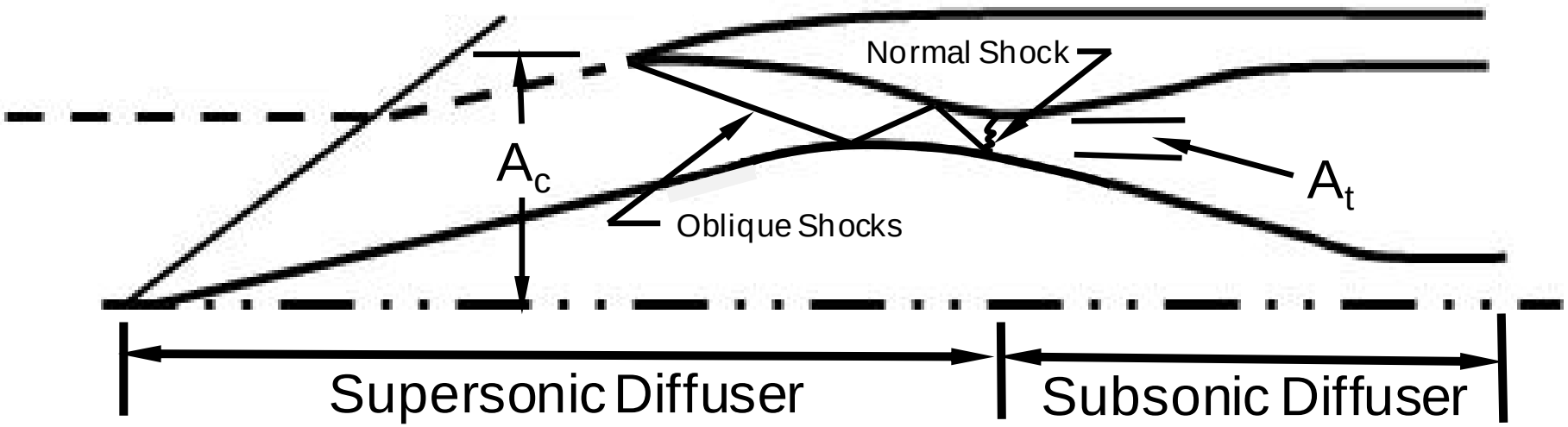
Vehicle	Velocity	Mach Number	$\frac{P_{ram}}{P_{ambient}}$	$\frac{P_{ram}-P_{ambient}}{P_{ambient}}$
Car	70 miles per hour	0.1	Less than 1.01	Less than .01
Airliner	530 miles per hour	0.8	1.5	.5
Fighter Max Speed	1300 miles per hour	2.0	7.8	6.8
SR-71	2130 miles per hour	3.2	49.4	48.4

A Figure Of Merit For Inlet Performance Is Recovery.

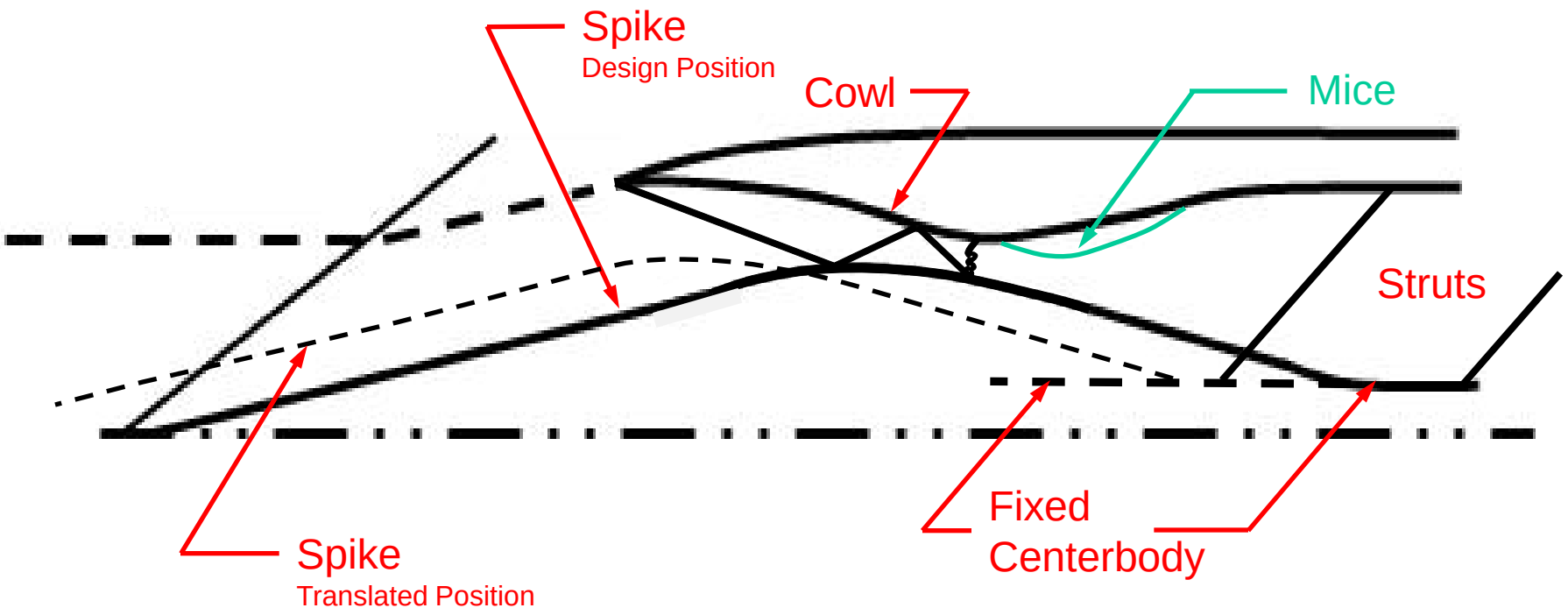
Recovery Is The Amount Of Ram Pressure That Is *Recovered* From The Inlet Compression Process.

Recovery = P_{t2}/P_{t0}

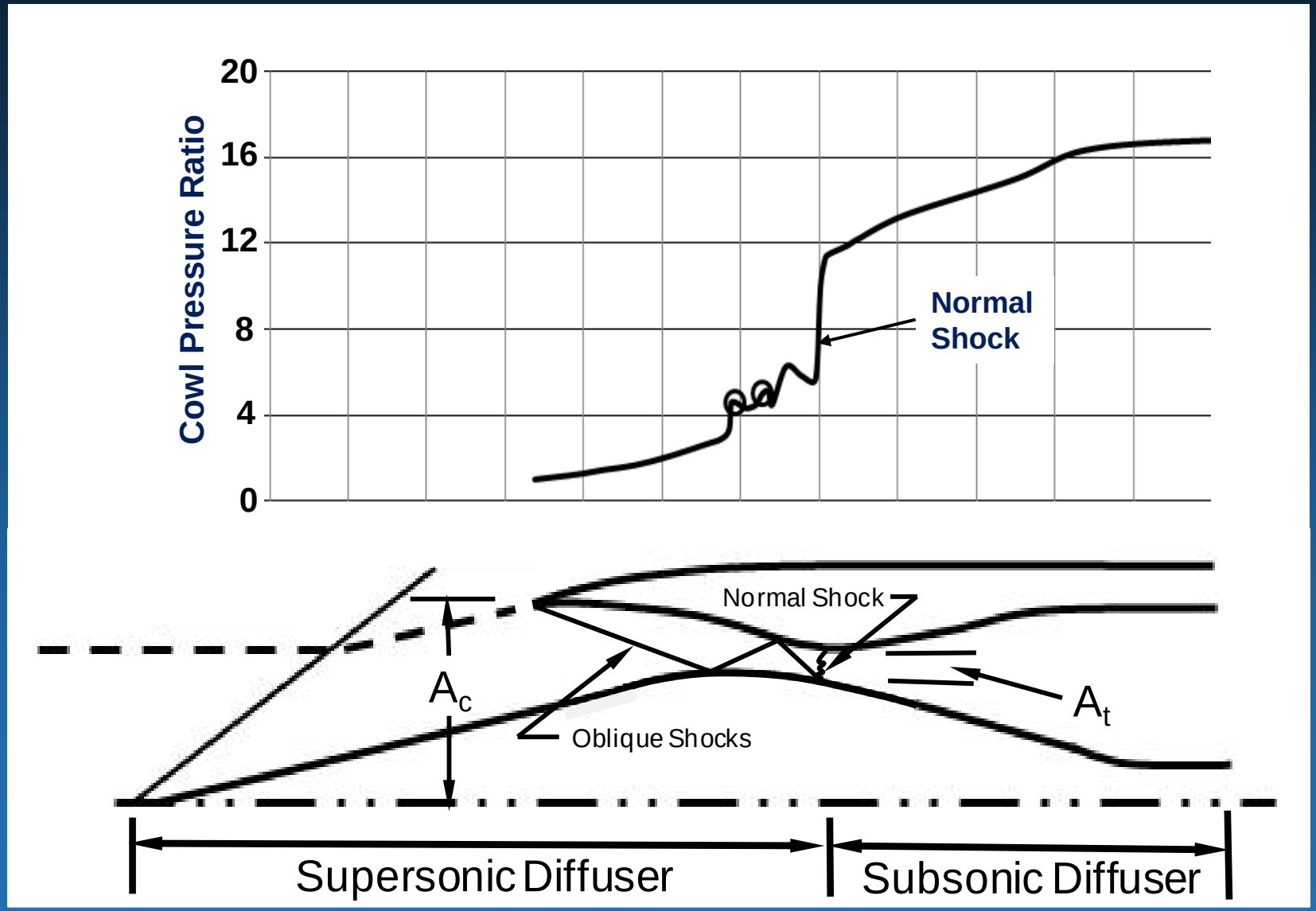
Inlet Compression Regions



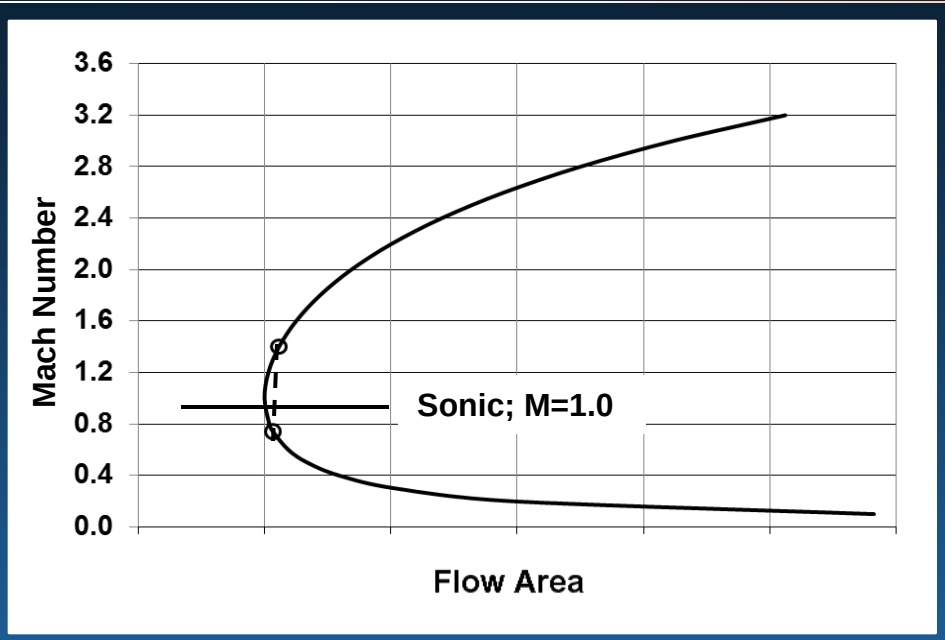
Inlet Configuration Definitions

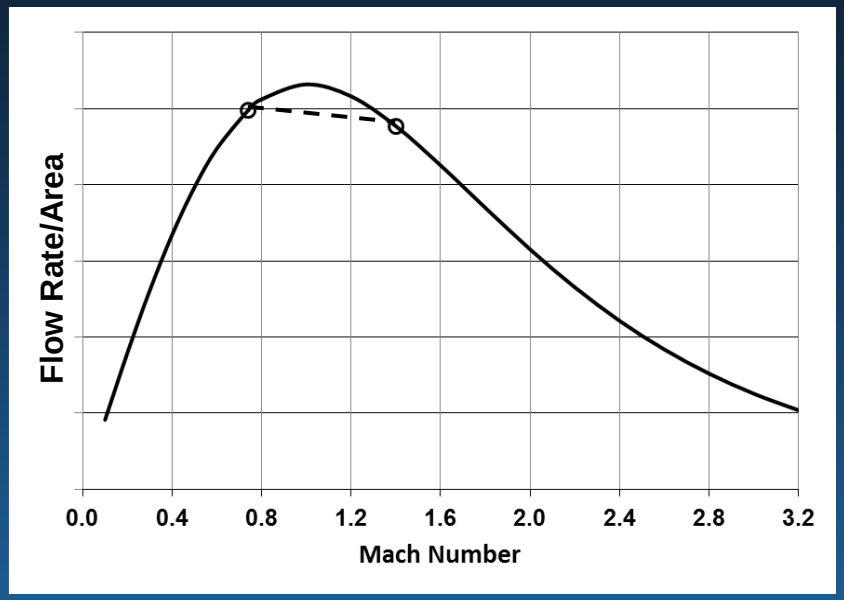


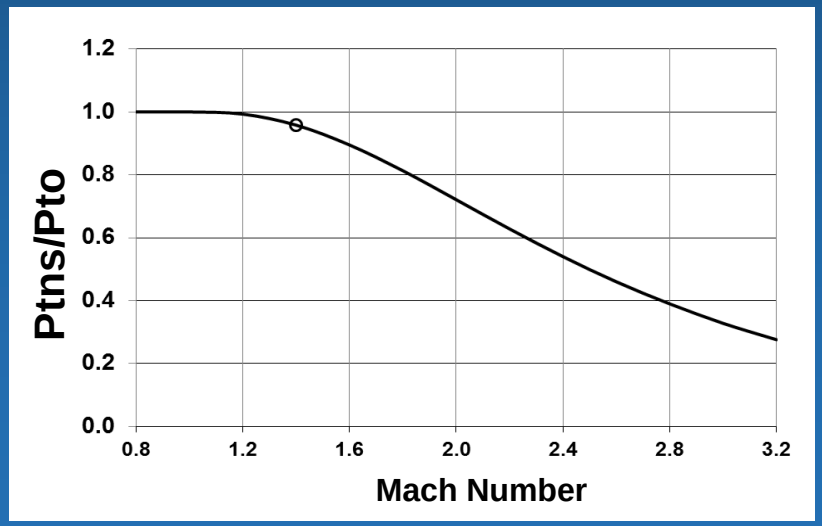
Inlet Cowl Pressure Distribution

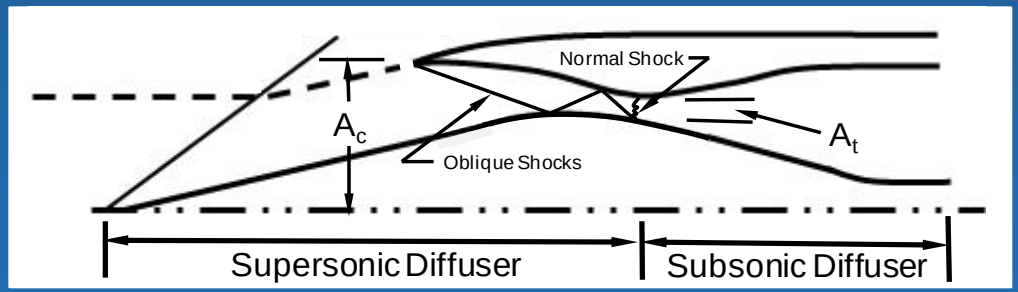


Supersonic Compression Ends With Normal Shock

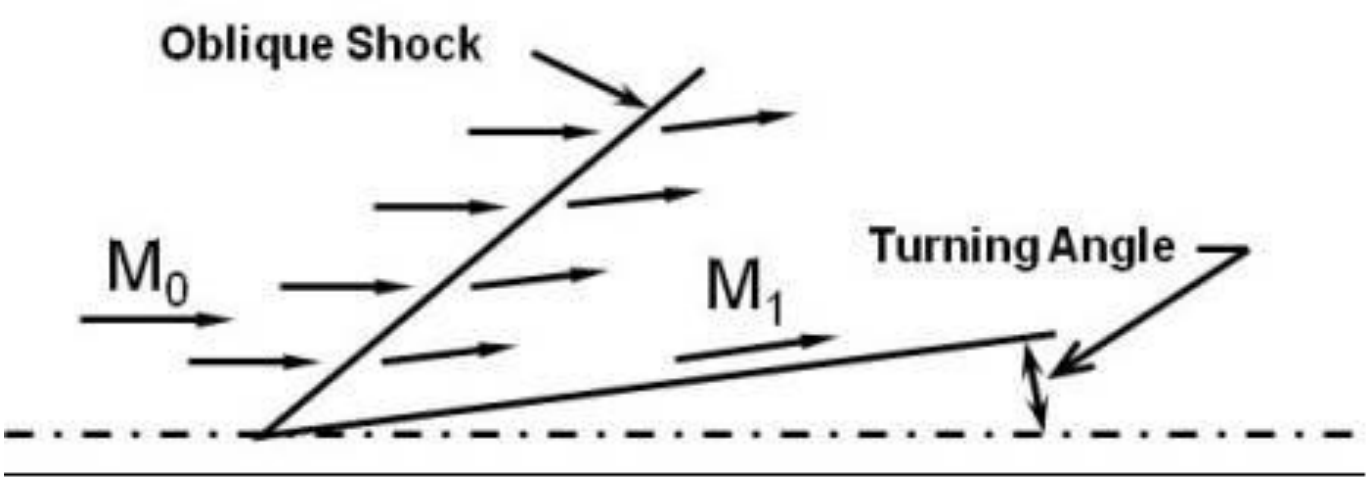








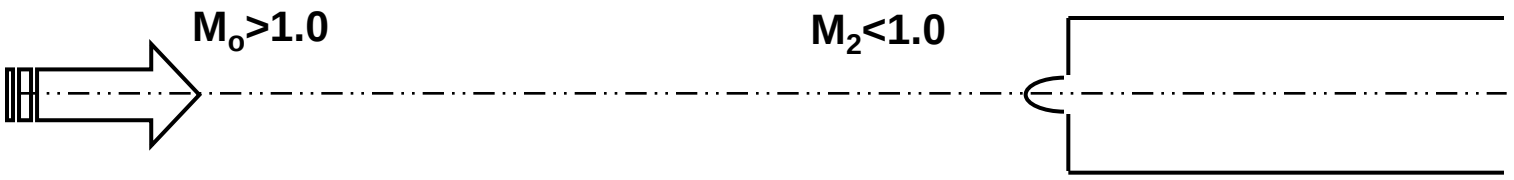
Supersonic Compression Done Through Compression And Shock Waves



Basic Law Of Physics
Continuity

- Everything That Enters The Inlet Must Leave Or Be Stored.
- The Inlet Does Not Act Like A Balloon And Will Not Store Air.
- Therefore Flow In Must Equal Flow Out.
  - $W_{in} = W_{out} = W_{engine} + W_{bleed} + W_{bypass} + W_{leak}$
- Flow In Is Approximately 200 lbs/sec.
  - *Therefore Events Happen VERY Rapidly.*

The "Problem"



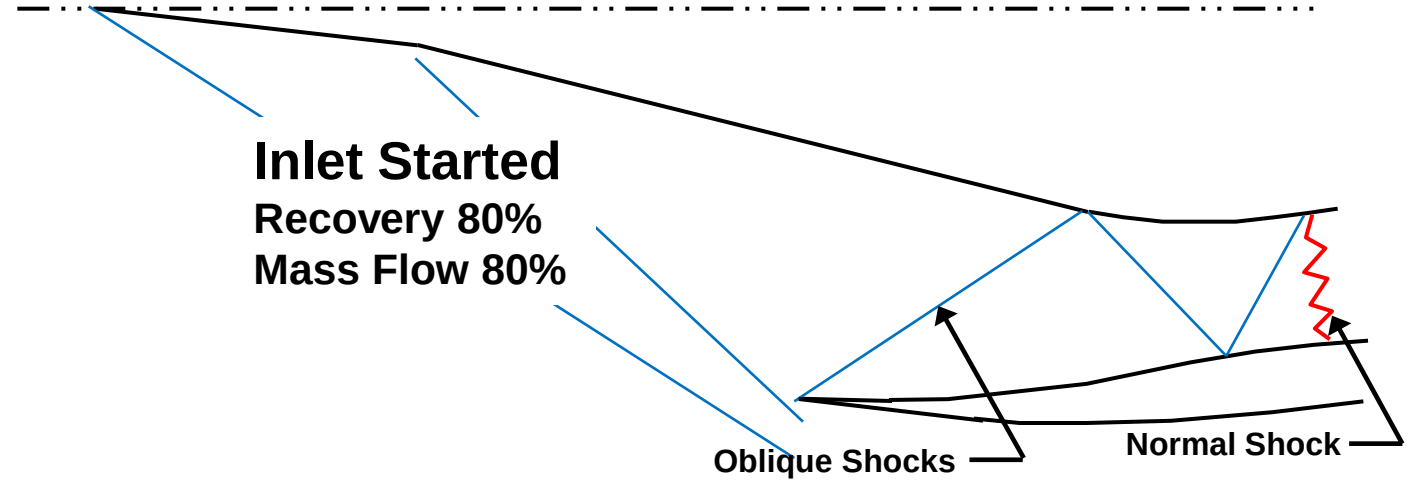
Subsonic Air

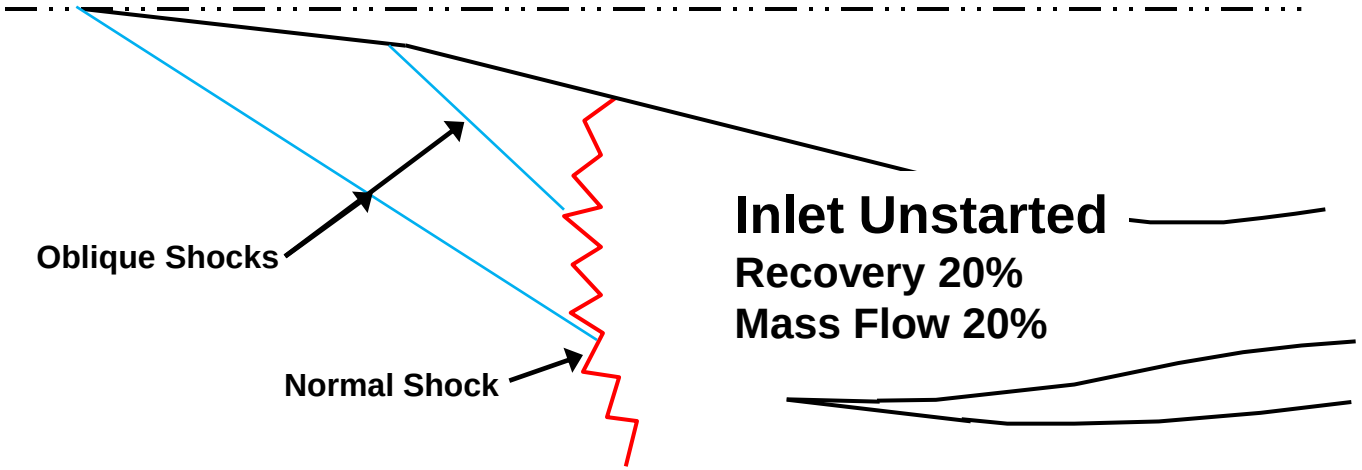
Skier Is Working Hard

Supersonic Air

Skier Is Blind

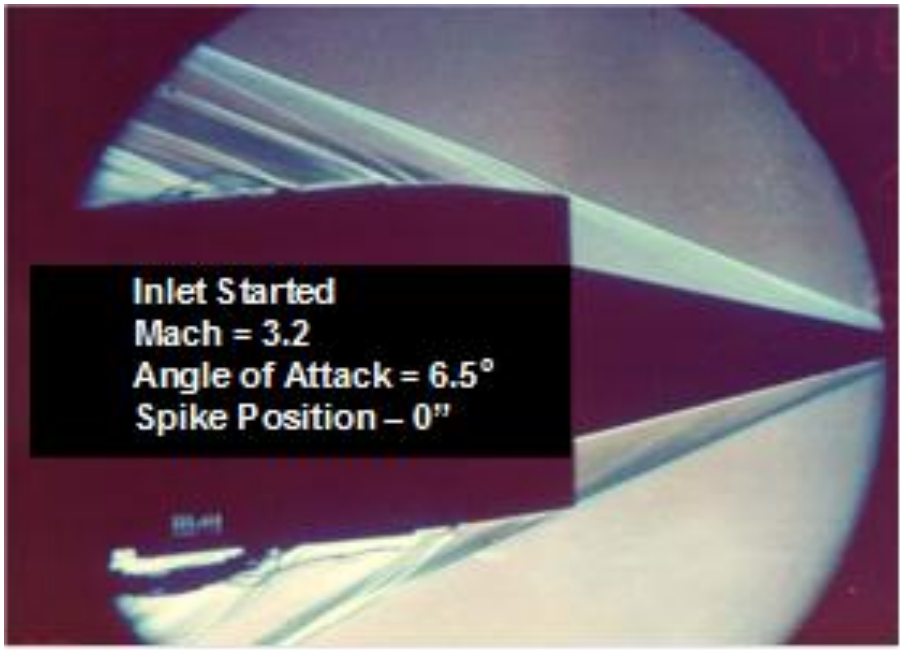
Comparison Of Mo=3.2 Started And Unstarted Performance





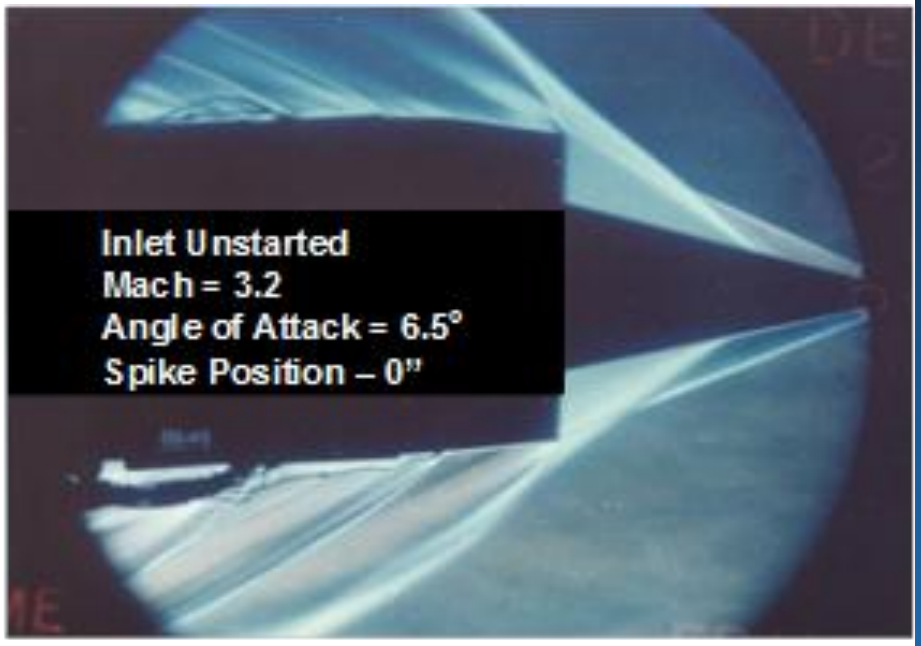
Inlet Flow Schlierens Show Started And Unstarted Operation

Inlet Started



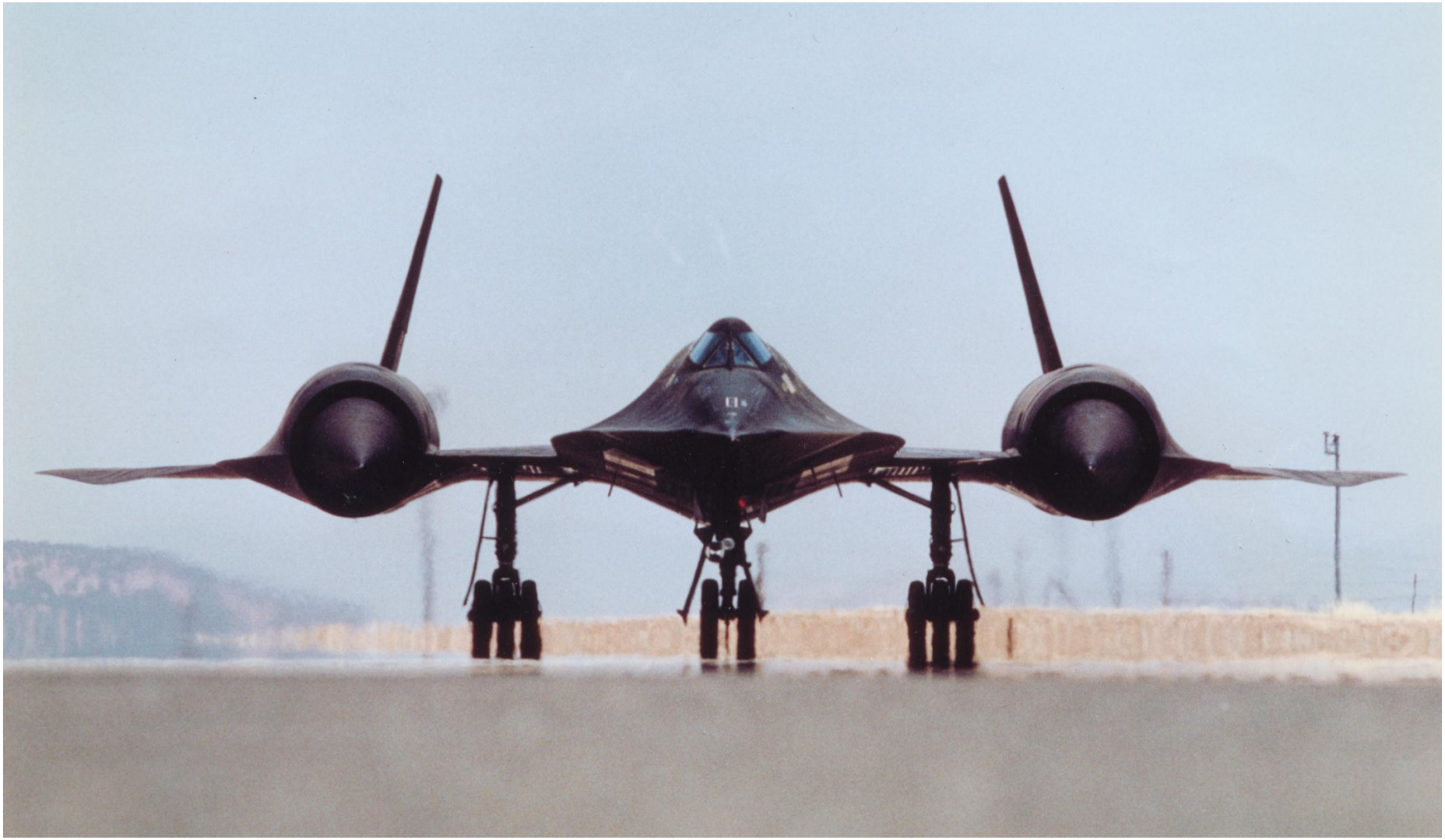
Ram Recovery = 0.8
Mass Flow Ratio = 0.8

Inlet Unstarted

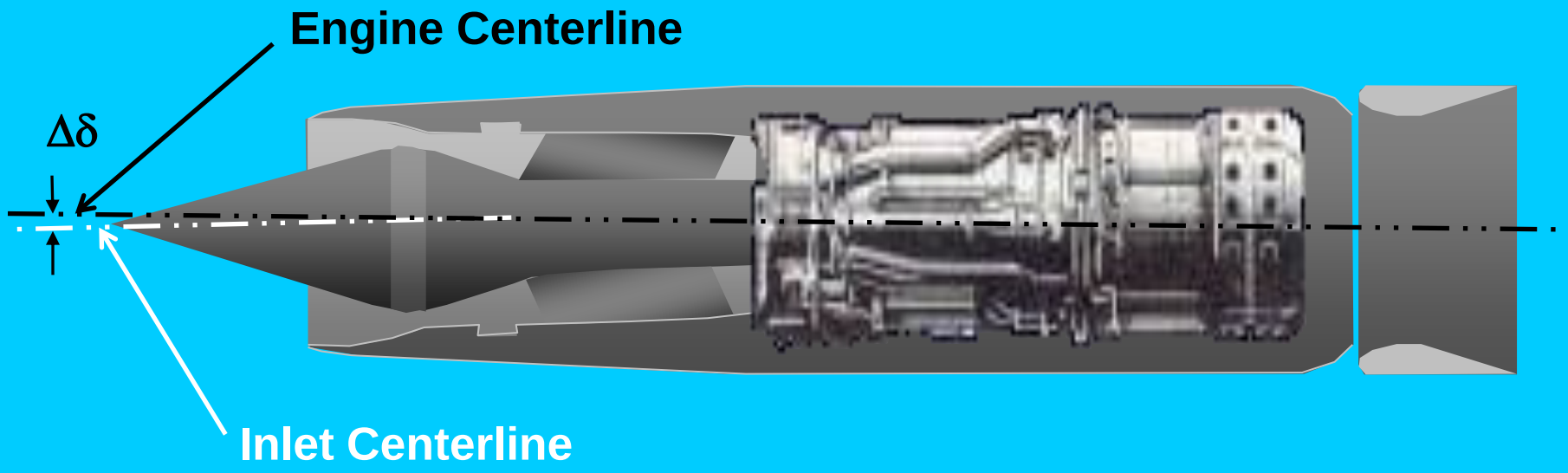


Ram Recovery = 0.2
Mass Flow Ratio = 0.2

SR-71 Inlet Orientation
Facing Into The Wind At Cruise

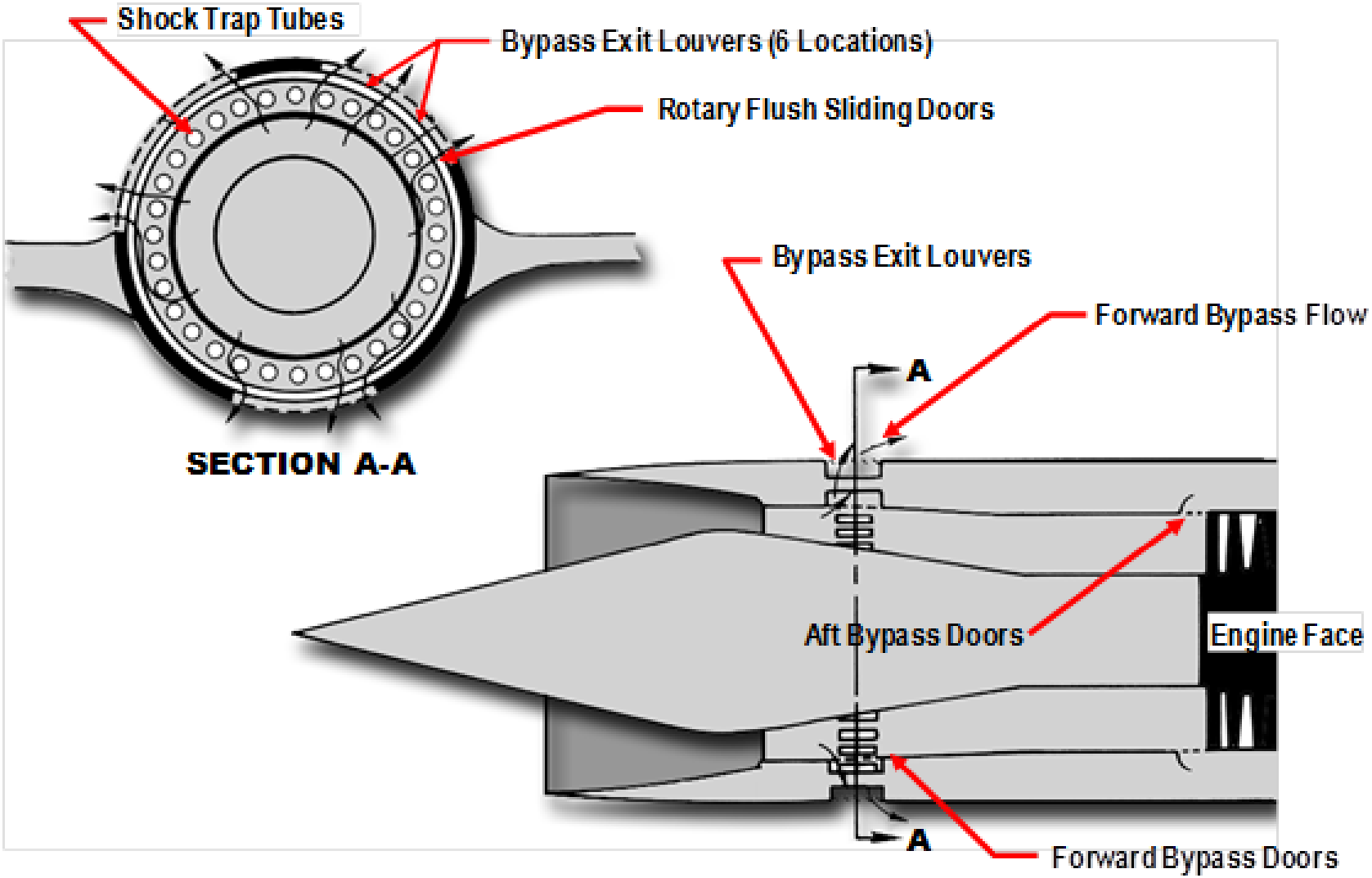


Nacelle Centerlines

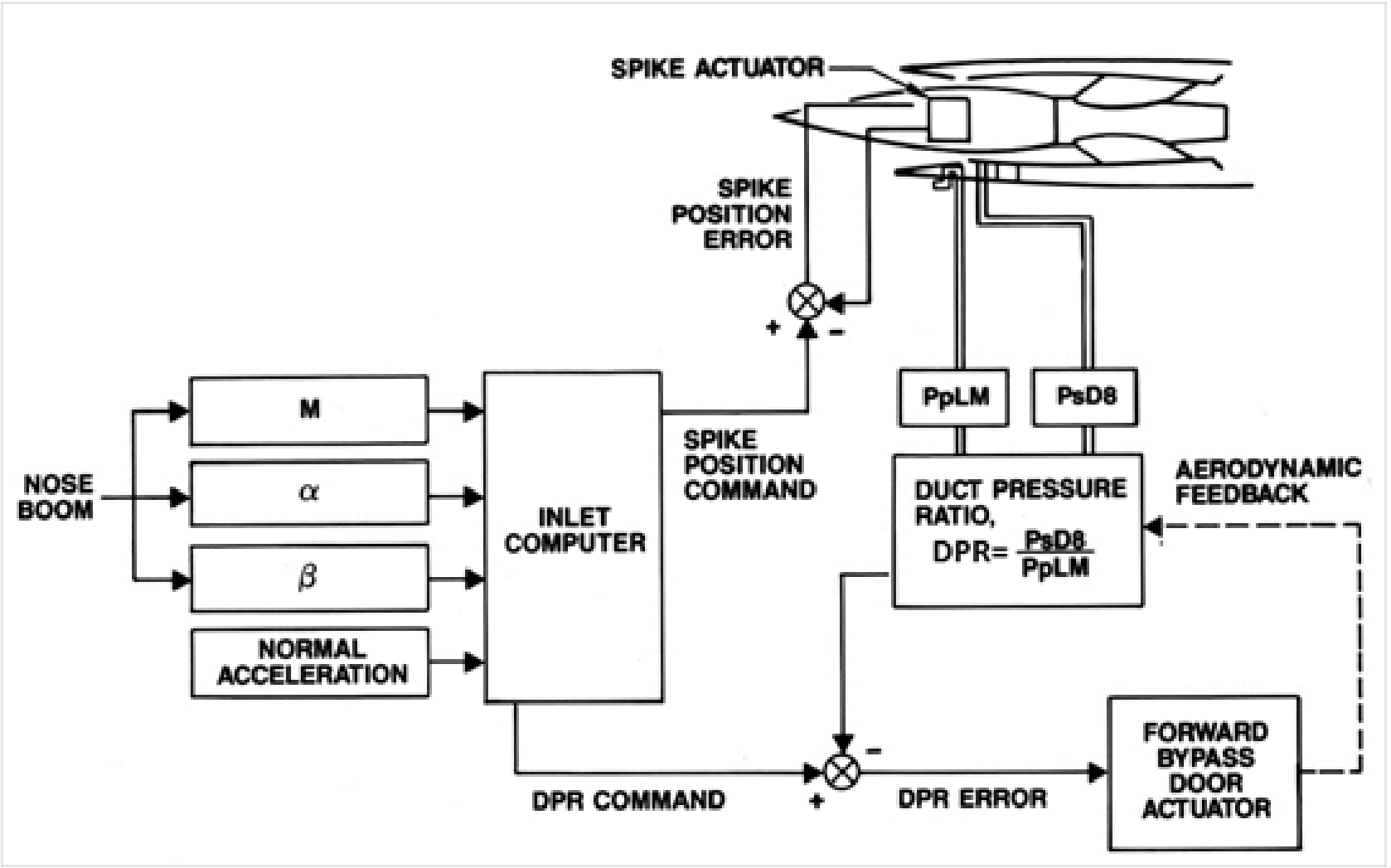


Inlet Cant	Δδ (Downward)	Δδ (Inboard)
Preliminary	6.5 deg.	0 deg.
Final	5.6 deg.	3.2 deg.

Forward Bypass Matches Inlet And Exit Airflow



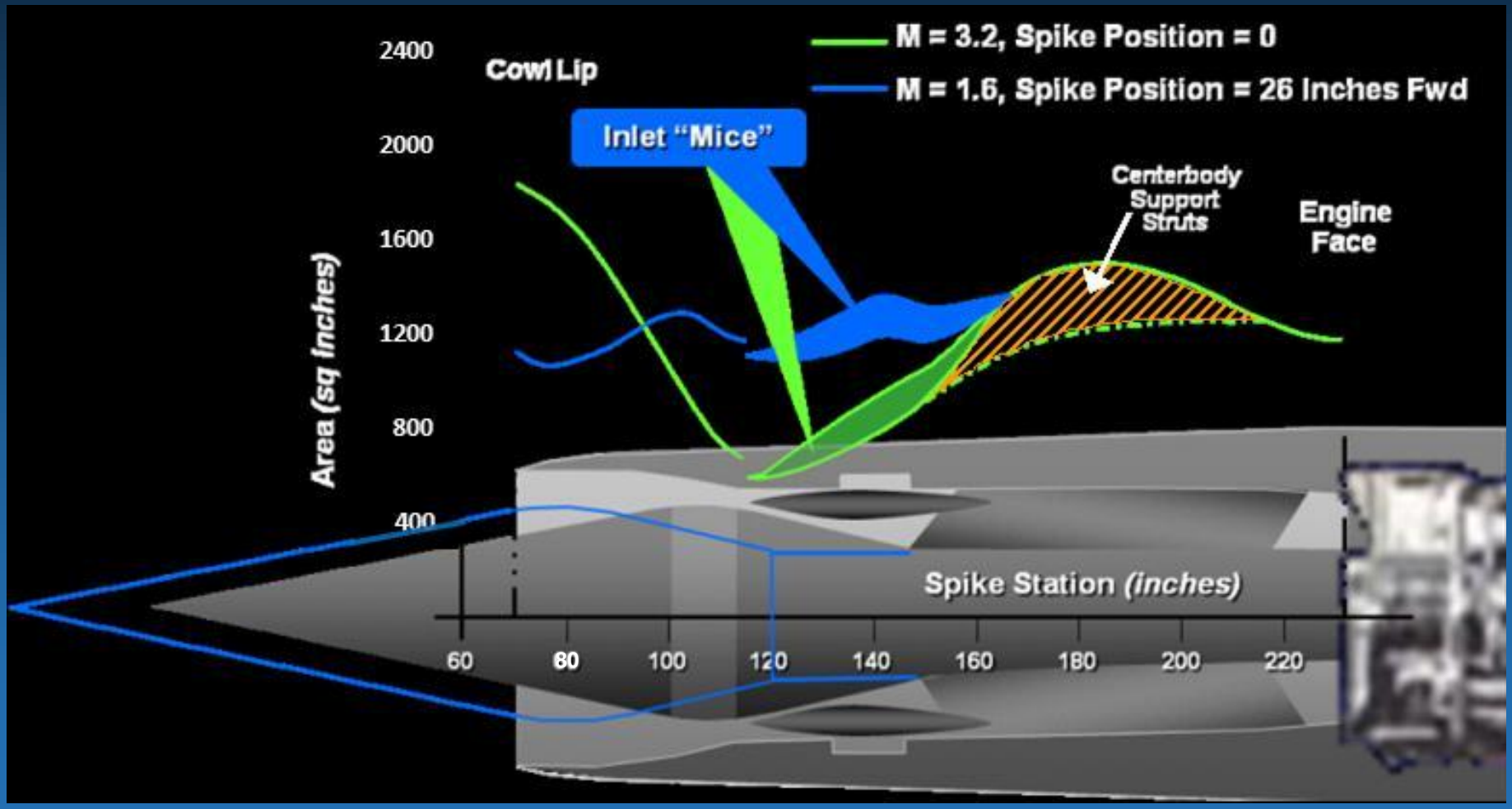
Inlet Automatic Control System



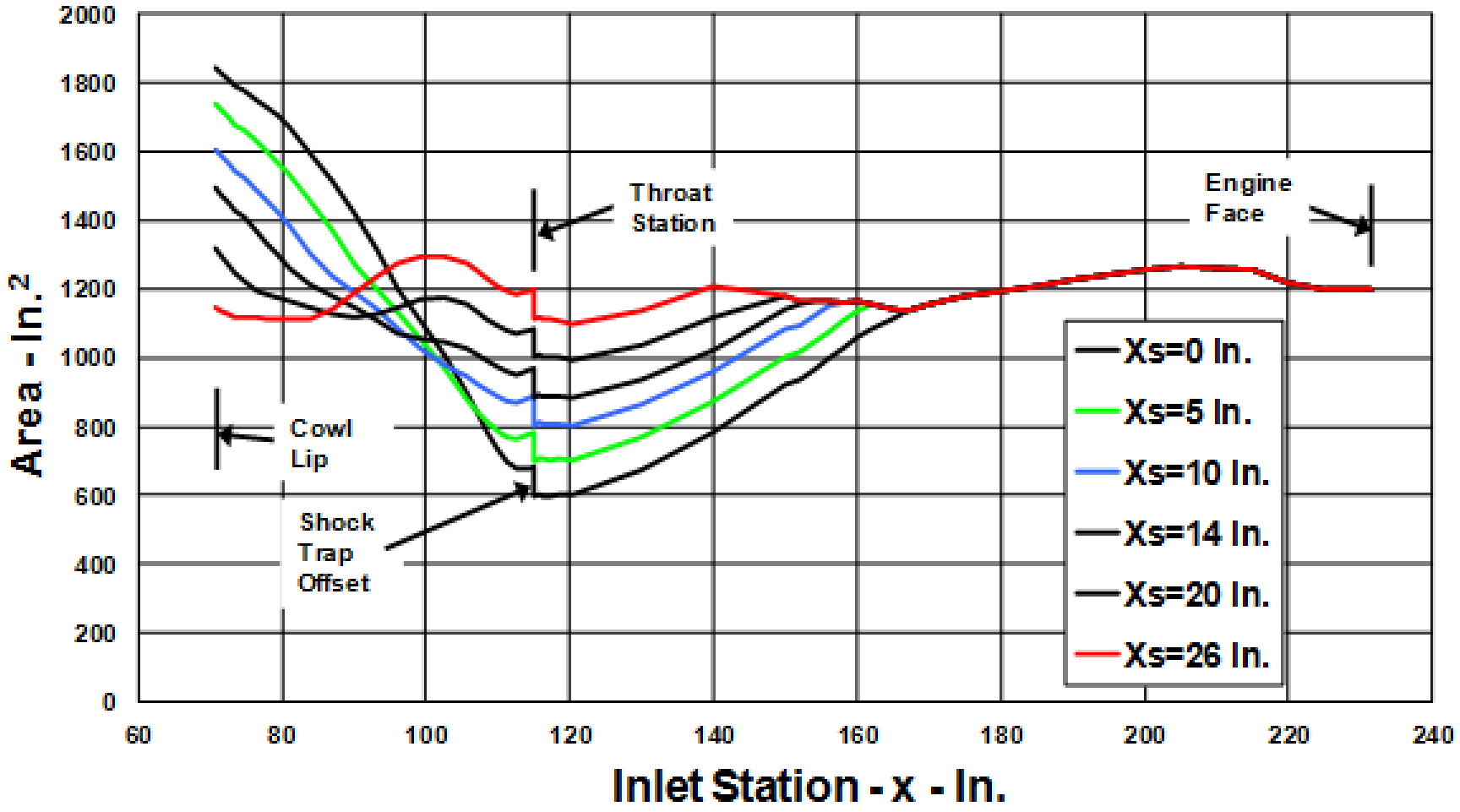
Variable Geometry Is Required

- **Mach Numbers Below Cruise Require Increased Throat Area.**
- **Internal Flow Areas Must Grow In Order To Restart The Inlet From An Unstarted Condition.**
- **Therefore Variable Area Internal Geometries Are Required.**
- **This is Accomplished On The SR-71 By Spike Translation.**

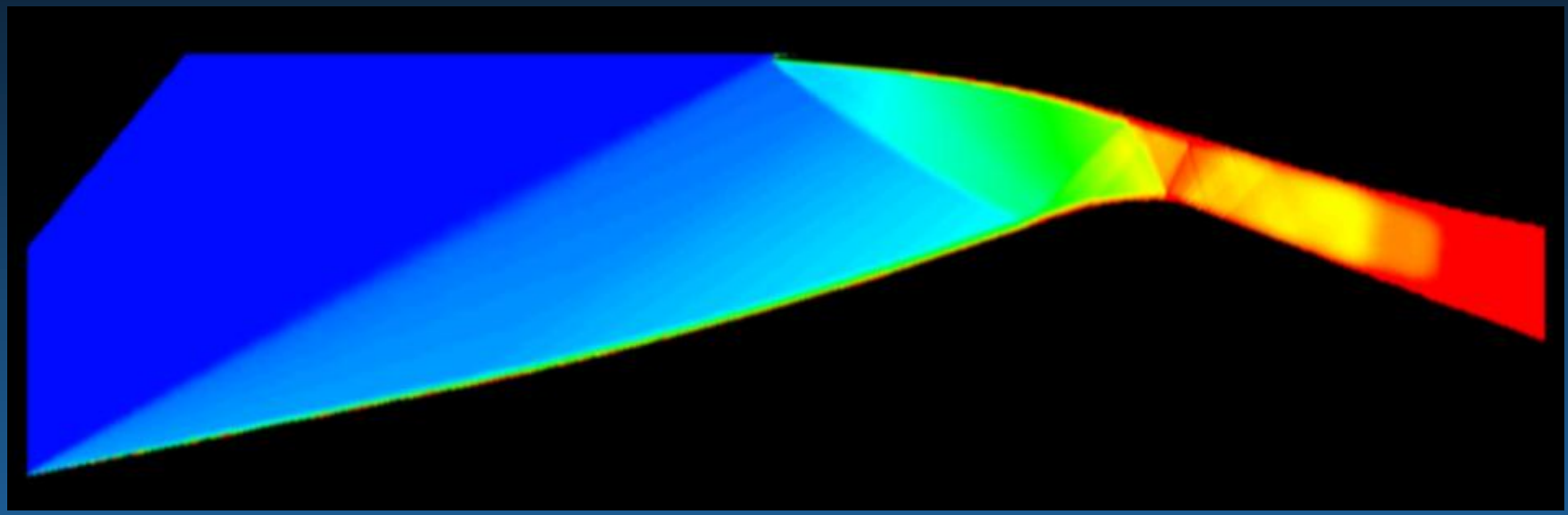
Inlet Geometry And Area Distribution

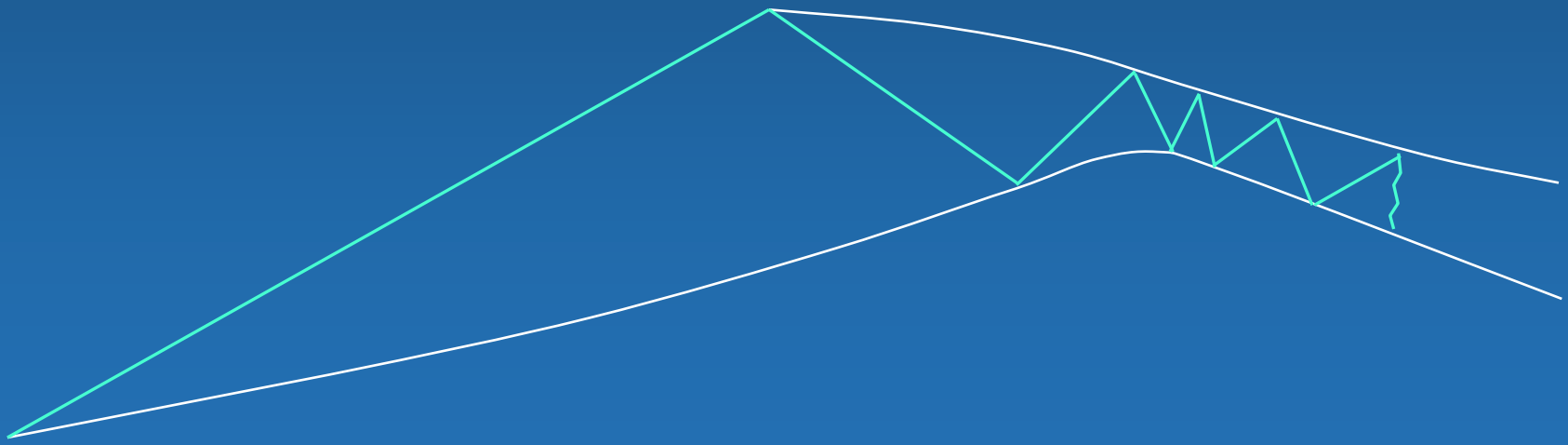


Spike Translation Varies Inlet Area Distribution

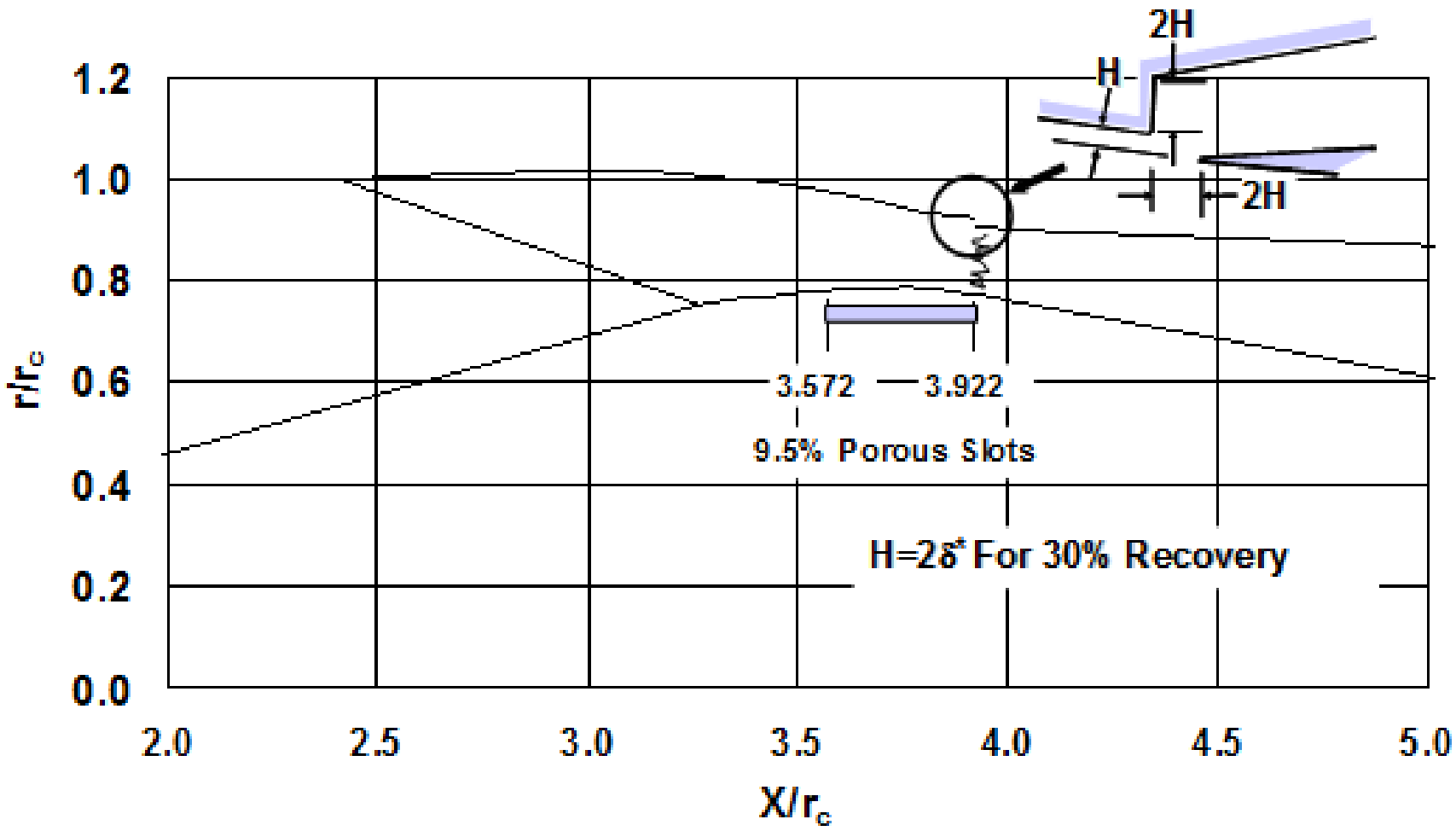


Supersonic Diffuser Flow Field

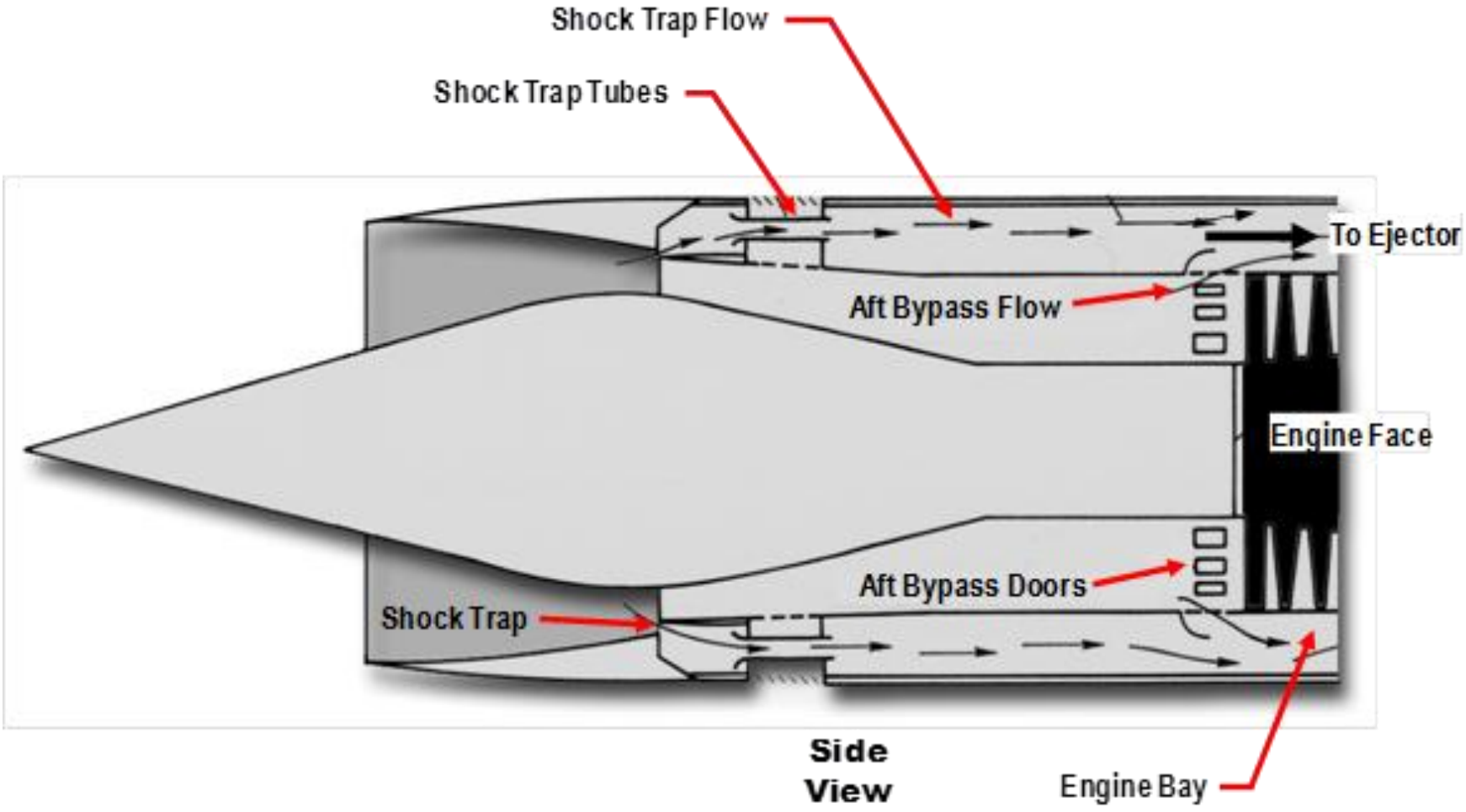




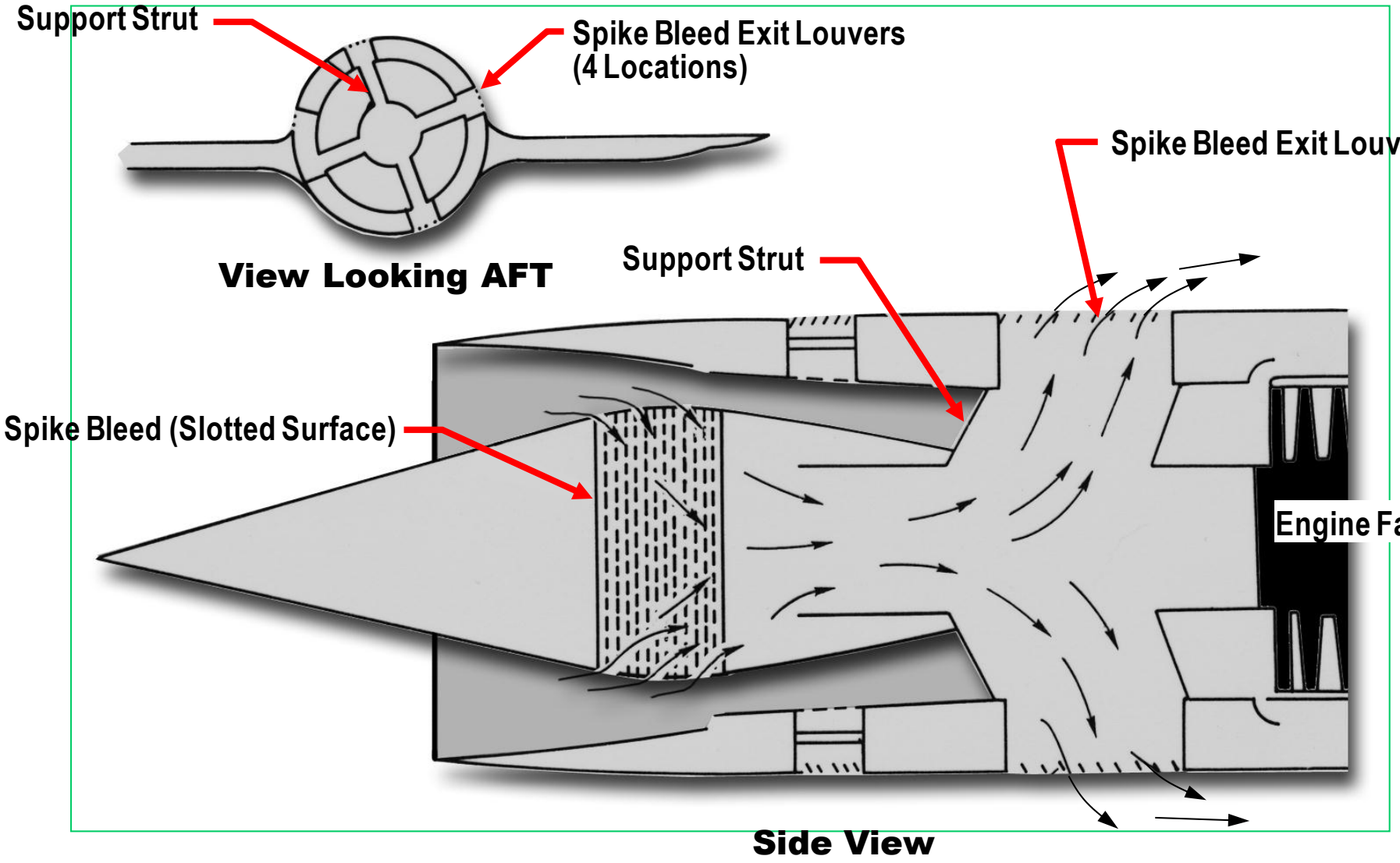
SR-71 Inlet Bleed Regions



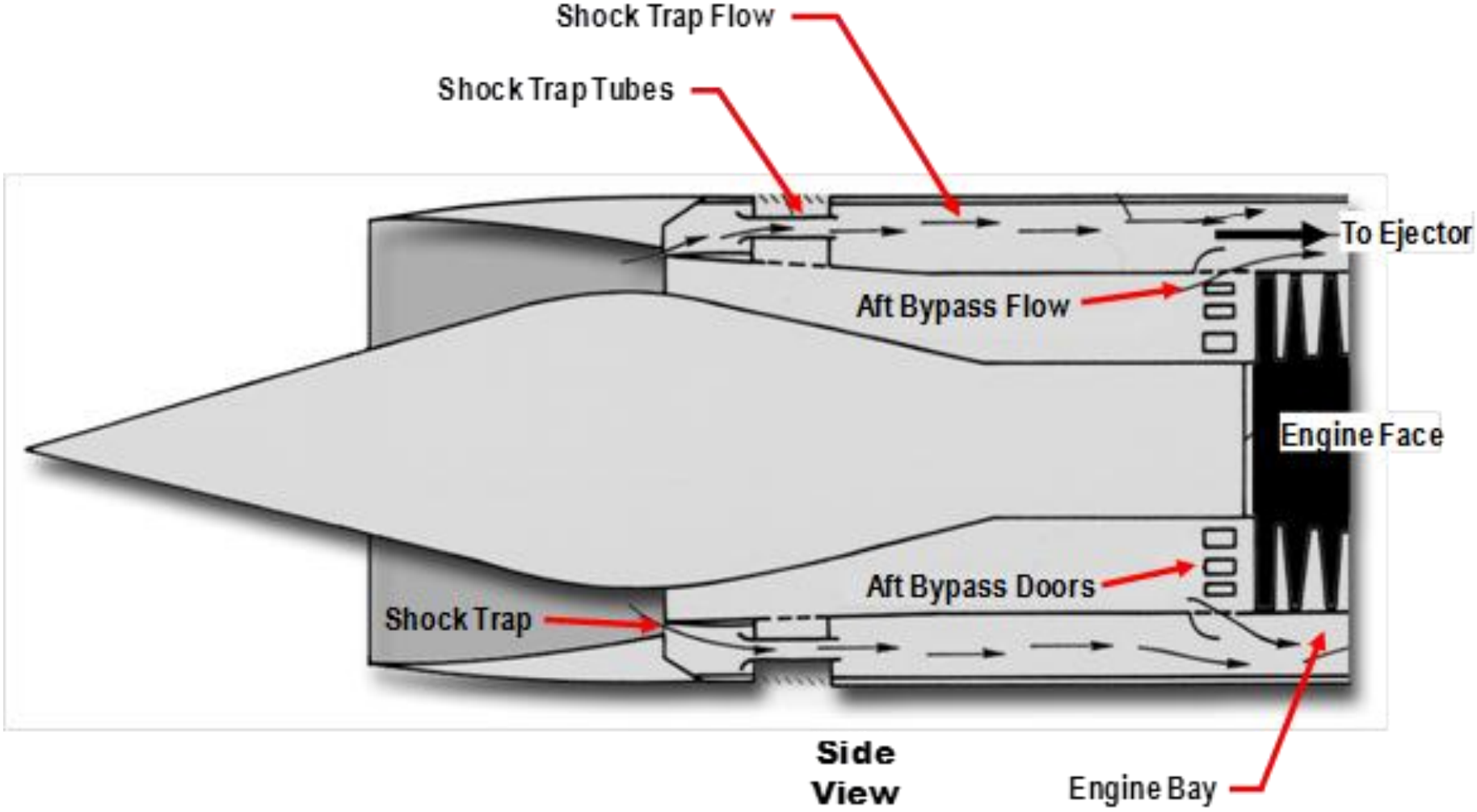
Cowl (Shock Trap) Bleed Flows To Nozzle



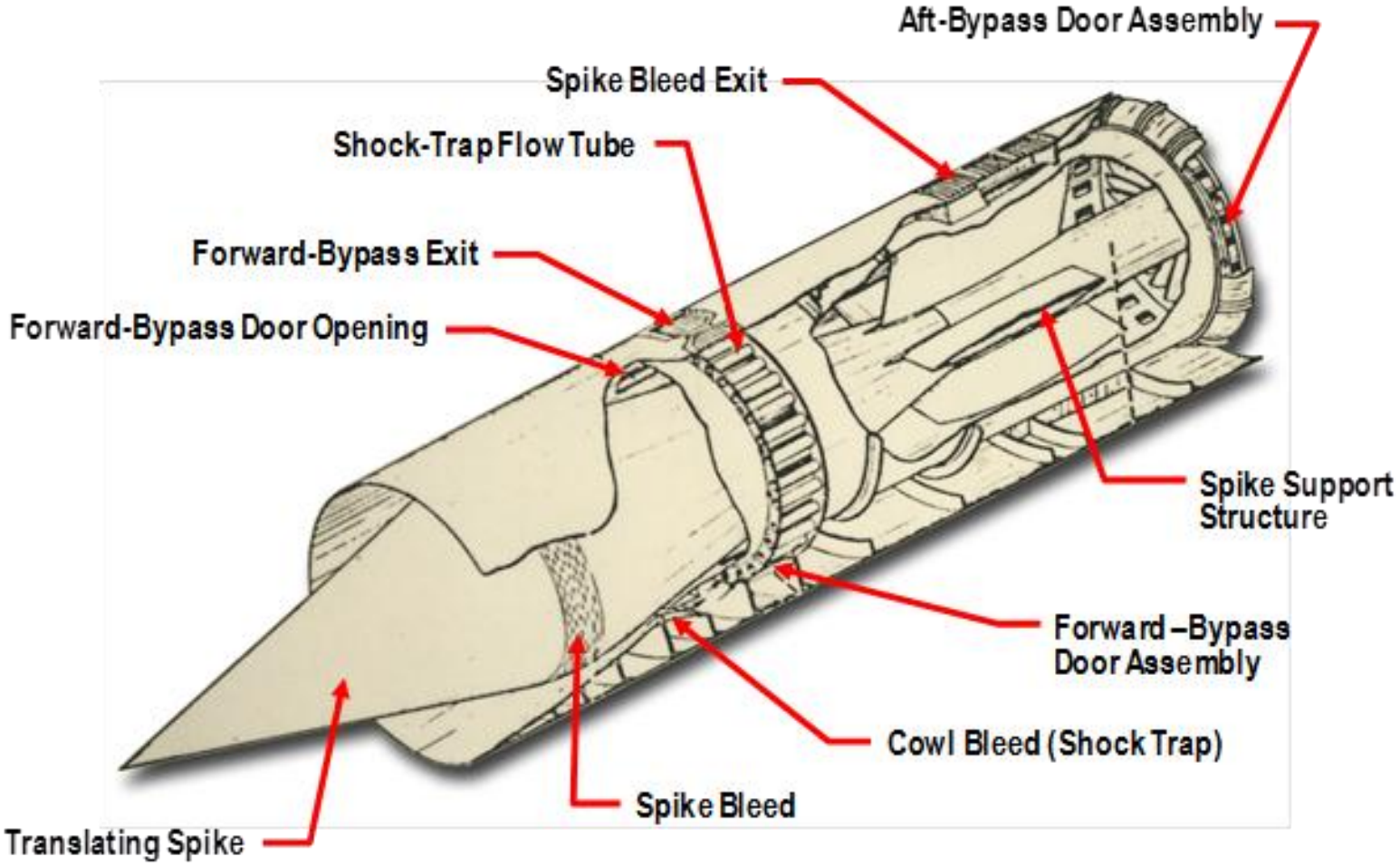
Centerbody (Porous) Bleed Flows Overboard



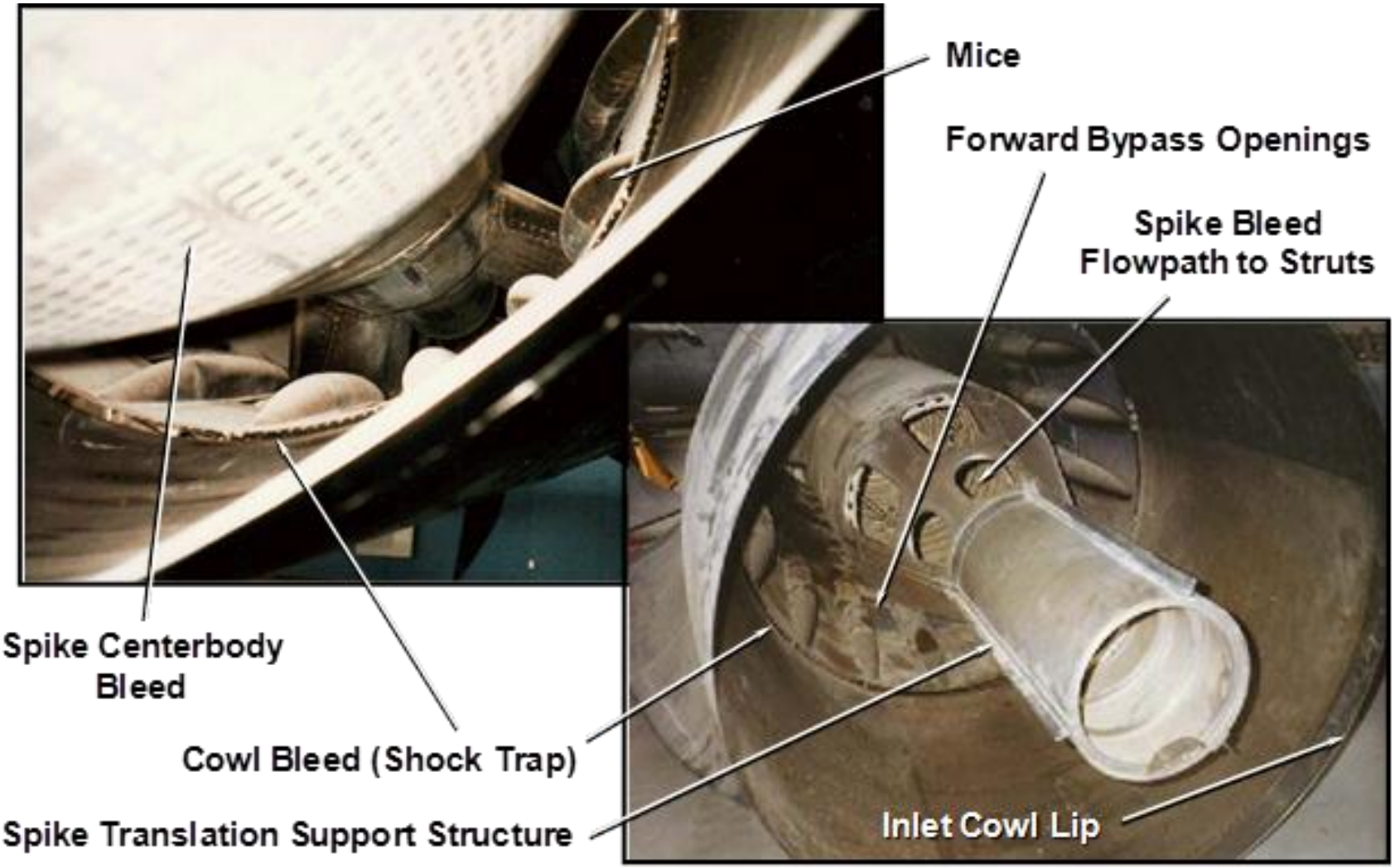
Aft Bypass Flows to Nozzle



Inlet Geometric Features



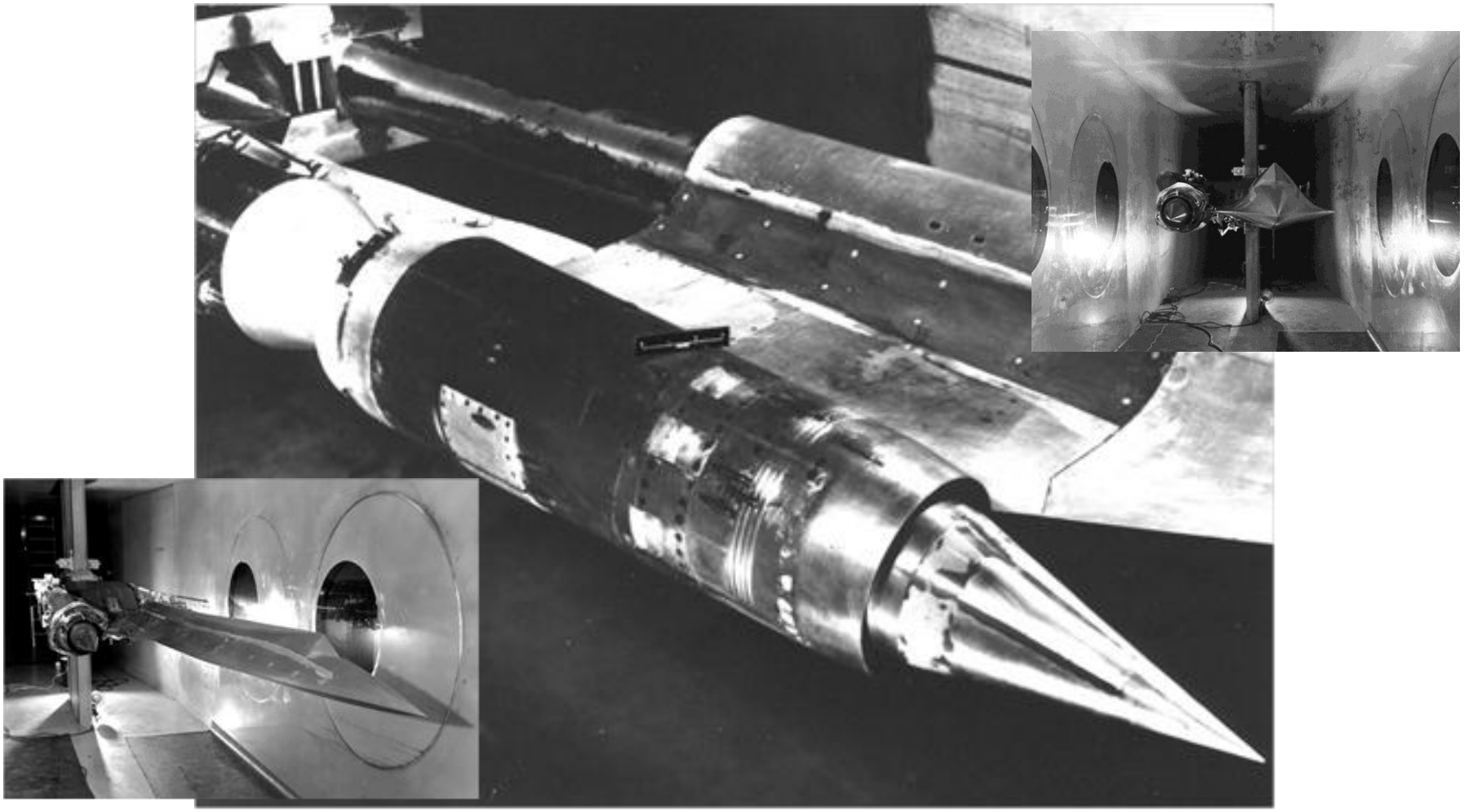
Inlet Diffuser Photos



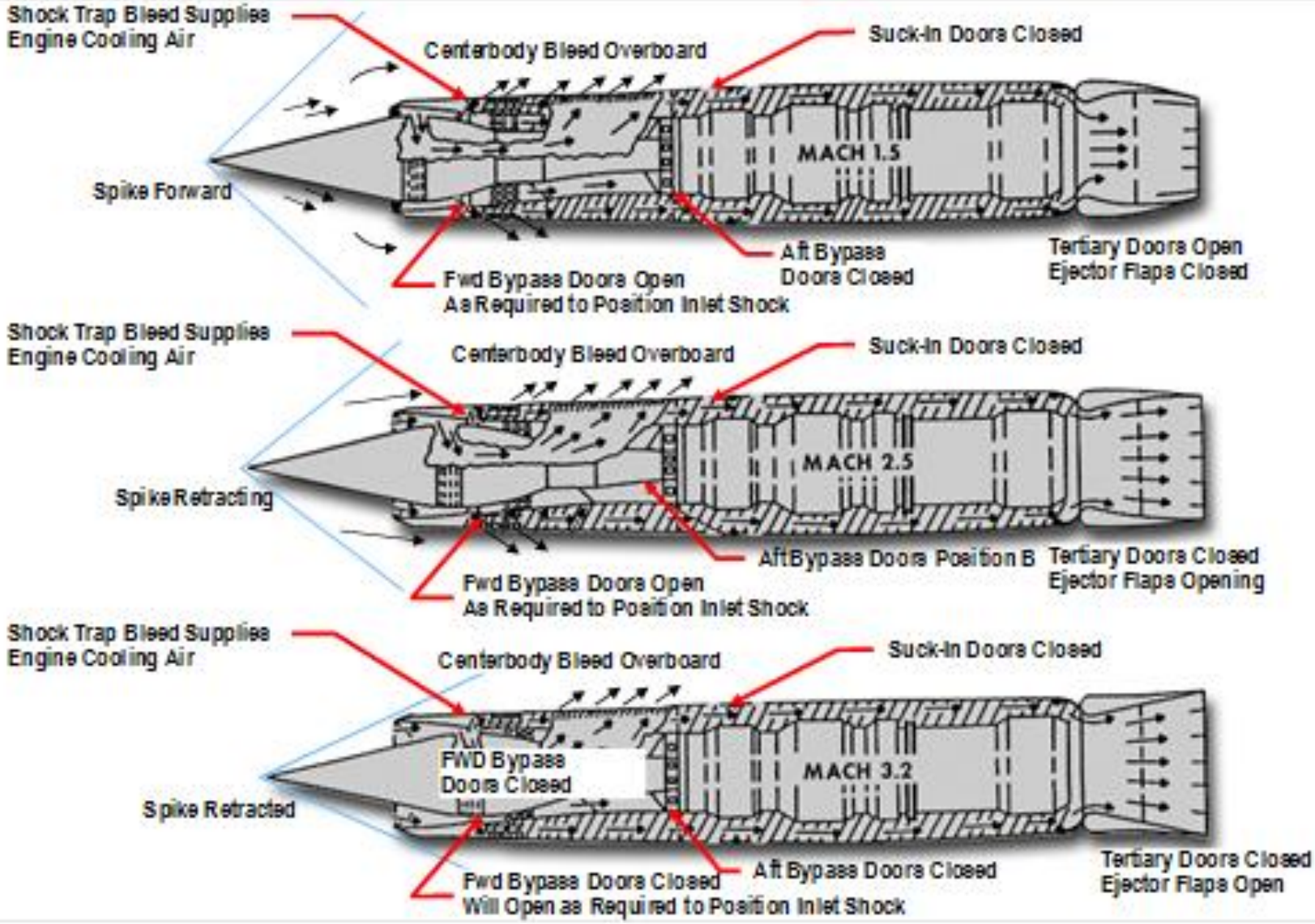
Nacelle Leakage Test Rig

Backup

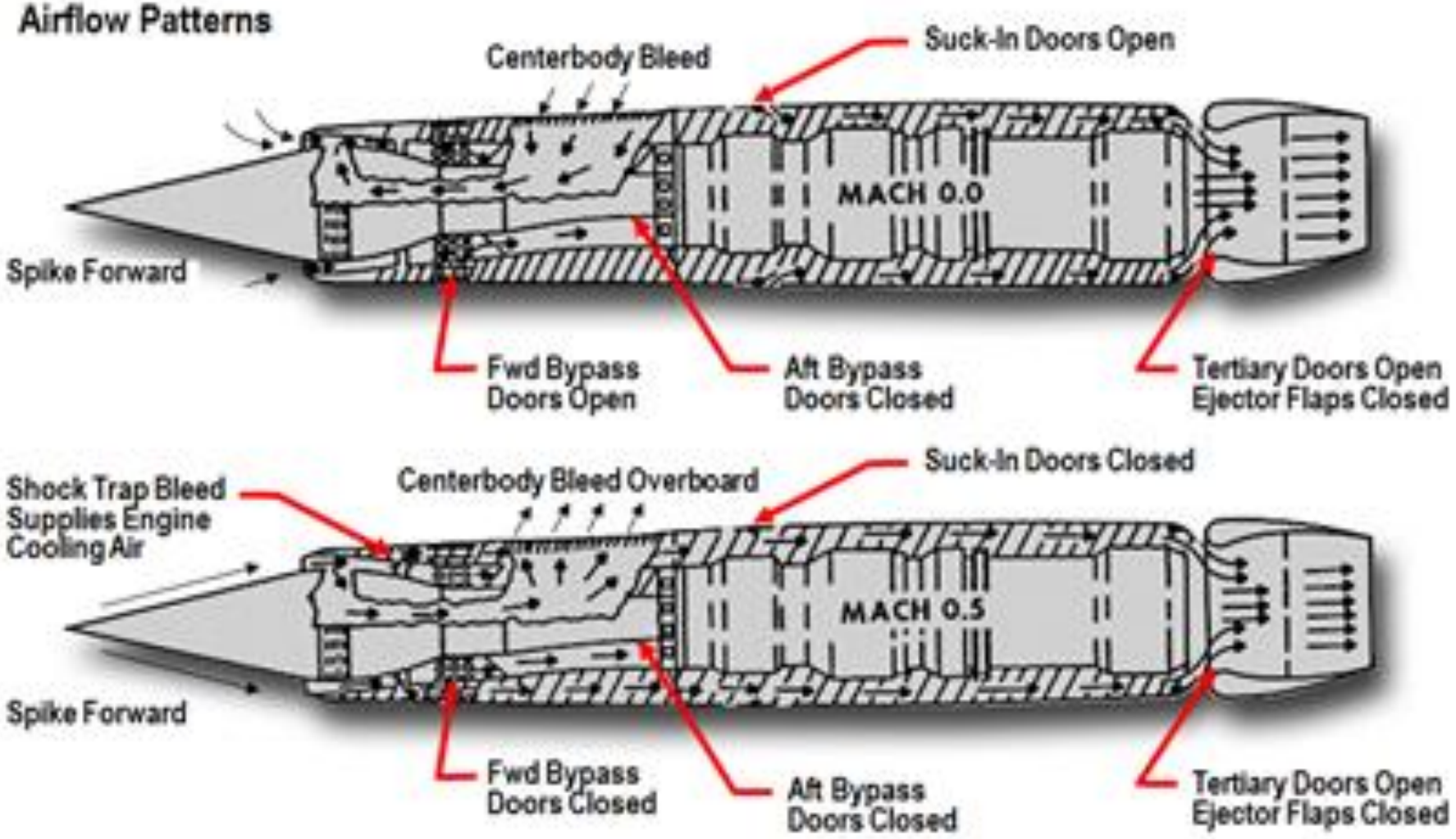
Inlet Wind Tunnel Model



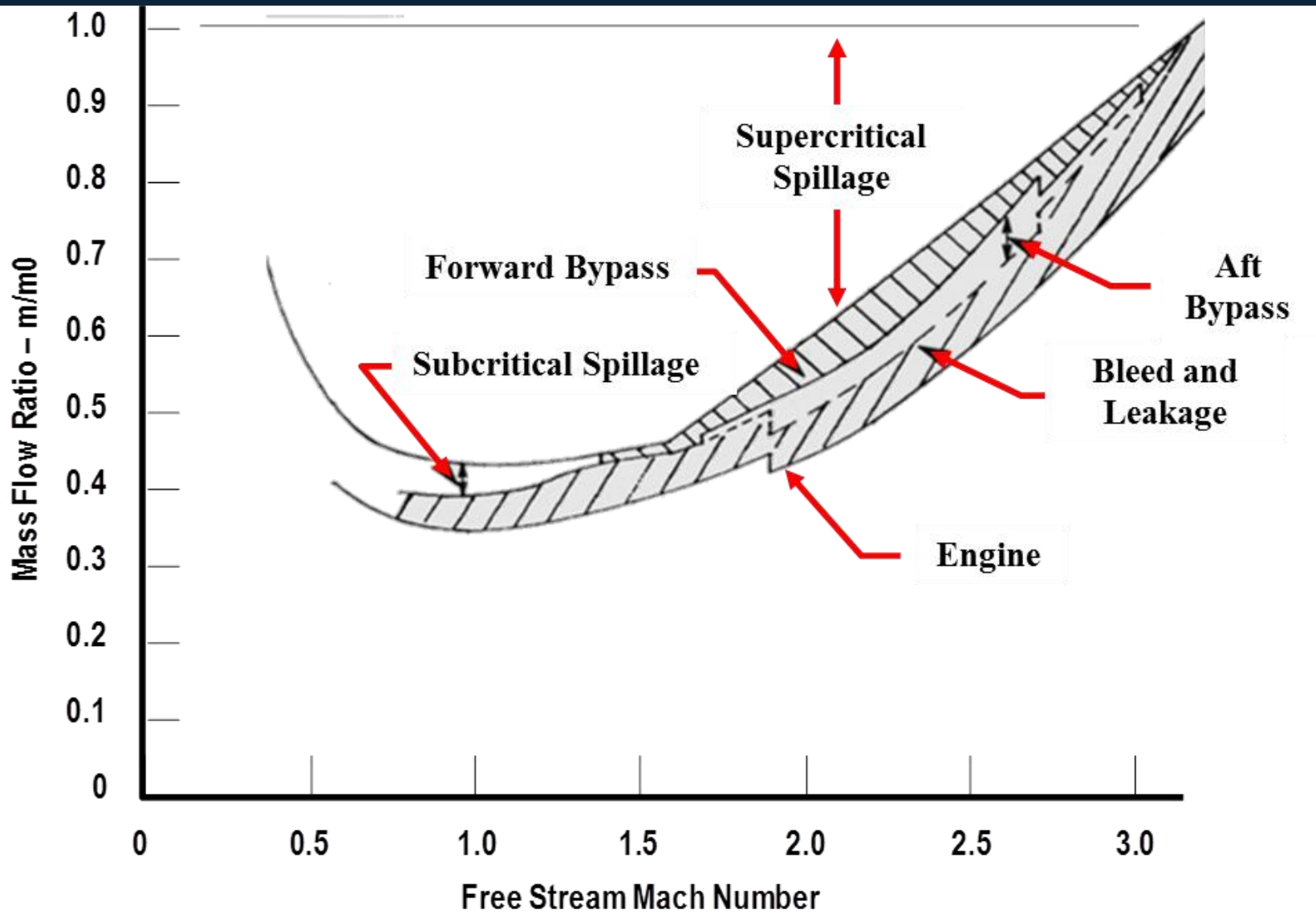
Inlet Airflow Paths



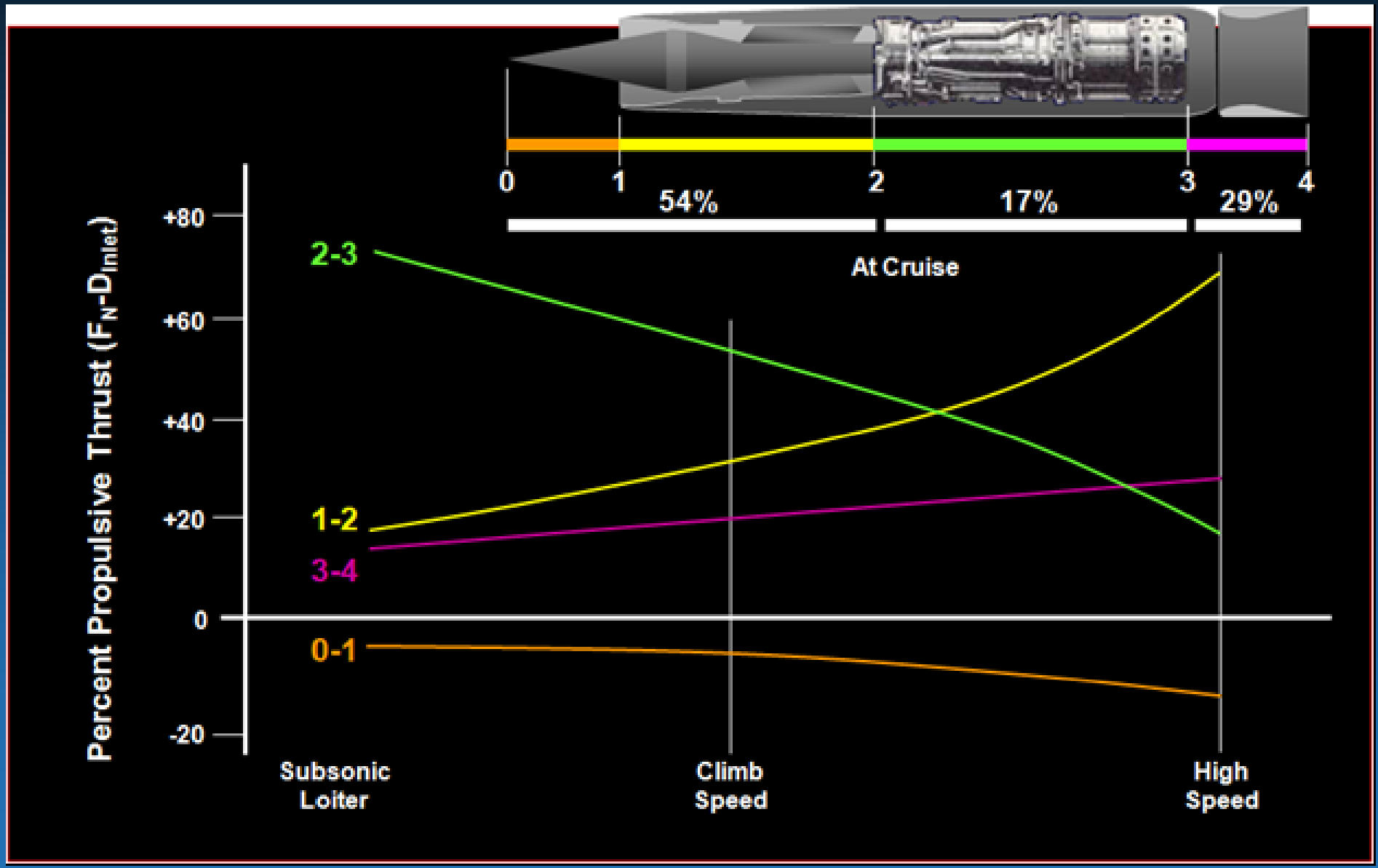
Inlet Airflow Paths



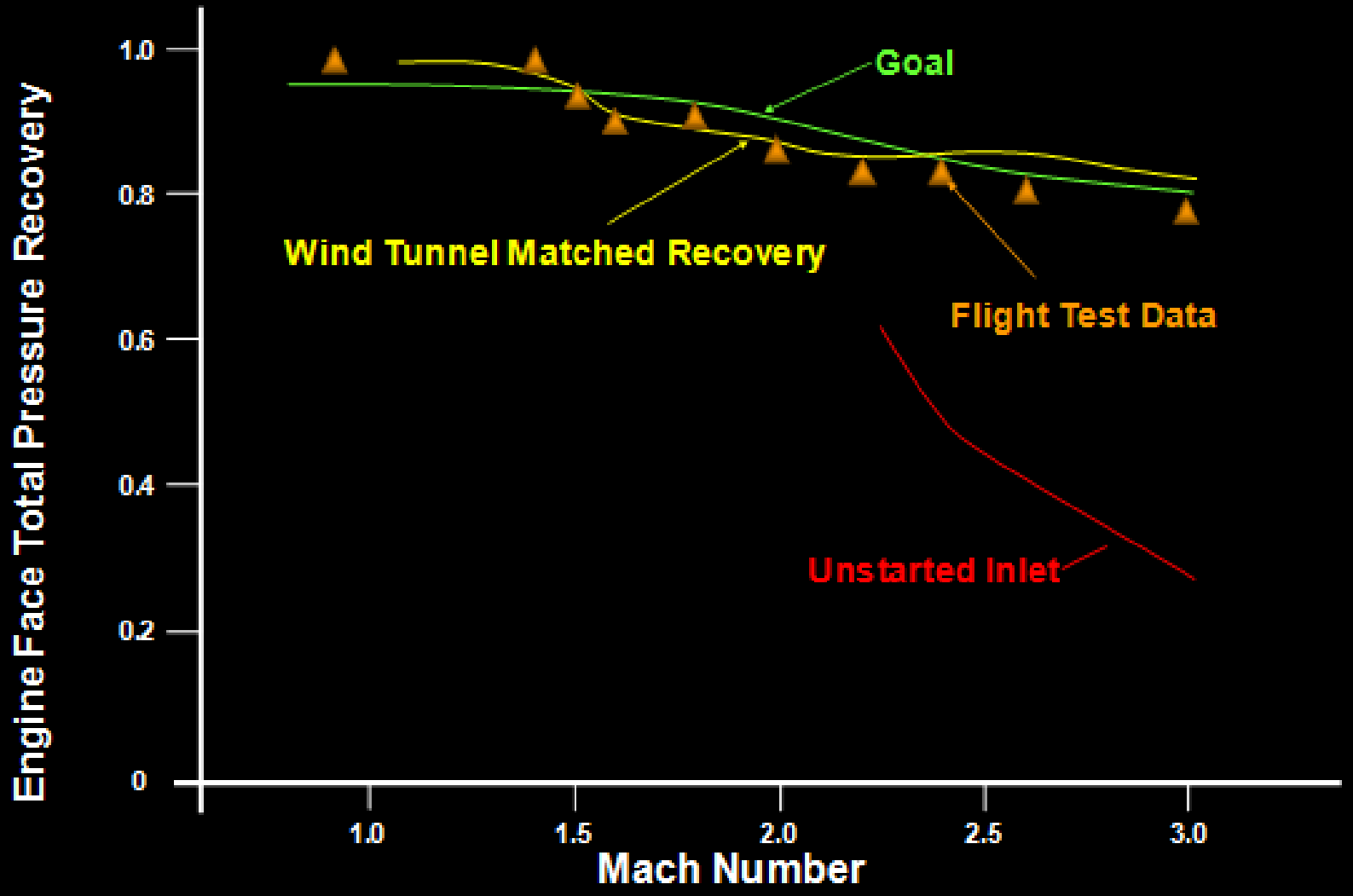
Inlet Airflows



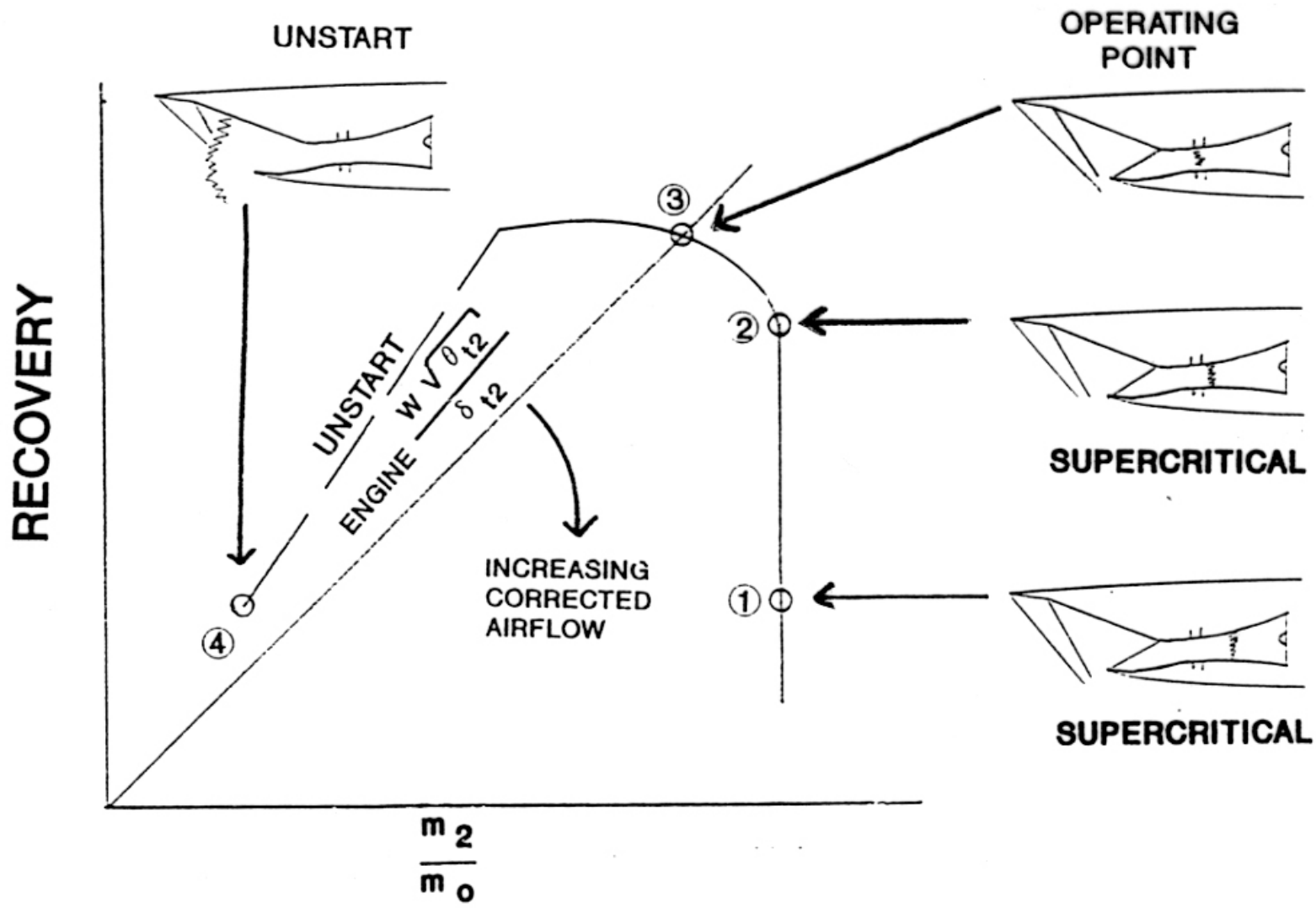
Nacelle Thrust Distribution



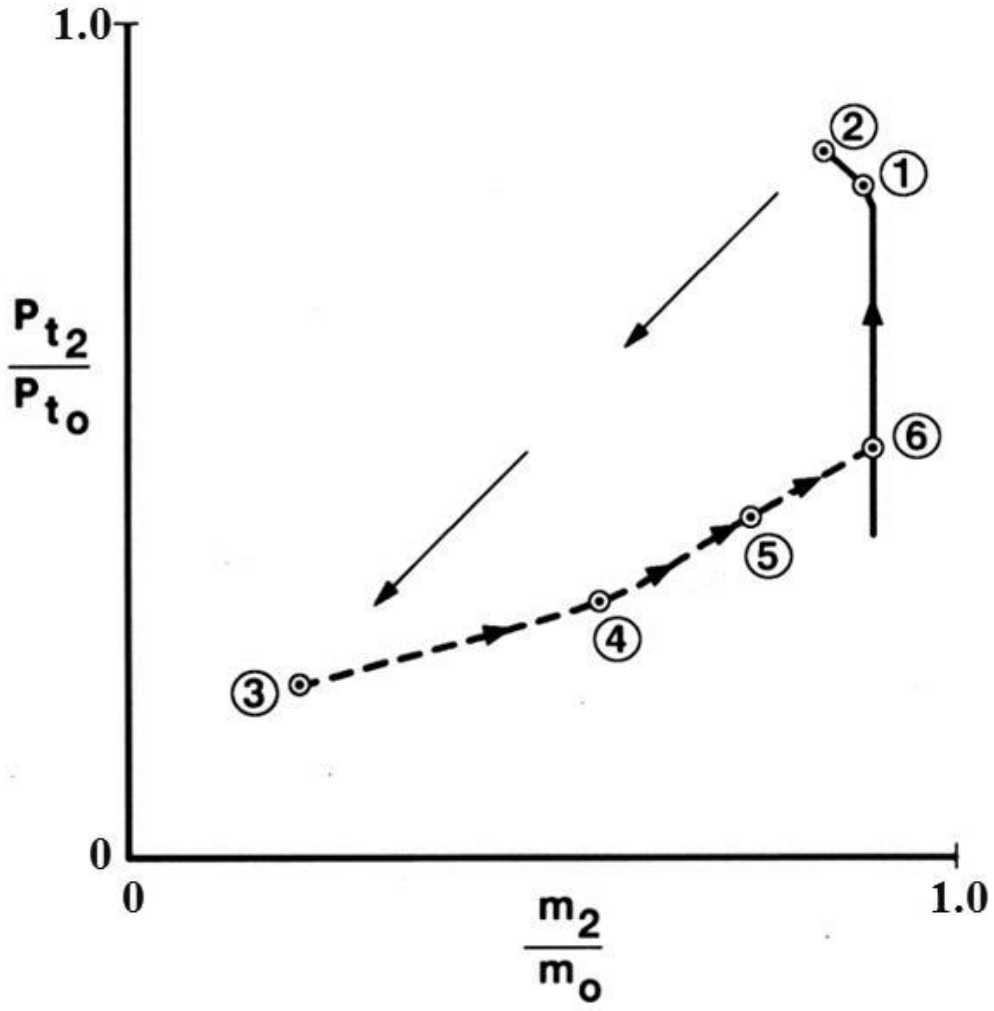
Inlet Pressure Recovery



Mixed Compression Inlet Characteristics



Inlet Restart Cycle



① OPERATING POINT

② UNSTART POINT

③ UNSTARTED POINT

③–④ EXTEND SPIKE
OPEN BYPASS

④–⑤ RESTART INLET

⑤–⑥ RETRACT SPIKE

⑥ ① CLOSE BYPASS