Lecture 20

Supersonic Inlets/Intakes/Diffusers

Typical Supersonic Inlets

A supersonic inlet must manage and exploit shock waves to effectively decelerate the airflow to a subsonic condition at compressor entry.

http://en.wikipedia.org/wiki/Inlet_cone

Mirage III detached half cone

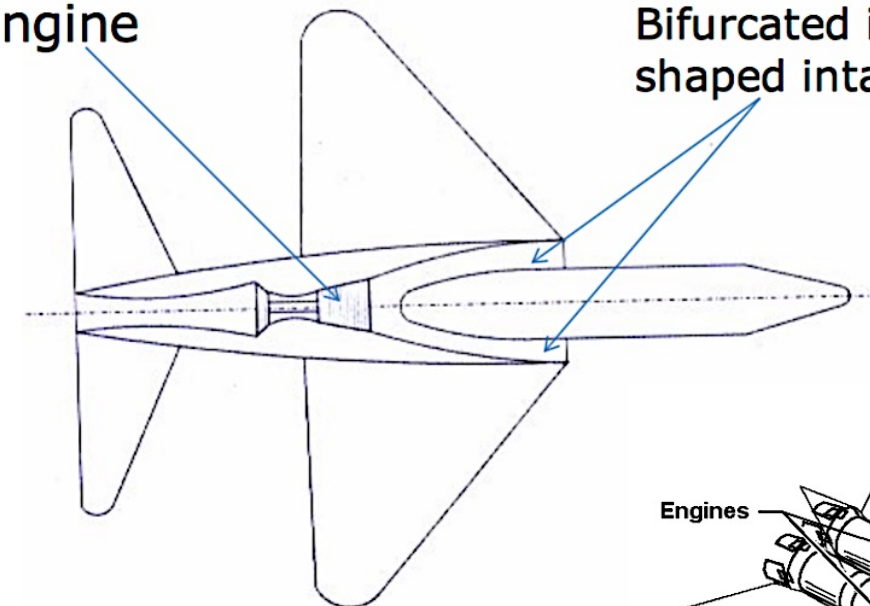
Inlet cone of SR-71 Blackbird

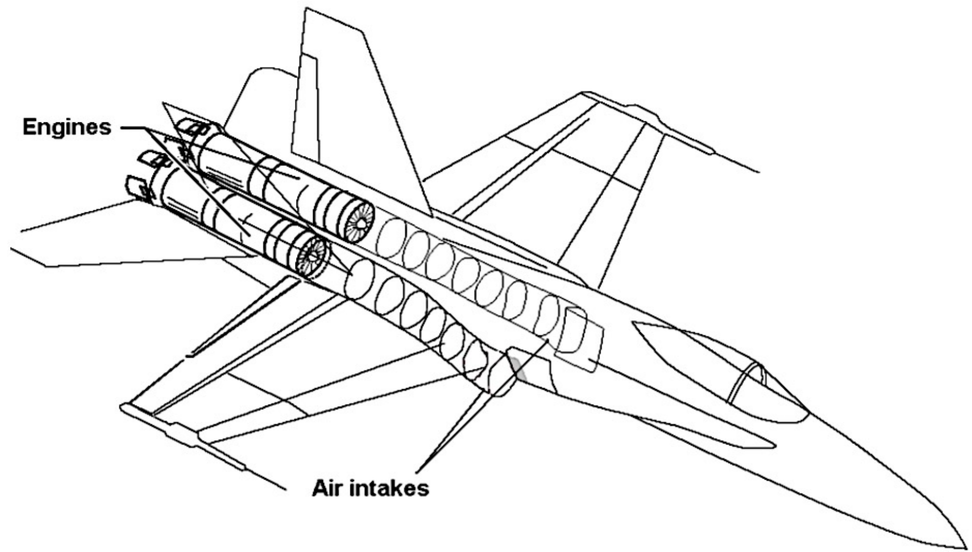
X-35 diverterless trapezoidal

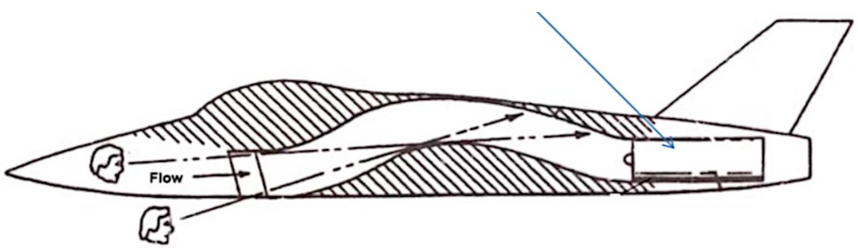
Inlet to Engine Configurations

Single engine

Bifurcated intakes or Y shaped intakes







Serpentine intake

Qualitative Summary for Isentropic Flow w/Area Change

$$\frac{dA}{A} = \frac{du}{u}\left[M^2 - 1\right] = \frac{dM}{M}\left[M^2 - 1\right]$$

Area-Velocity Relationship

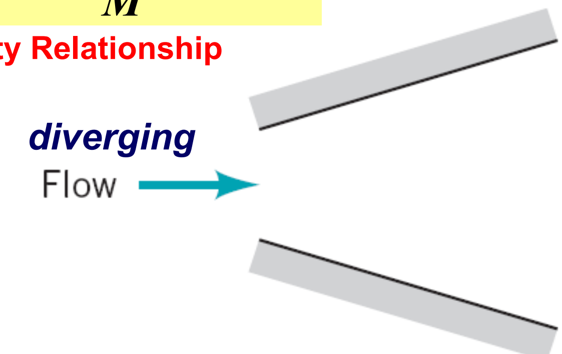
$$dp = -\rho u du$$

$$dh = -u du = c_p dT$$

$$\frac{d\rho}{\rho} = -\frac{du}{u} M^2$$

Cons. Mass, Cons. Energy,
2nd Law, Cons. Mom.

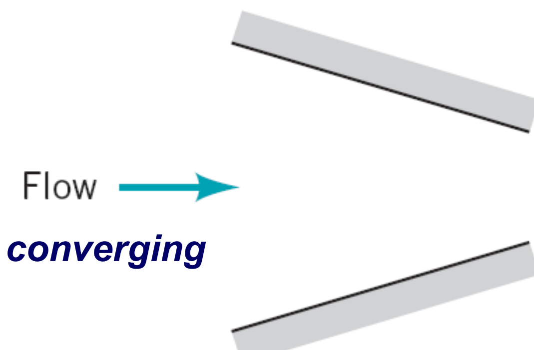
Supersonic Flow



$M > 1$

$dA > 0$

du increases
dM increases
p, h, T, and ρ decrease



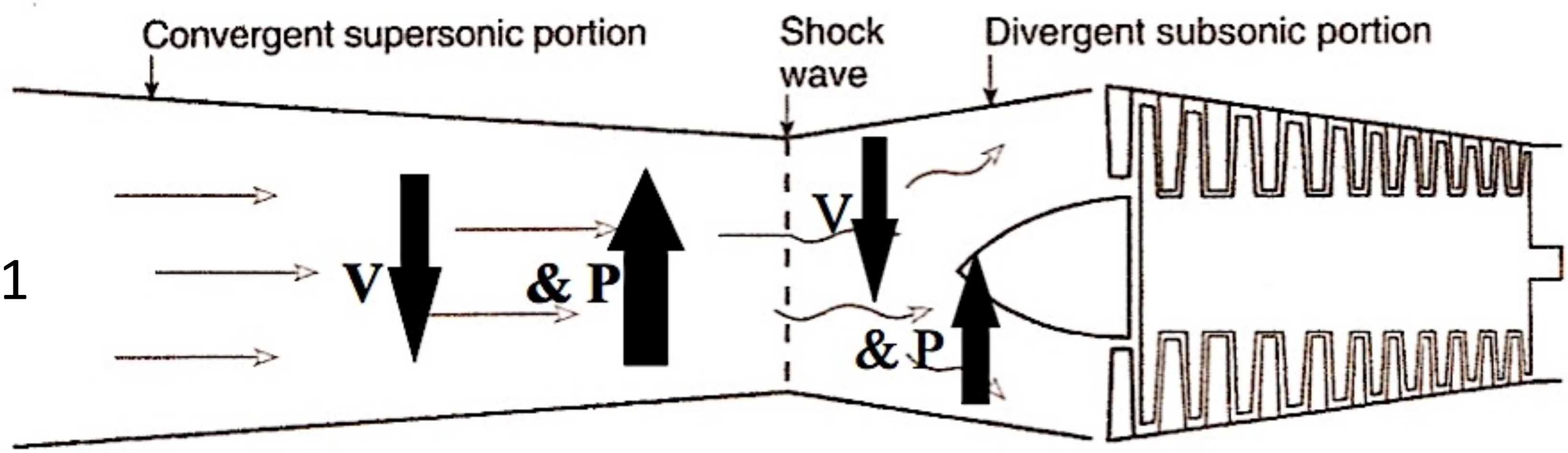
$M > 1$

$dA < 0$

du decreases
dM decreases
p, h, T, and ρ increase

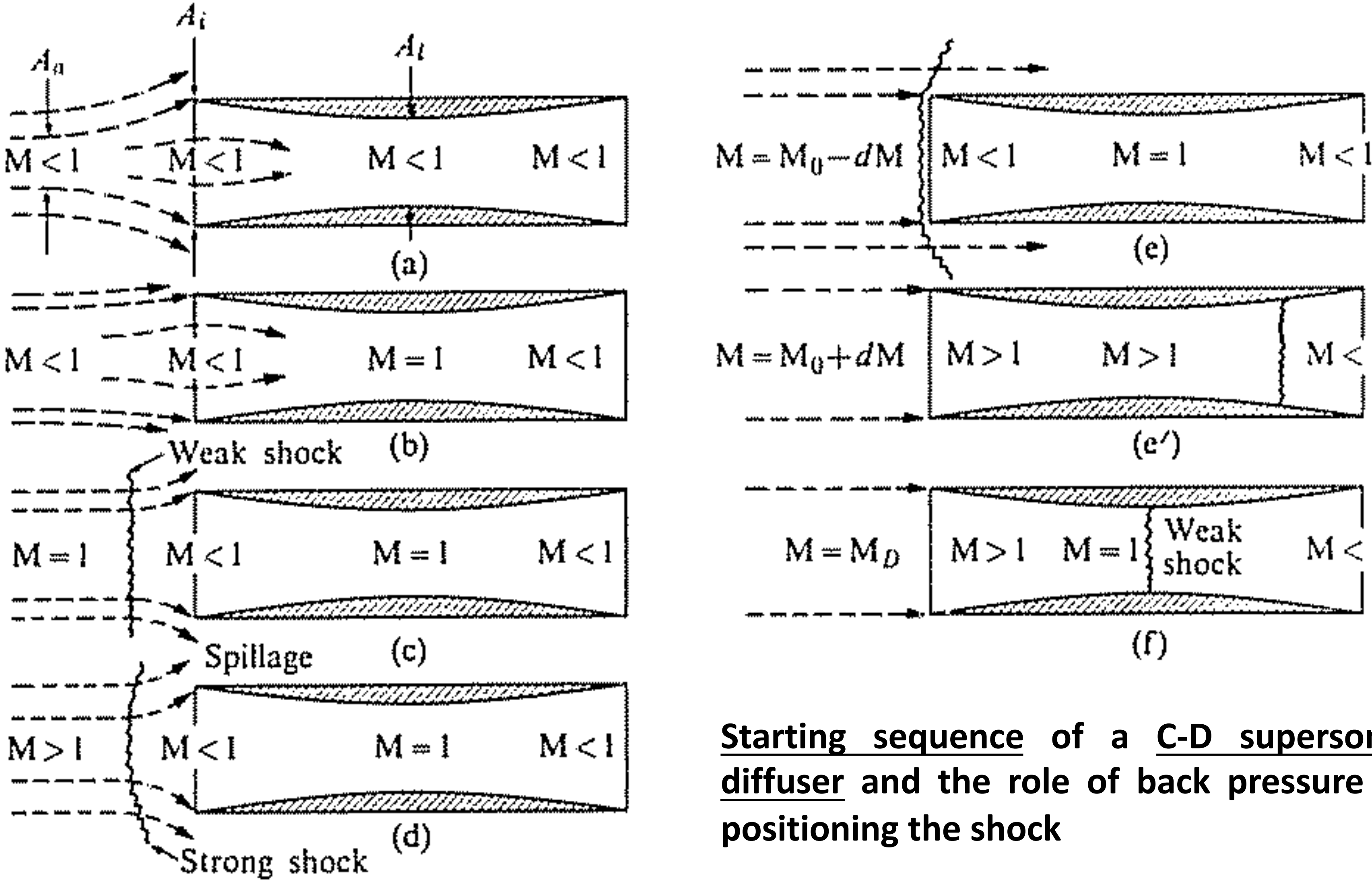
Converging-Diverging Diffuser

M > 1



- Can get close to isentropic flow
- Stability issues with shock position
- Starting problem – needs over-speeding or variable area throat, which makes it heavy
- the "reverse nozzle diffuser" is <u>not commonly used</u>

C-D NOZZLE IN REVERSE OPERATION (AS A DIFFUSER)

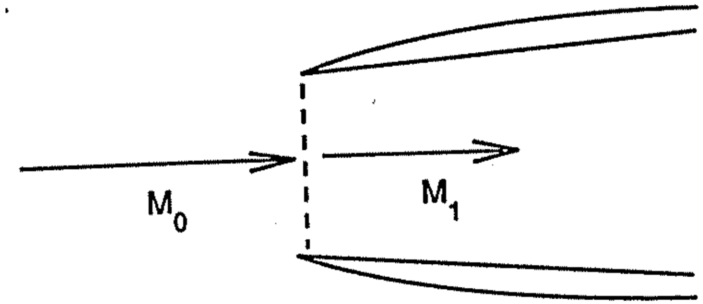


<u>**Starting sequence**</u> **of a** <u>**C-D supersonic diffuser**</u> **and the role of back pressure in positioning the shock**

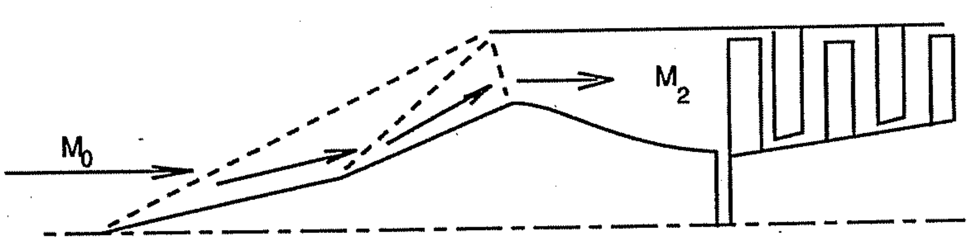
Practical Supersonic Inlet Types

F-16 Falcon (Normal Shock Inlet)

SR-71(Oblique Shock Inlet)



Normal Shock Diffuser
(chosen to minimize weight)

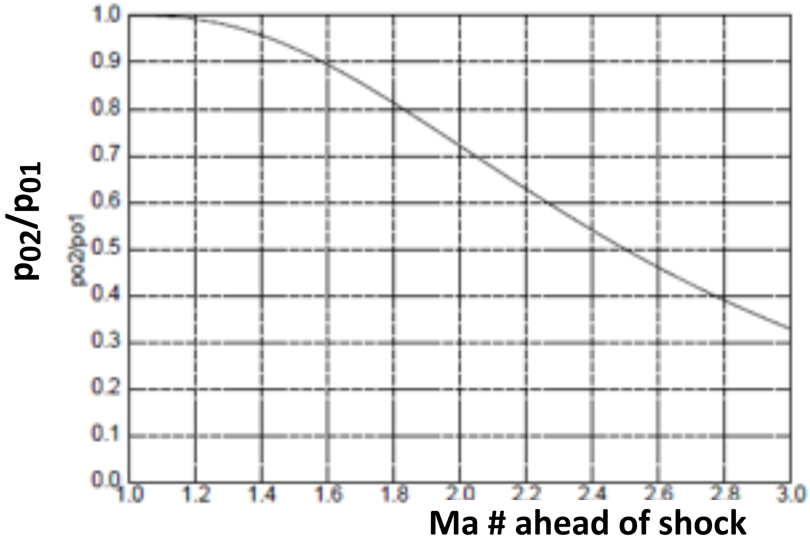


Oblique Shock Diffuser

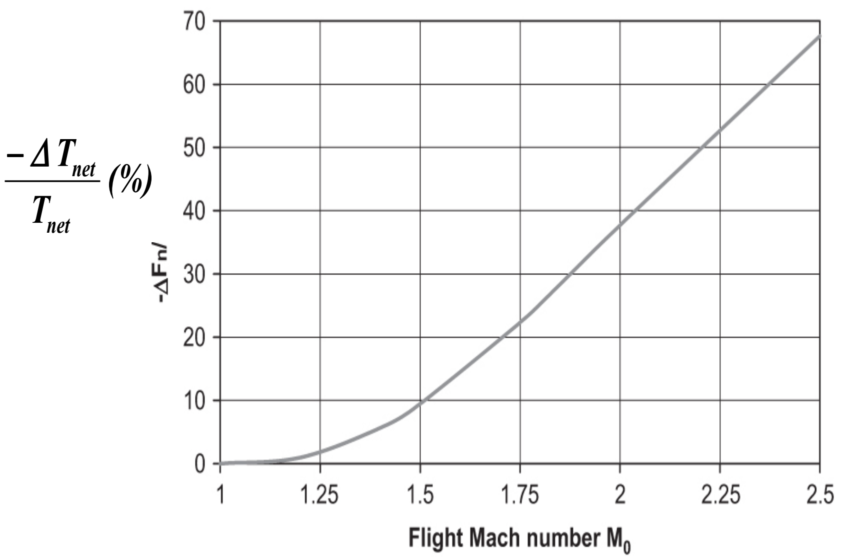
Normal Inlet Shocks

- In a supersonic inlet, transition to subsonic flow and compression occurs across a normal shock
- Significant compression can be achieved
- Associated energy losses increase rapidly with flight Mach number

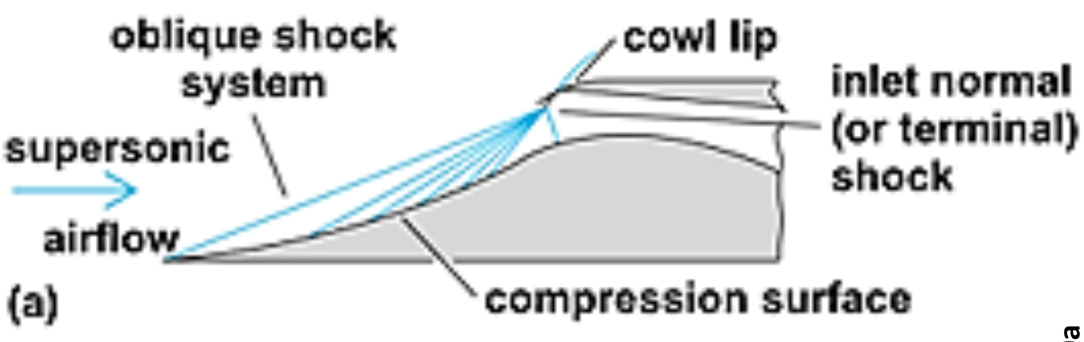
Vehicle	Velocity	Mach Number	Pram Pambient
Car	70 miles per hour	0.1	Less than 1.01
Airliner	530 miles per hour	0.8	1.5
Fighter Max Speed	1300 miles per hour	2.0	7.8
SR-71	2130 miles per hour	3.2	49.4



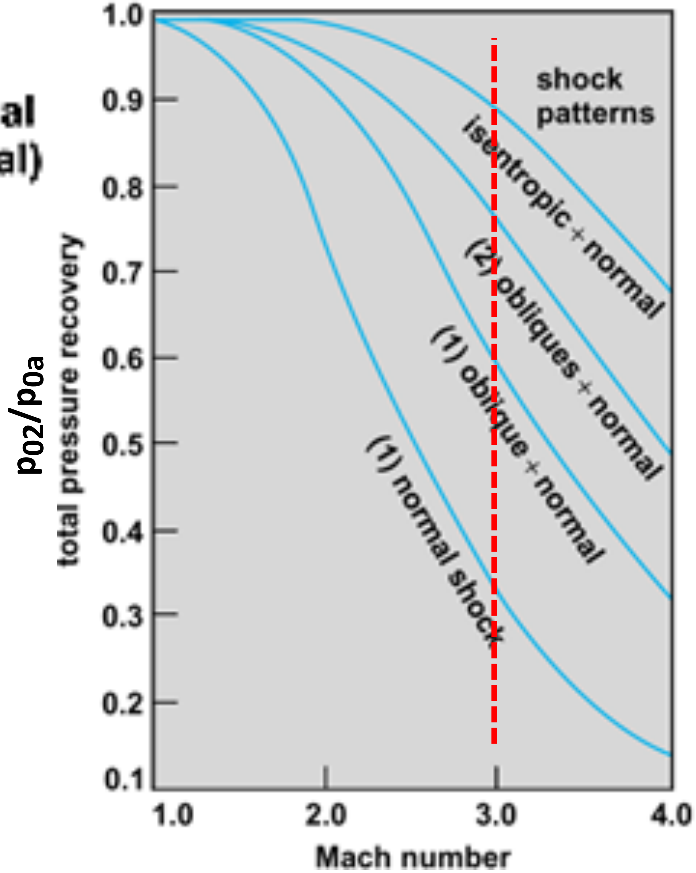
Net reduction in thrust using a normal shock inlet



Gradual External Deceleration



Also in Figure 6.15, Hill and Peterson

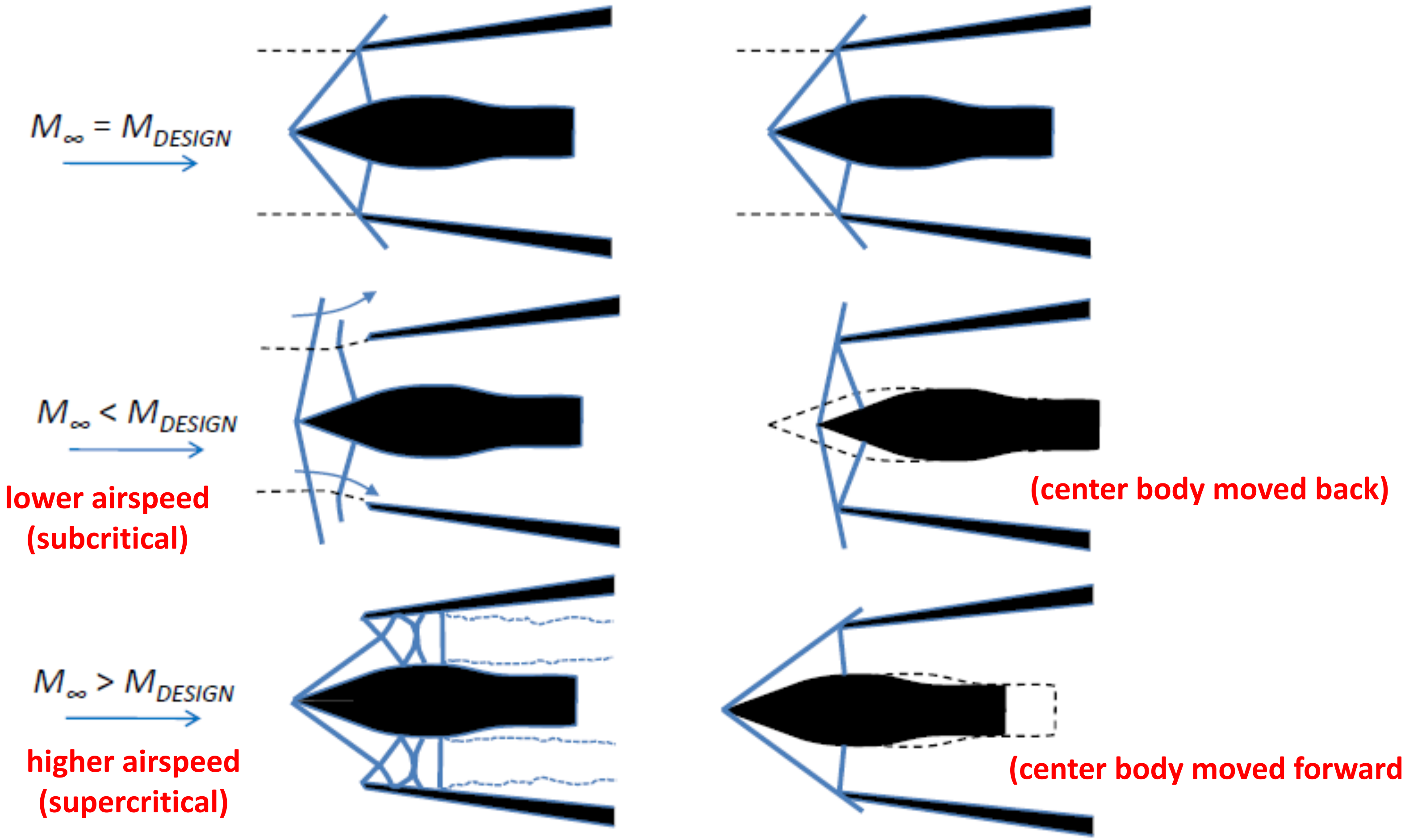


- Supersonic deceleration occurs at or ahead of the cowl lip (or throat station).
- Multiple oblique shocks occur ahead of a final, normal shock.
- Static pressure recovery increases with the number of oblique shocks and stagnation pressure loss is significantly reduced.
- However, off design operation is inefficient

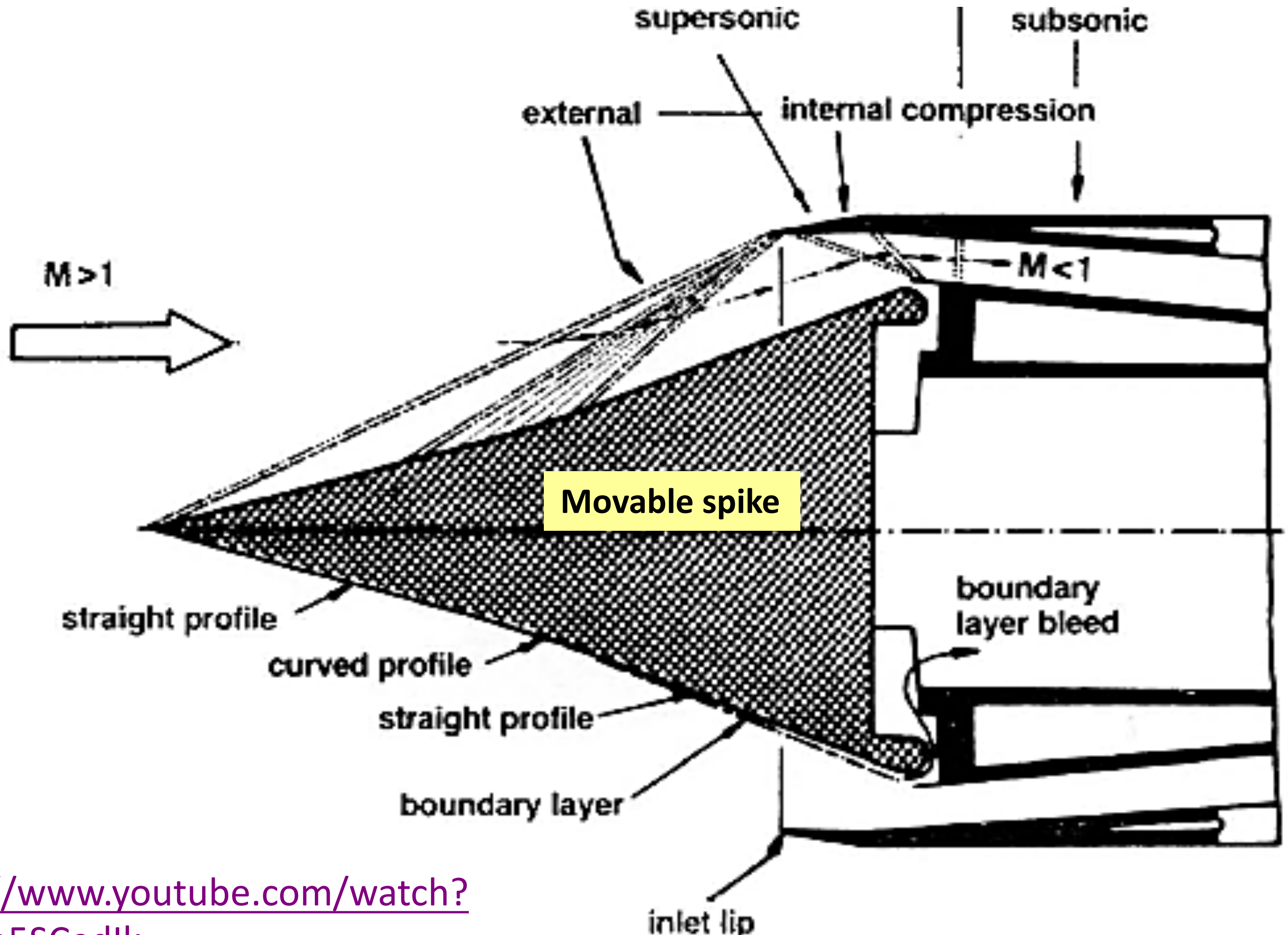
Best stagnation pressure retention occurs through a series of equal strength oblique shocks, terminated by a normal shock.

http://accessscience.com/content/Supersonic-diffuser/670100

Off-Design Operation



Example: SR-71 movable inlet spike



https://www.youtube.com/watch?v=F3ao5SCedIk