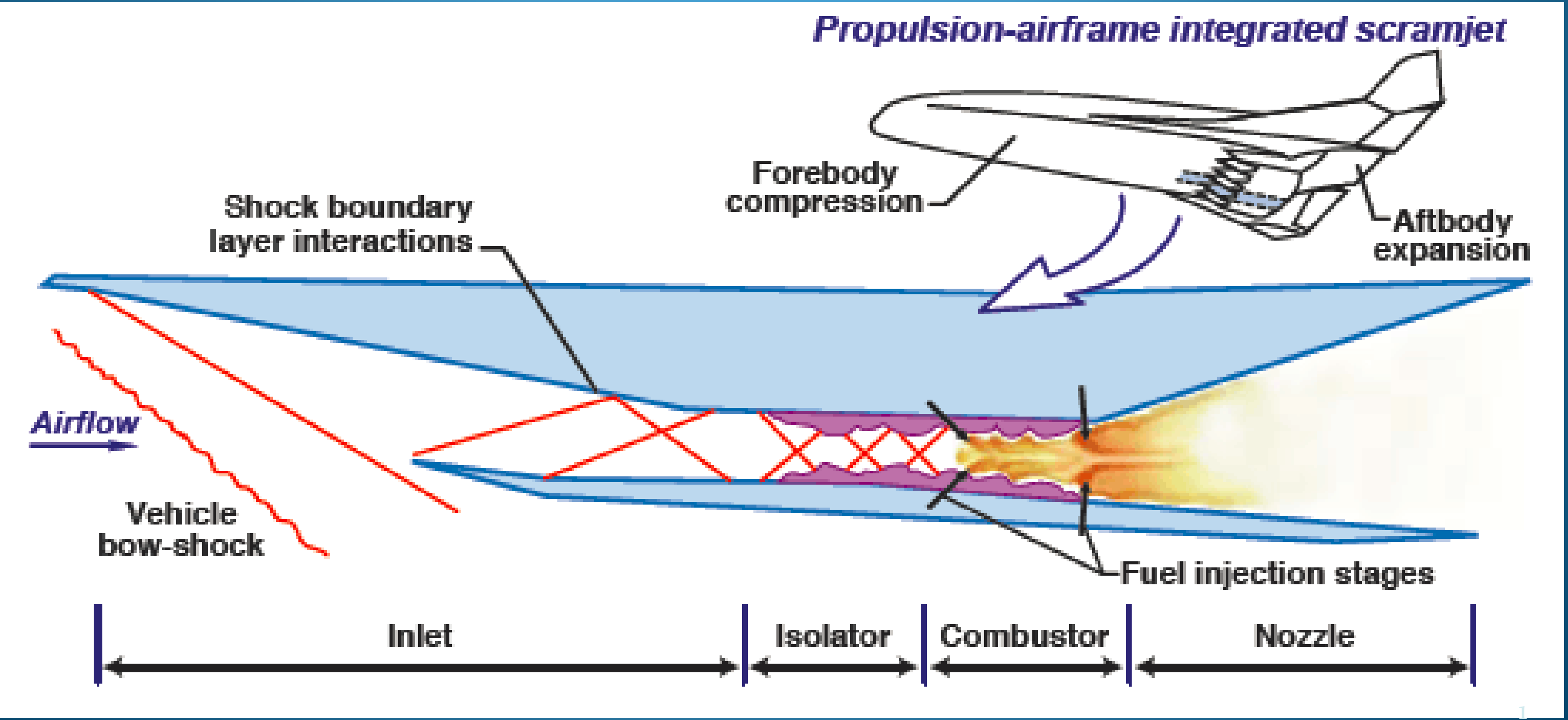
ISOLATOR

By Deependra and Ankit

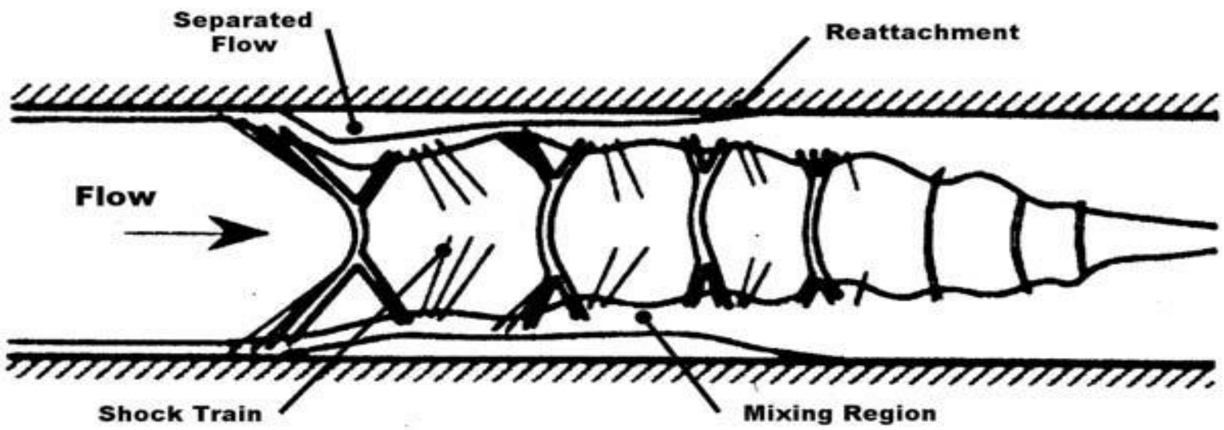


Function of Isolator

- to avoid the propagation of disturbances generated by heat release in combustor to the upstream of fuel injection

- A short length of duct (isolator) is usually added to the scramjet flow path upstream of the combustor to contain the flow separation phenomenon and stop it from disrupting the operation of the inlet.

Geometry of Isolator



- There is a series of bifurcated curved shock waves inside an isolator.
- The flow separates due to large adverse pressure gradient caused by shock train.

EMPERICAL CORRELATION BETWEEN SHOCK TRAIN LENGTH AND PRESSURE RISE

- In 1970s, Waltup and Biling developed the following emperical correlation:

$$\frac{s(M^2-1)(\mathrm{Re}_\theta)^{1/4}}{D^{1/2}\theta^{1/2}} = 50\left[\frac{\Delta P}{P}\right] + 170\left[\frac{\Delta P}{P}\right]^2$$

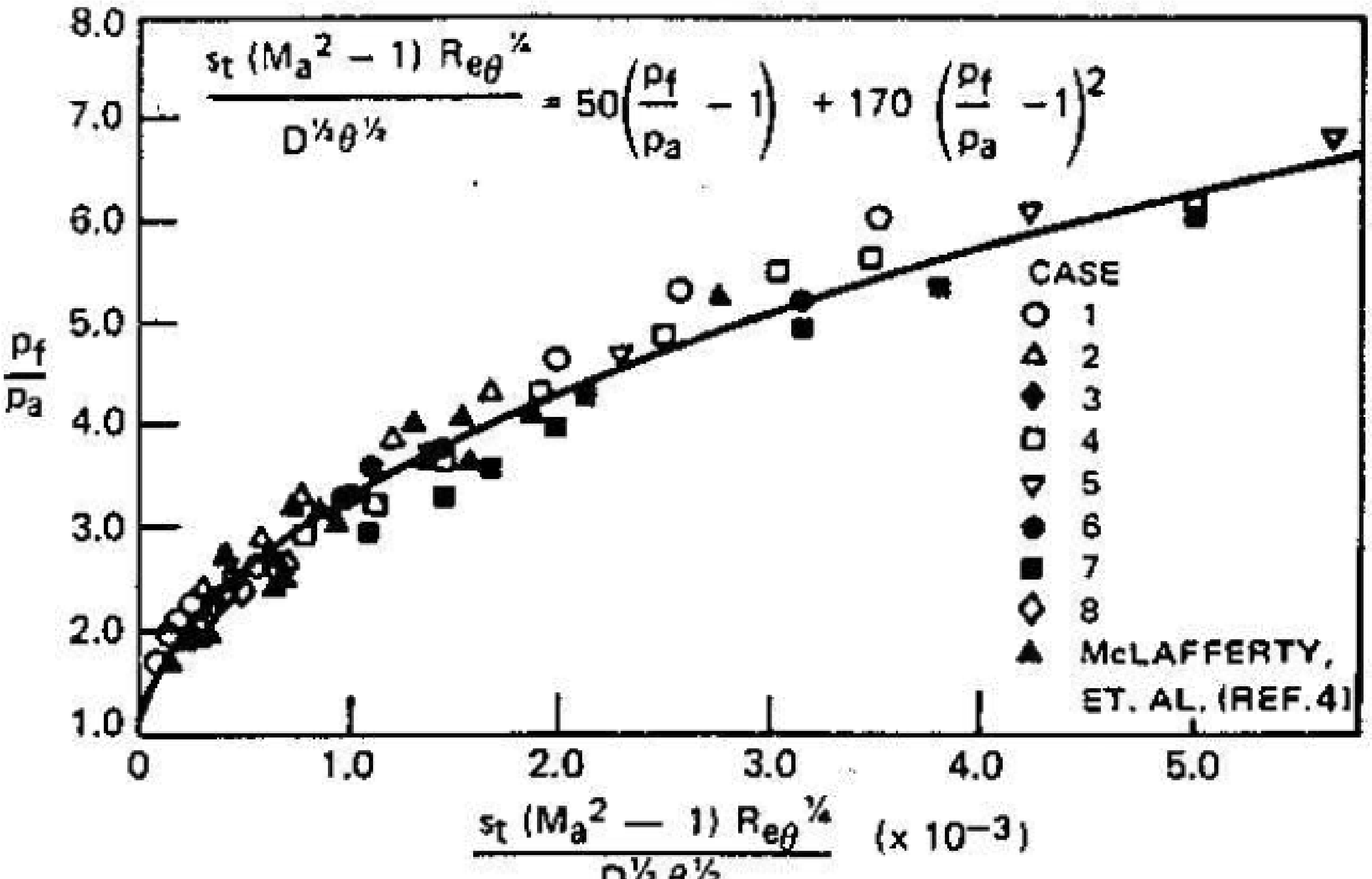
s = shock train length, M = mach number,

D = duct diameter, delta_P = pressure rise

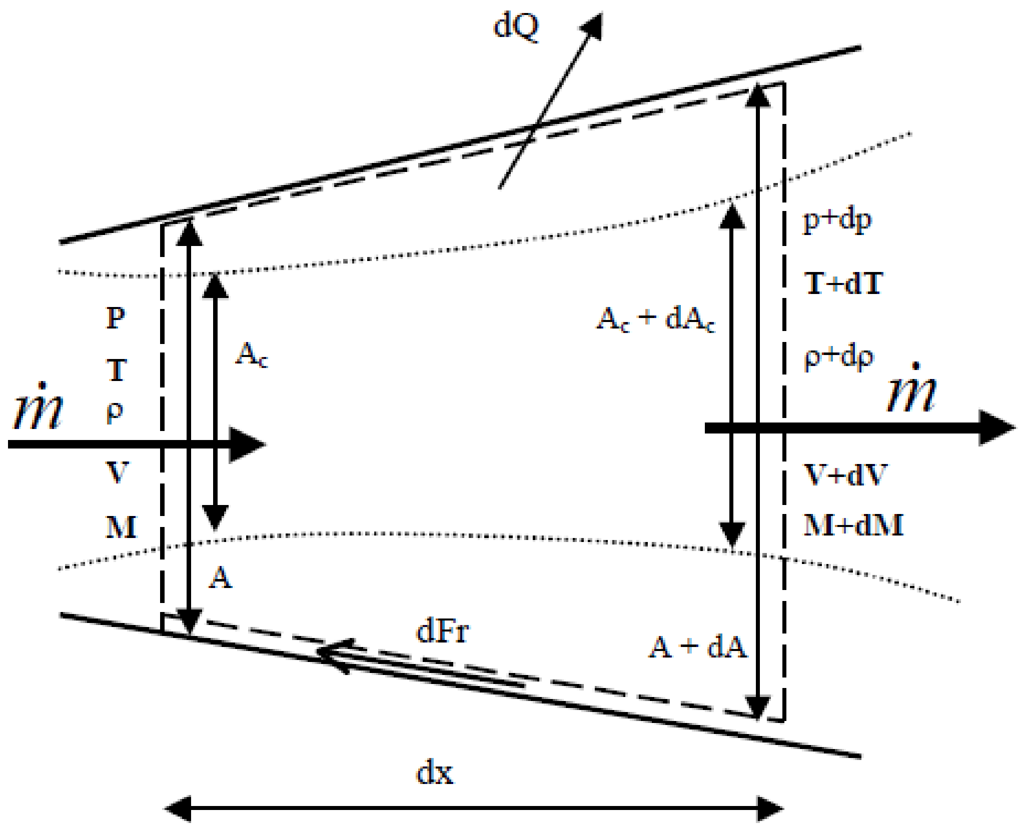
θ = momentum thickness

Re_θ = Reynolds number based on theta

- By varying incoming (to isolator inlet) Mach numbers between 1.5 and 2.7, they made the following experimental plot.



ONE DIMENSIONAL FLOW ANALYSIS



Differential element of separated flow.

The differential conservation equations are:

$$\frac{d\rho}{\rho} + \frac{dV}{V} + \frac{dA_c}{A_c} = 0 \qquad (1)$$

$$\frac{dp}{p} + \frac{\gamma M^2}{2}\frac{4C_f dx}{D} + \frac{\gamma M^2}{2}\frac{A_c}{A}\frac{dV^2}{V^2} = 0 \qquad (2)$$

$$\frac{dT}{T} + \frac{\gamma - 1}{2}M^2\frac{dV^2}{V^2} = \left(1 + \frac{\gamma - 1}{2}M^2\right)\frac{dT_t}{T_t} \qquad (3)$$

The equation of state and the definition of Mach number in differential form are:

$$\frac{dp}{p} - \frac{d\rho}{\rho} - \frac{dT}{T} = 0 \qquad \text{(equation of state)} \qquad (4)$$

$$\frac{dM^2}{M^2} - \frac{dV^2}{V^2} + \frac{dT}{T} = 0 \qquad \text{(from M=V/a)} \qquad (5)$$

After some algebraic manipulations of equations 2, 3 and 5, we get

$$\frac{d(M^2)}{M^2} = -\left(1 + \frac{\gamma - 1}{2} M^2\right) \left[\frac{dp / p}{\frac{\gamma M^2}{2} \frac{A_c}{A}} + \frac{4C_f \frac{dx}{D}}{\frac{A_c}{A}} + \frac{dT_t}{T_t} \right] \qquad (6)$$

- The following equations were taken (by M. Smart) from other research papers.

$$\frac{dP}{dx} \approx \frac{89}{D_H} C_{f0} \left(\frac{\rho V^2}{2}\right) \quad (7)$$

(Ortwerth's diffuser relation; emperical)

$$\frac{d(A_c/A)}{A_c/A} = \left[\frac{1 - M^2\{1 - \gamma(1 - A_c/A)\}}{\gamma M^2 A_c/A}\right]\frac{dp}{p} + \left(\frac{1 + (\gamma - 1)M^2}{2A_c/A}\right)4C_f\frac{dx}{D} + \left(1 + \frac{\gamma - 1}{2}M^2\right)\frac{dT_t}{T_t} \quad (8)$$

- Equation 8 is for the ratio of 'core flow area' to 'duct area'.

- The change in total enthalpy of the flow through element (in Slide 6) is

$$\Delta H_0 = Q_R \cdot f_{st} \cdot \phi - Q_{loss} \qquad (9)$$

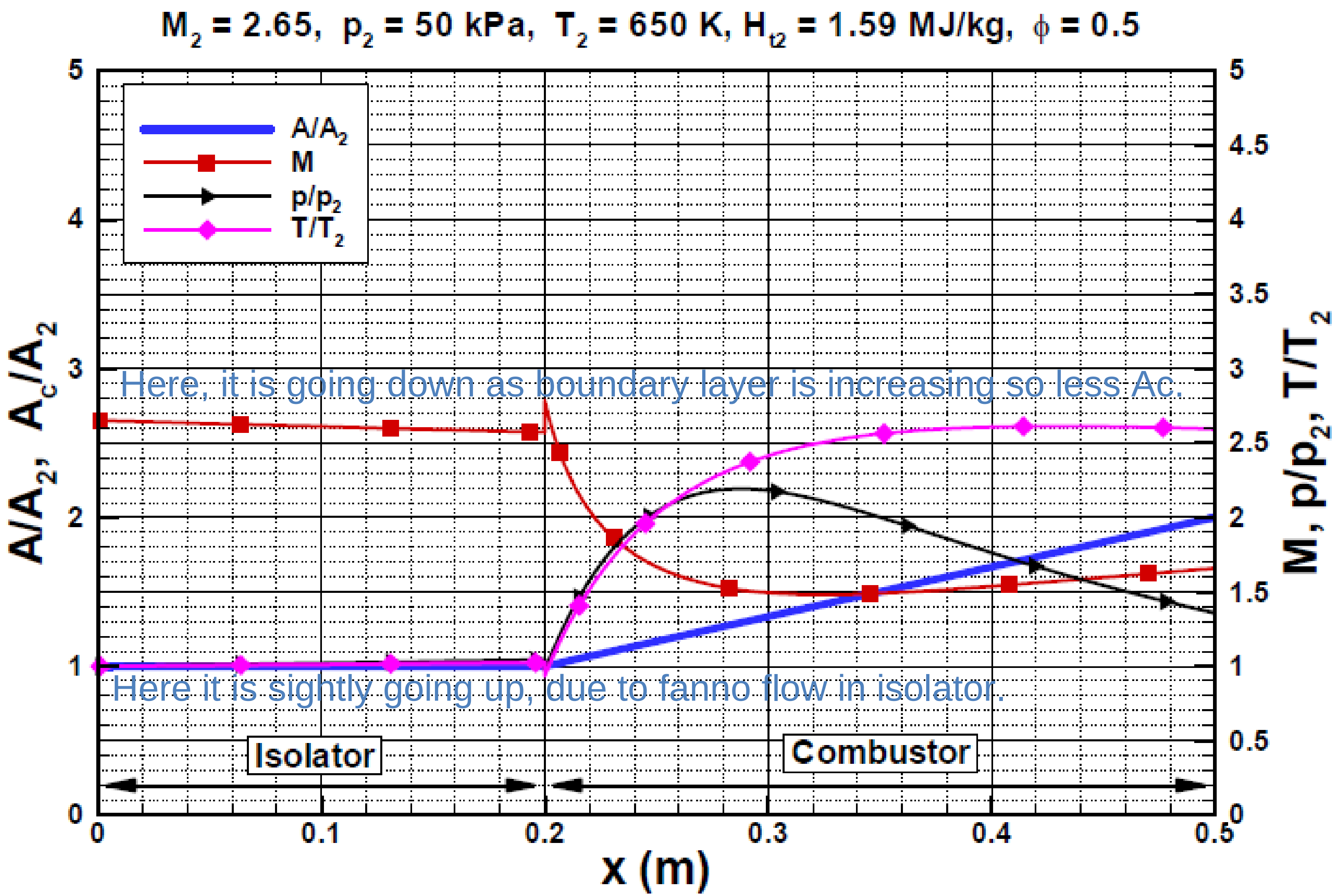
where Q_R = heat of combustion,

f_{st} = stoichiometric fuel to air ratio

ϕ = equivalence ratio for fuel

Q_{loss} = heat loss to the structure

Using equations (1) – (9), some initial conditions and assumptions, Michael Smart et al. got a plot of axial variations of various flow properties (using some standard ODE solver).



Fuelling at $\phi = 0.5$; attached flow through the isolator/combustor duct.

THANK YOU

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