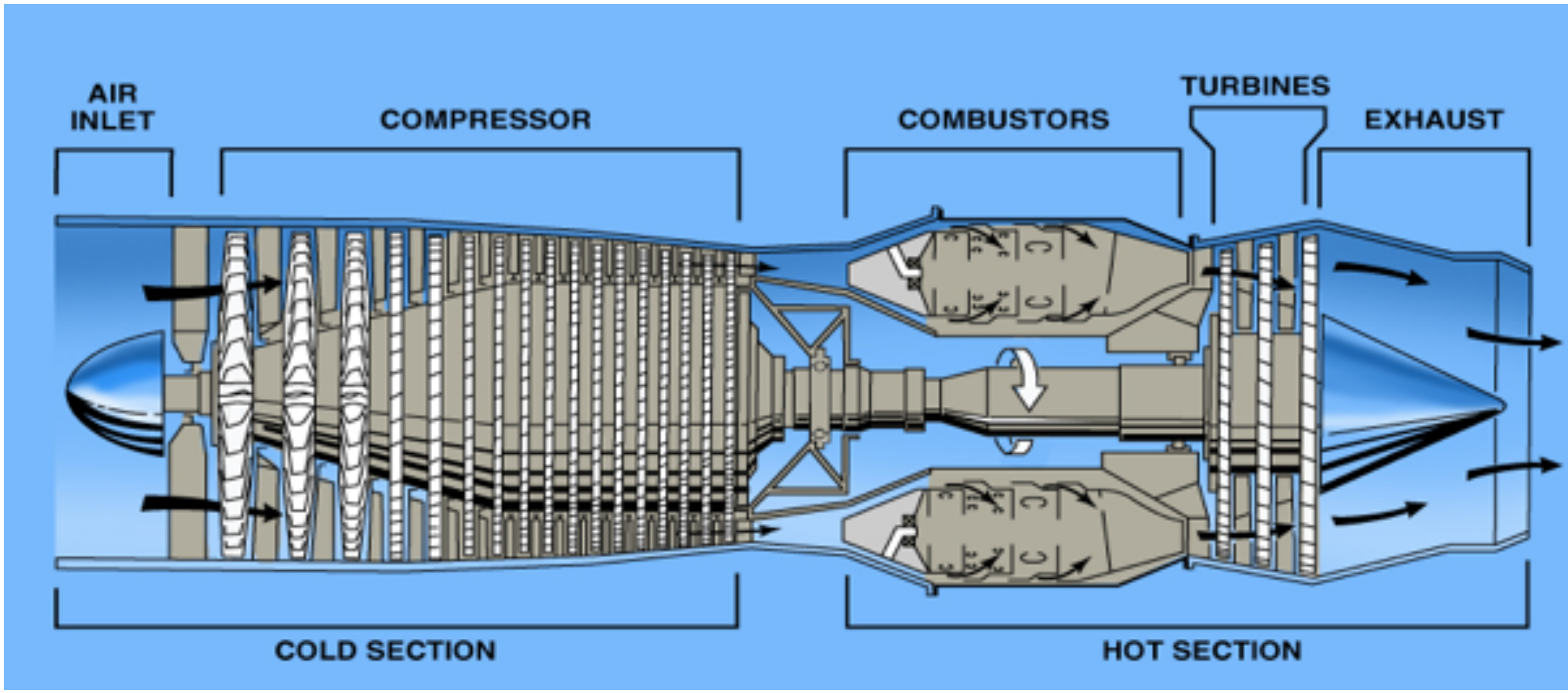
Lecture 19

Subsonic Inlets

Air-breathing Engine Components



	Inlet	Compressor	Combustor	Turbine	Nozzle
Fluidic					
Thermodynamic					
Mechanical					

Typical Subsonic Inlets

Careful radiusing of the lip region required to optimize intake pressure recovery (and avoid flow distortion) throughout the flight envelope

thin round intake lip with more internal compression

thick round intake lip with more external compression

Inlets/Diffusers Requirements

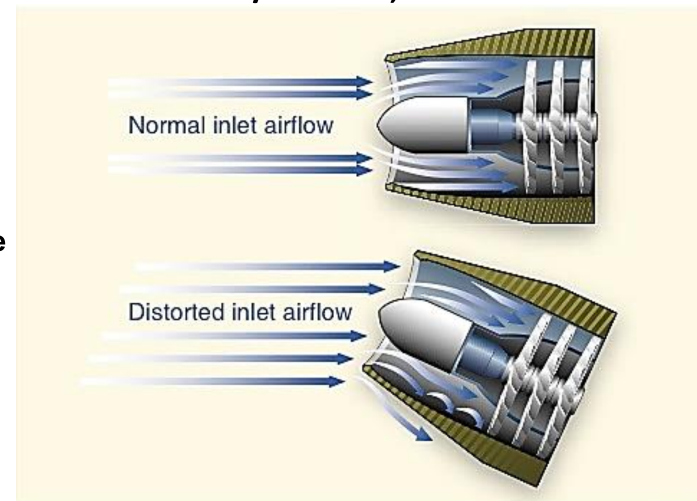
- Capture incoming stream tube to provide required mass flow rate of air to engine
- Bring inlet flow to engine with highest possible stagnation pressure
  - Measured by inlet pressure recovery, $r_d = P_{02}/P_{0a}$
- Condition flow for entrance into compressor (and/or fan) over full flight range
  - At take-off (M_0~0), accelerate flow to $0.4 < M_2 < 0.6$
  - At cruise (M_0~0.85), slow down flow to $0.4 < M_2 < 0.6$
- Provide compressor (and/or fan) with uniform flow
  - Remain as insensitive as possible to angle of attack, cross-flow, etc. in order to prevent surge/stall

Normal vs distorted airflow into a compressor

Compressor blades sections are airfoils:

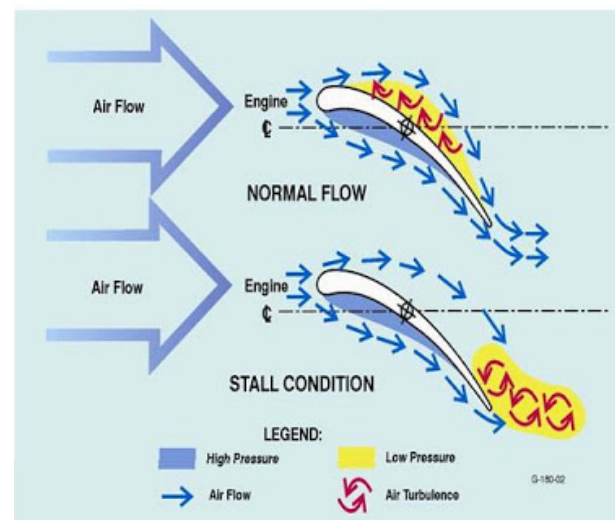
- **angle of attack** is a result of **absolute** inlet air velocity and blade **rotational** velocity → forms **relative** velocity
- compressor **stall** happens when the relative velocity occurs at an angle of higher than the stall angle for the airfoil
  - Above the stall angle, the flow separates and **turbulence** is created with **pressure fluctuations**
  - air flowing in the compressor slows down / stagnates, sometimes reversing direction
  - compressor cannot generate pressure
- compressor stall can be **transient and intermittent** or **steady state and severe**
  - indications of a transient/intermittent stall are usually an intermittent "bang" due to **backfire** and **flow reversal**
  - **strong vibration** and a **loud roar** may develop from continuous flow reversal
  - **severe damage** from a steady state stall is immediate.
- Most gas turbines use **variable inlet guide vane** (VIGV) **and variable stator vanes to inhibit stall**

ascent/descent; crossflow winds



http://talkaviation.com/content/turbine-engines-242/

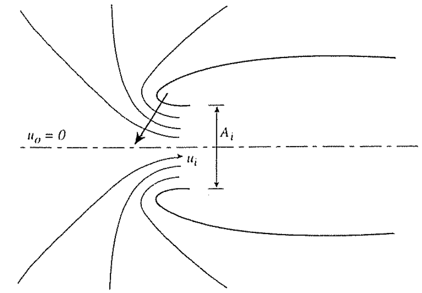
https://www.youtube.com/watch?v=EWAsQ3qldo8



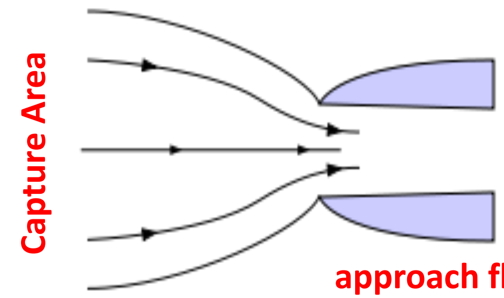
STALL CONDITION

Subsonic Inlets Airflow Patterns

Pitot intakes **are the dominant type; basically a tube with an aerodynamic cowling**



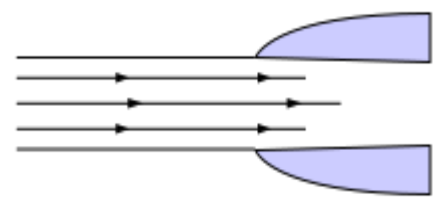
At zero airspeed:
Streamtube approaches from many directions, even from behind the plane of the intake lip



Low speed sucking condition

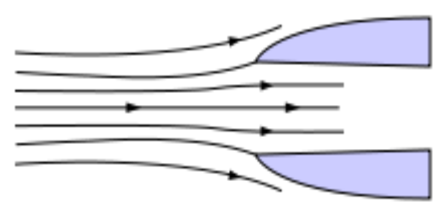
approach flow nozzle like

At low airspeed:
Streamtube larger in cross-section than the lip flow area



Subsonic design point capture area matches intake area

At design flight Mach number, The two flow areas are equal.

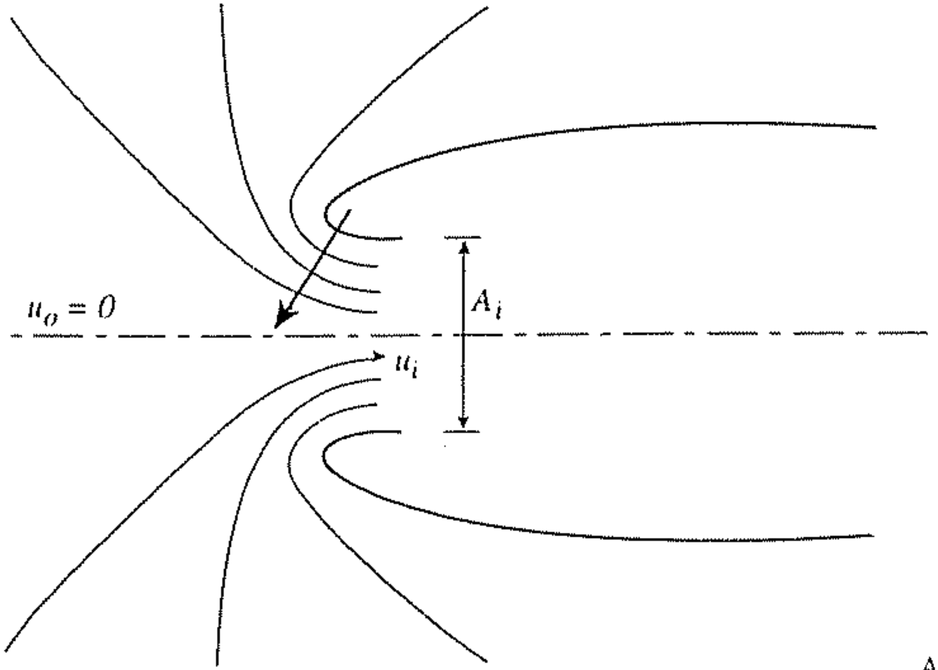


High speed (subsonic) intake spilling

approach flow diffuser like

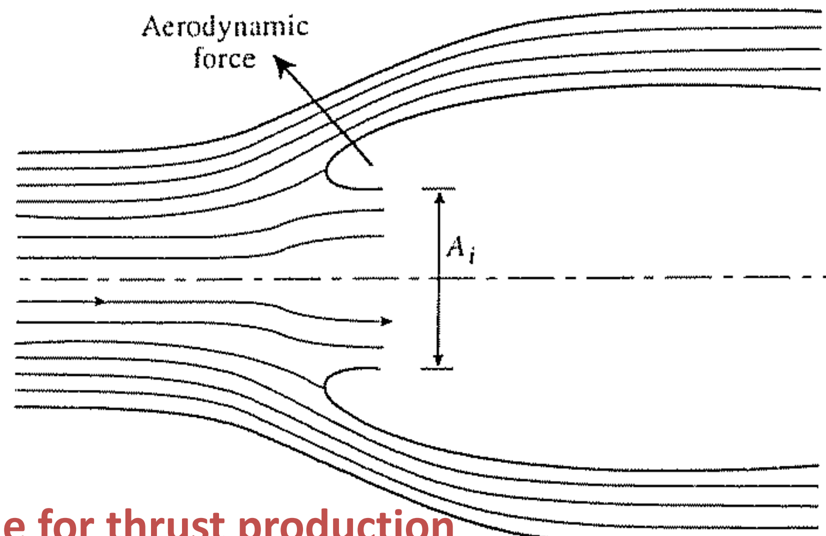
At higher airspeed:
Streamtube is smaller, with excess air spilling over the lip.

Take-Off vs Cruise



High Thrust for take-off
Low Speed, $M_0 \sim 0$
High Mass Flow
Stream Tube Accelerates

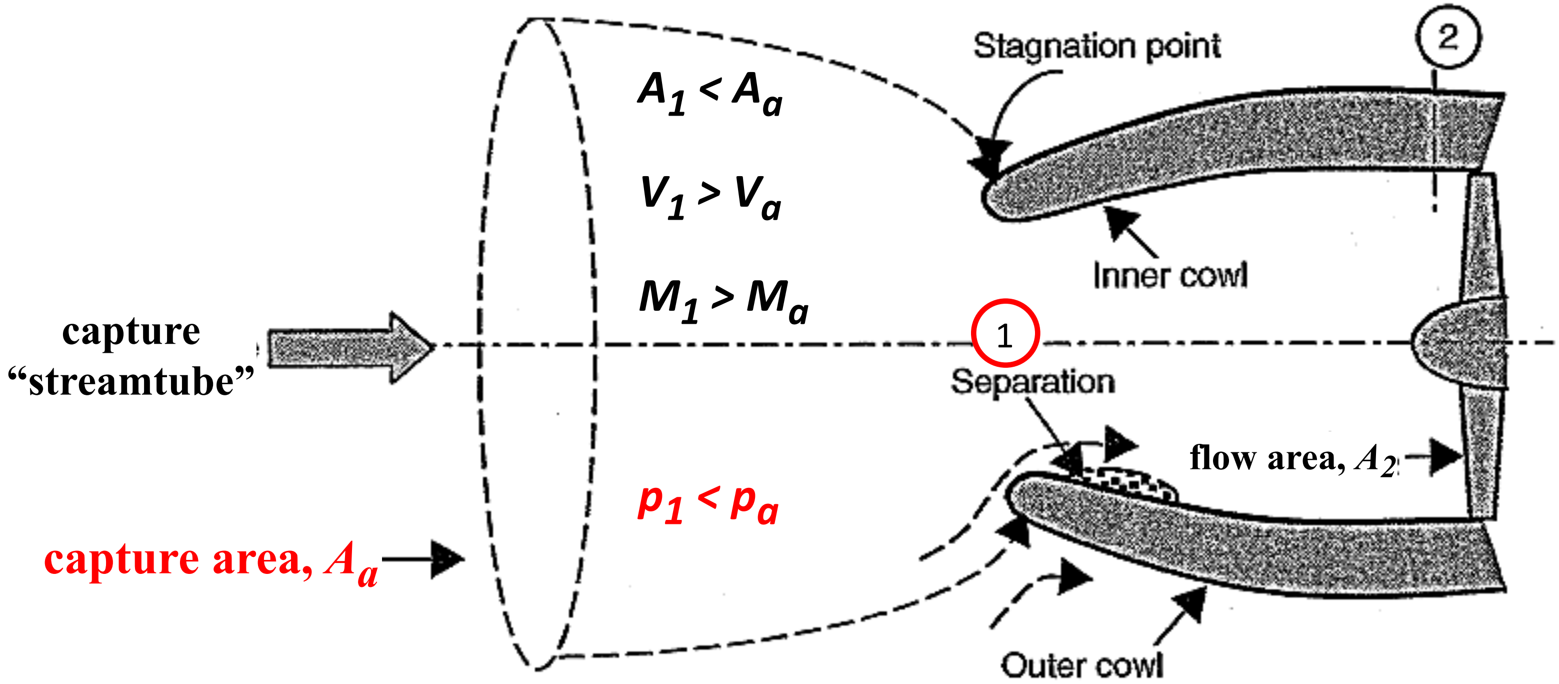
Lower Thrust for cruise
High Speed, $M_0 \sim 0.8$
Low Mass Flow
Stream Tube Decelerates



Aerodynamic force is typically favorable for thrust production

Take-Off or Low Speed

Under low speed or takeoff conditions, the captured stream tube will undergo acceleration and act like a nozzle!



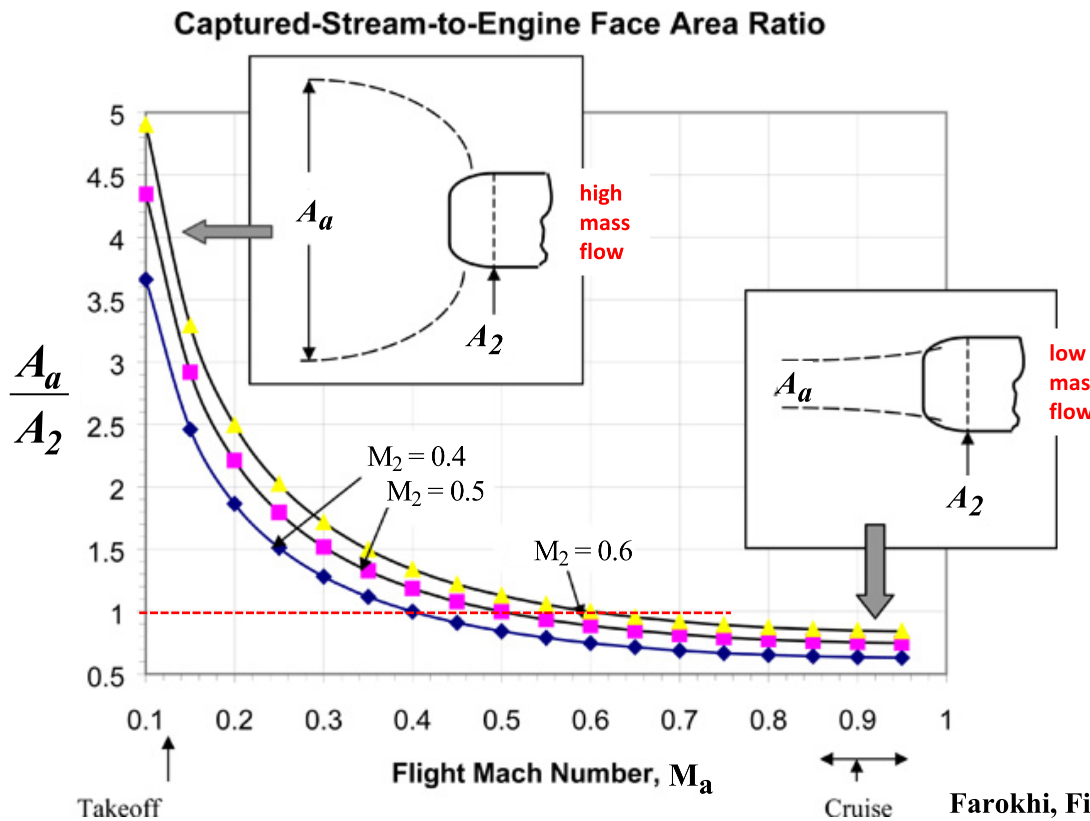
This configuration is far more likely to separate along the inner cowl and lead to performance issues; but at least it's temporary (rapid climb) and there are no shocks.

What is the capture area?

Captured Stream-to-Engine Face Area Ratio

A well designed <u>subsonic</u> inlet attains very high (0.995 to 0.997) static pressure recovery between atmospheric conditions at altitude and the engine inlet face; if we <u>approximate</u> this as isentropic:

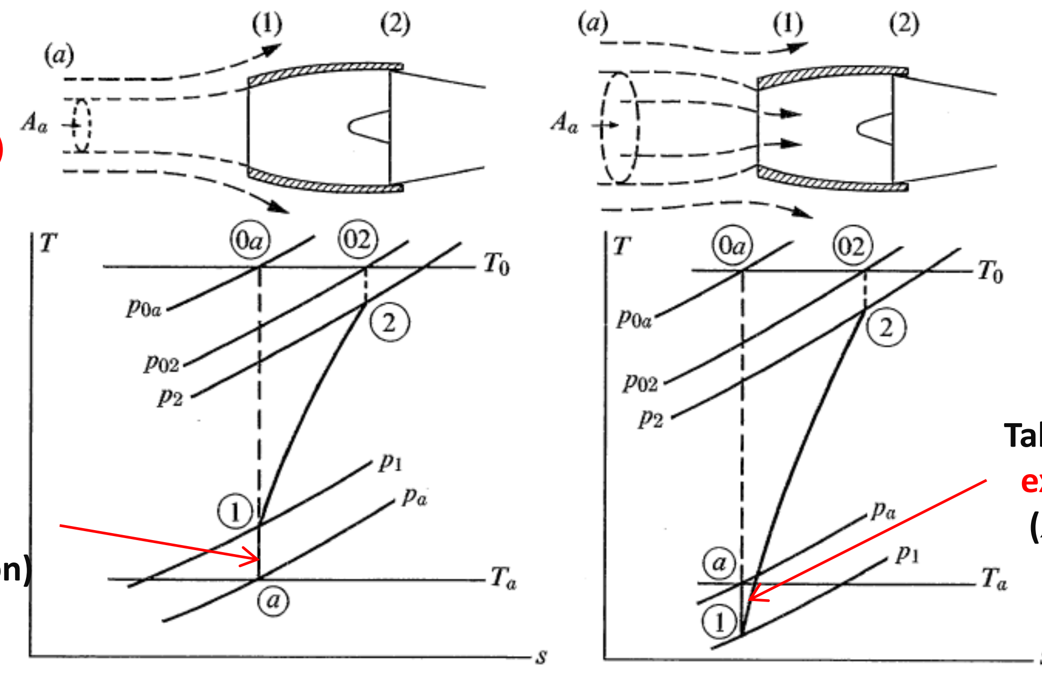
$$\frac{A_a}{A_2} = \frac{M_2}{M_a}\left[\frac{1+\frac{\gamma-1}{2}M_a^2}{1+\frac{\gamma-1}{2}M_2^2}\right]^{\frac{\gamma+1}{2(\gamma-1)}}$$



Farokhi, Fig 5.23

Subsonic Inlets

capture area
(captured "streamtube")



(a) High speed or low mass flow

(b) Low speed or high mass flow

M_a ~ 0.8

Level cruise flight:
external deceleration
(*KE* → *Δp*, compression)

M_a ~ 0.2

Takeoff and/or climb:
external acceleration
(*Δp* → *KE,* expansion)

FIGURE 6.1 Typical streamline patterns for subsonic inlets.

Subsonic inlets decelerate and straighten the approach airflow from at most low transonic conditions to *$0.4 \leq M \leq 0.6$* at compressor entry. Performance is characterized by:

For Subsonic Diffusers, two parameters are important: