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AIR-BREATHING PROPULSION: THE FUTURE OF ACCESS TO SPACE

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Space Glasgow Research Conference

28th October 2014

OVERVIEW

- Hystorical overview
- Present technology
- High-speed intakes
- Pseudo-shock waves
- Conclusions

ORIGINS

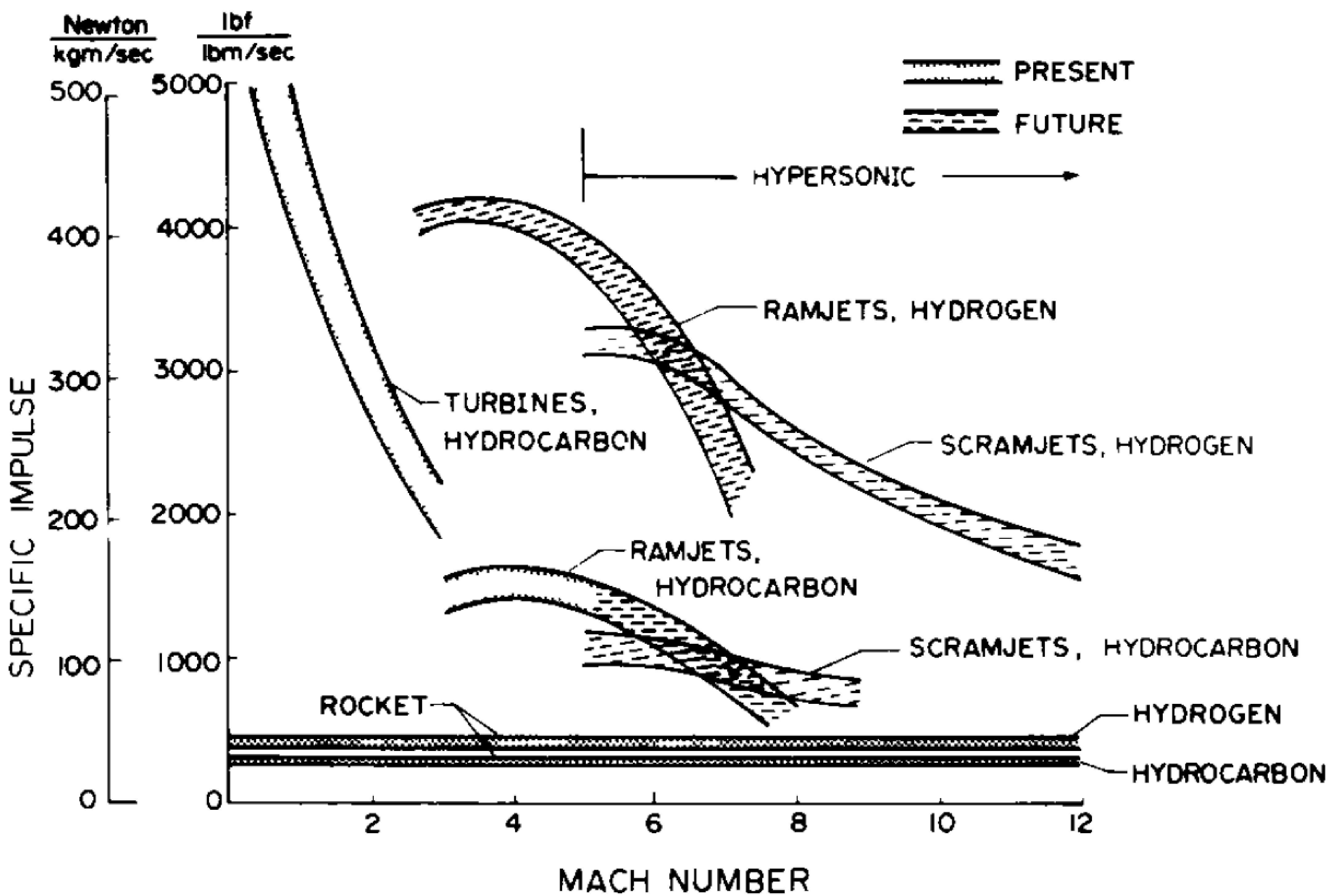
- 1913 - René Lorin: jet propulsion created by directing exhaust from combustion into nozzles.
- 1944 - *Messerschmitt Me 163 Komet*: rocket-powered fighter aircraft flight.
- 1949 - *Leduc 0.10*: world's first aircraft powered exclusively by a ramjet at M= 0.9.
- 1958 - *Nord 1500 Griffon:* reached M= 2.19.

AIR-BREATHING PROPULSION

- Mach number greater than 3 and less than 18.

(Courtesy of NASA)

ENGINE COMPARISON



(Frank & James 1977)

AIR-BREATHING PROPULSION

- Mach number greater than 3 and less than 18.
- Air compression by geometry changes, i.e. shock waves.
- Absence of rotating components.
- Ambition to reusable launch systems.

(Courtesy of NASA)

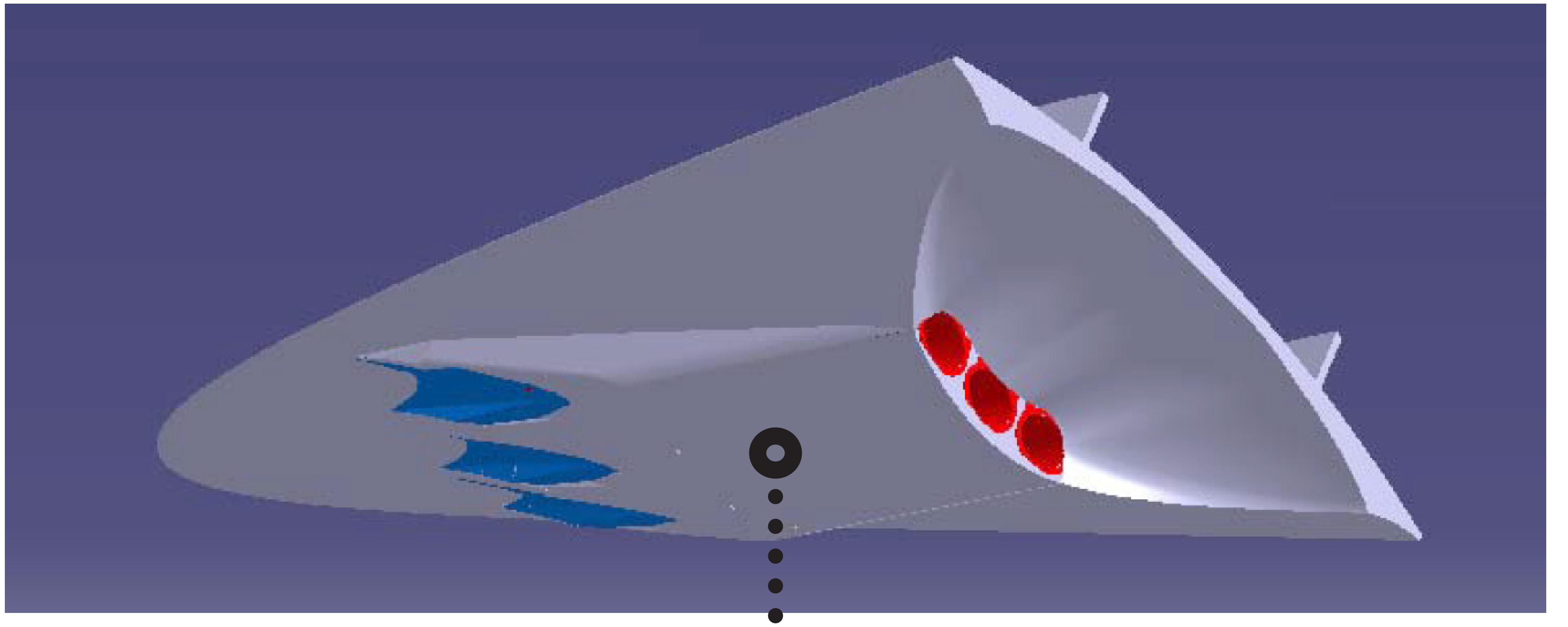
SCRAMJET VS ROCKET

- Absence of oxidants.
- Improvement in payload capability and manoeuvring.
- Increase in the propulsive efficiency.
- Reduction of volume and structural weight.
- Simplicity for absence of rotating components.
- Drawback no thrust at zero speed.
- Need to fly in the atmosphere: aerodynamic forces and heating.

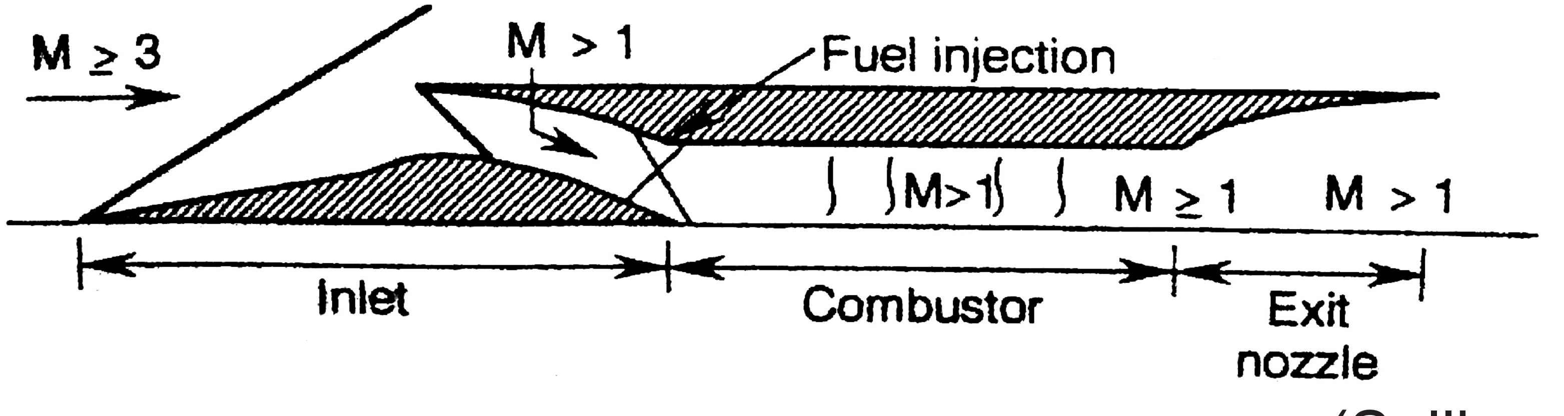
PRESENT TECHNOLOGY

- Maintaining an acceptable thrust level and fuel consumption over the entire flight range.
- Multi-mode vehicles & combined-cycle engines.
- Combined-cycle systems are problematic in the transition from gas-turbine to ramjet/scramjet power and vice-versa.
- Scramjet technology for space access is one generation behind that for missiles due to the requirement for testing at such high Mach number.

SCRAMJET ENGINE



(Smart 2008)



(Sullins 1993)

HIGH-SPEED INTAKES

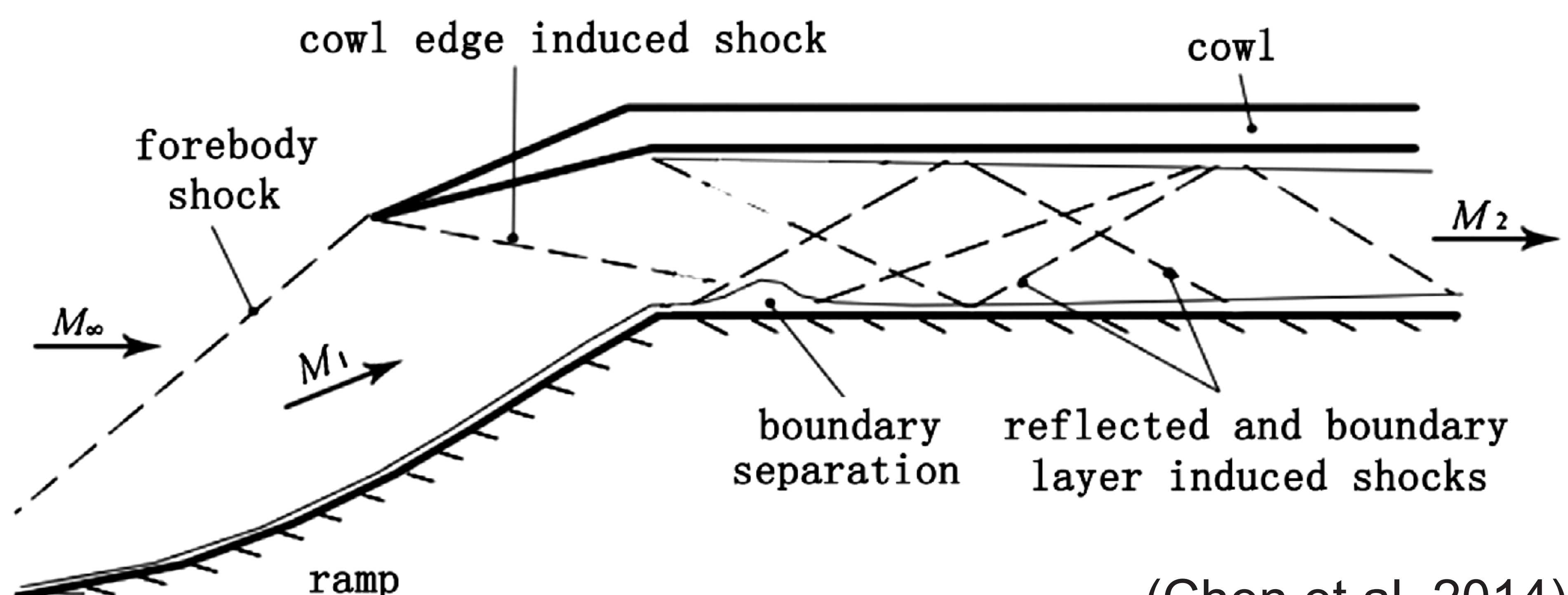
Large compression ratio.

Provide stable flow to combustion chamber.

Mixed compression: shock structure externally and internally the engine.

Composed of:

- Forebody
- Cowl
- Isolator



(Chen et al. 2014)

ISOLATOR

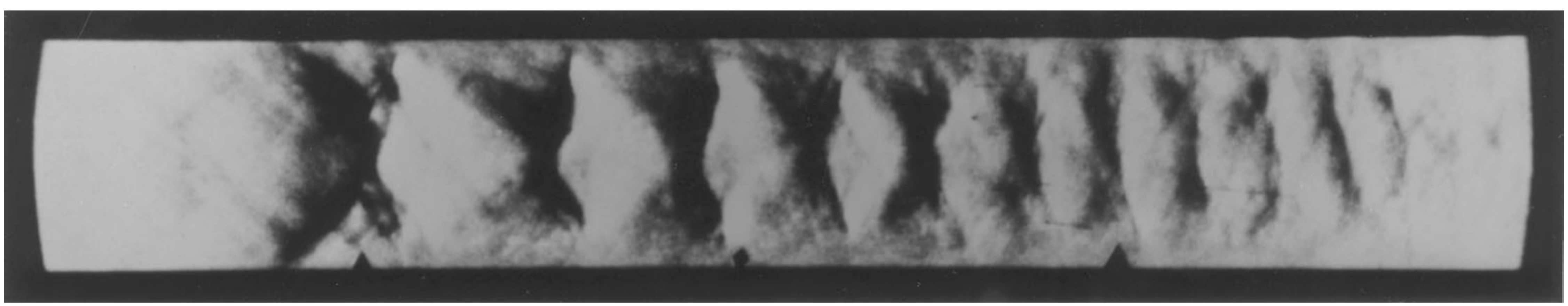
Nearly parallel duct placed between the inlet and the combustor.

Maintain different conditions upstream and downstream the duct.

Allows the generation of the precombustion shock wave.

Flow stabilisation.

Higher engine thrust.



(Ikui & Matsuo 1969)

NORMAL SHOCK TRAIN

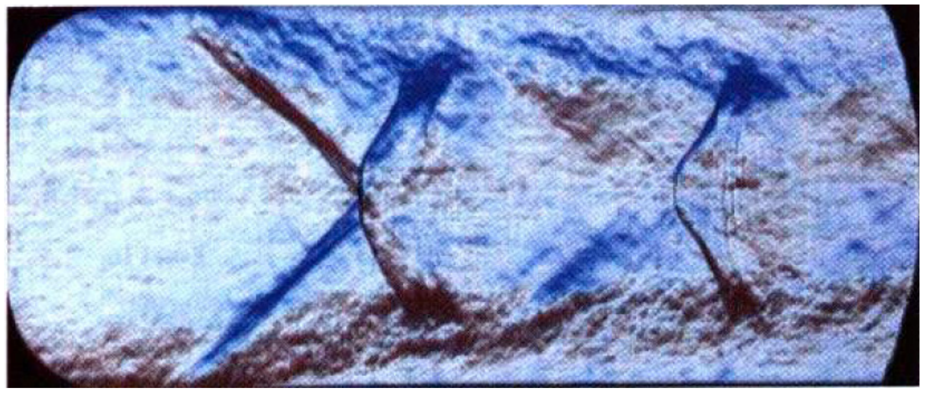
Series of normal shocks with decreasing strength and distance.

Major portion of compression at the first shock.

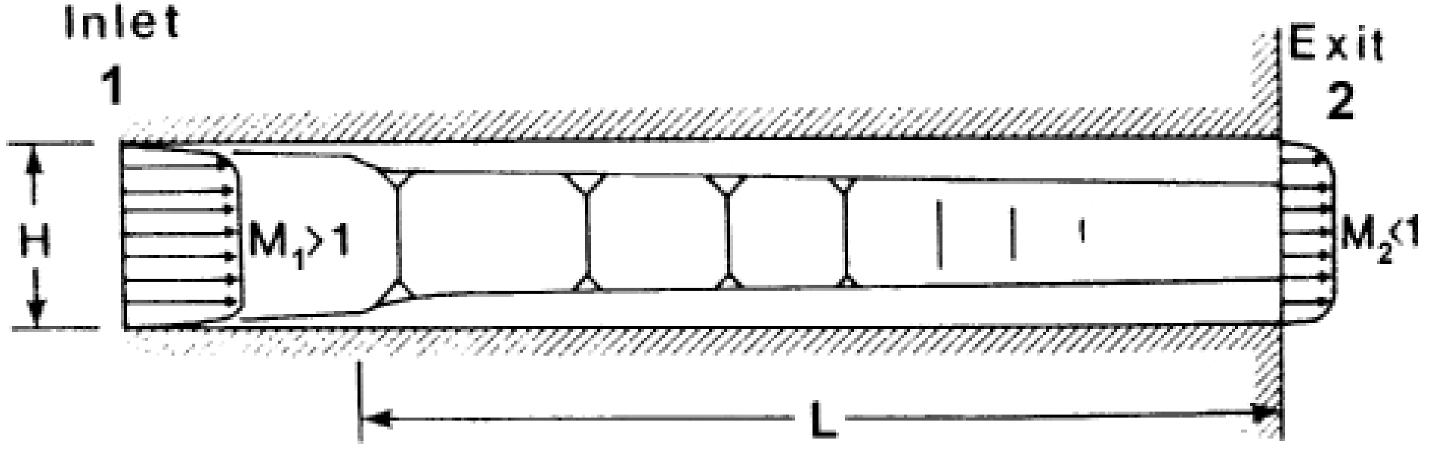
Normal shock in the centre of the duct.

Oblique shock waves near the wall.

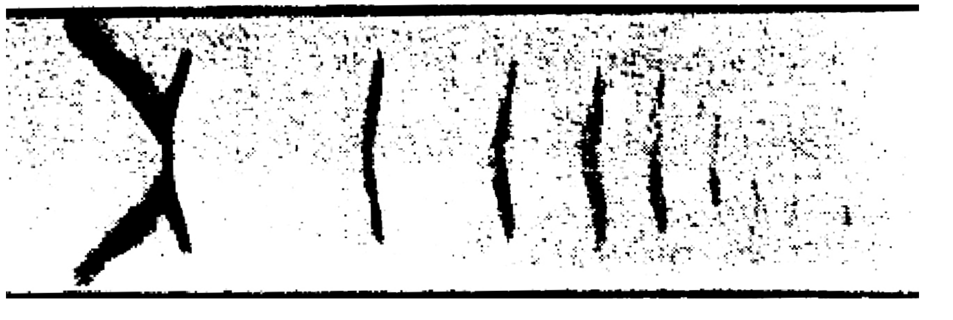
Sequential flow de- and acceleration.



(Sun 2004)



(Heiser & Pratt 1994)



(Weiss et al. 2010)

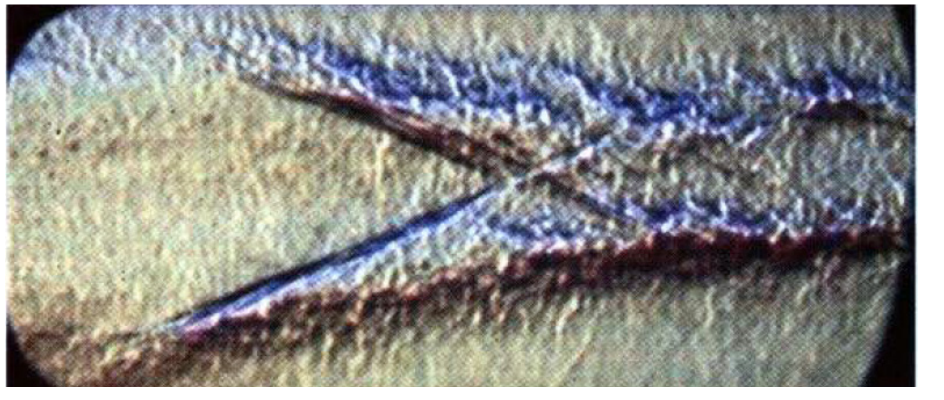
OBLIQUE SHOCK TRAIN

Initial oblique shock separates the boundary layer.

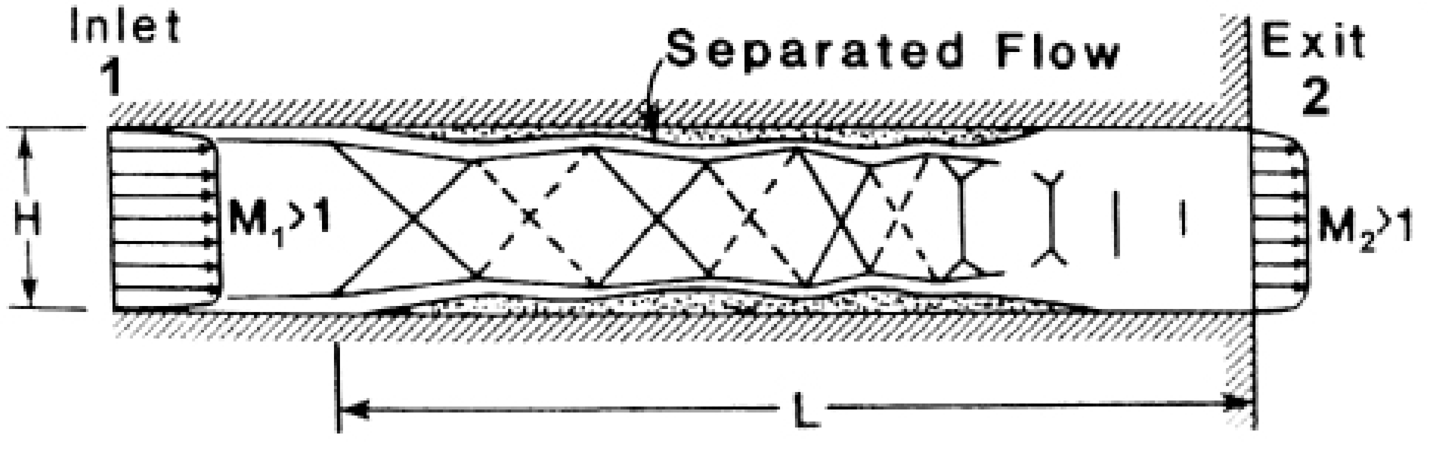
Alternating compression and expansion as a consequence of shock propagation along the duct.

Greater flow Mach number.

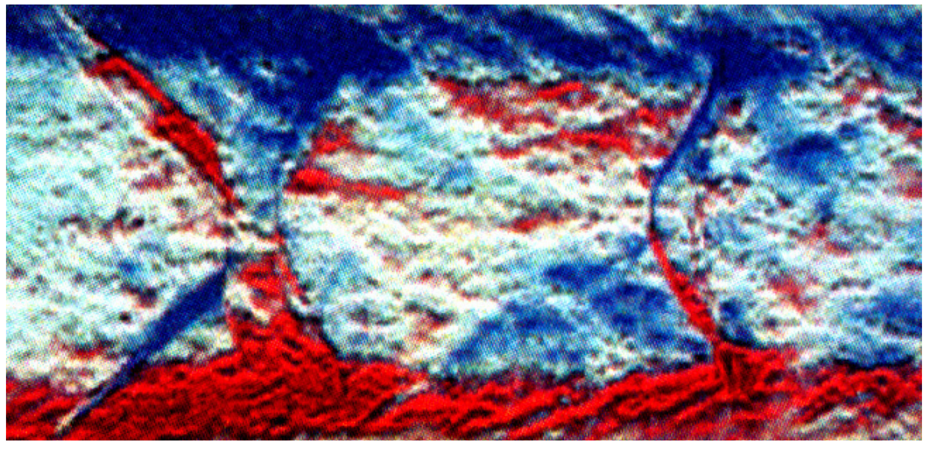
Larger boundary-layer separation.



(Sun 2004)



(Heiser & Pratt 1994)



(Sugiyama et al. 2006)

CONCLUSIONS

- Current understanding on the mechanisms of the pseudo-shock phenomena is not sufficient.
- Aim to design a completely reusable, single-stage space plane, able to take off and land without the aid of another vehicle.
- The study shock wave structure inside isolator is a highly important to design advanced vehicles.

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