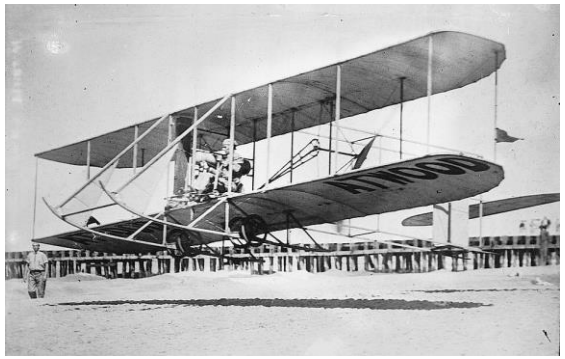
Reusable Launch Systems

Expendable Launchers

1904



1960s

1957

- 60 years
- Trillions of dollars
- Most reliable, cost effective is still the rocket that launched sputnik 1

2017

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Expendable Launchers – Stats

Imagine dumping an A380 after each flight.

The best can only offer:
- 1 in 70 failure rate
- 3 year wait
- $10,000 / kg (after a 50% subsidy)

50 years ago, no one would have thought we would still be there, but today people still argue for expendable launchers…

Why Do We Reusable Launchers?

- On Demand launches, not years ahead.
- Cheap: the main drawback today.
- Reliable and safe (not a loss rate of 1/50 – 1/70 and no abort recovery).
- Provide a two way capability with return traffic from space.

Existing Projects

The Space Shuttle

- The first serious attempt at a reusable system developed by NASA in the 70s – initially fully reusable but for costs issues eventually semi reusable.

- Eventually more like an expendable launcher cost and safety wise.

SpaceX

- Finally managed to develop a fully reusable first stage.
- As expected, has already had a huge impact on economics of space travel.

Two Stage vs Single Stage Reusable

Two Stages to Orbit

- Double effect leading to cost and complexity issues.

- Handling two stages and assembling them before launch is never going to be aircraft like.

Single Stage to Orbit

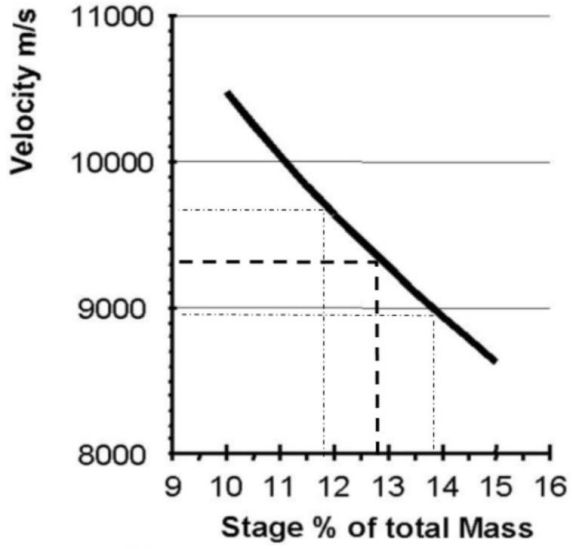
- No double effect.
- Potential to be aircraft like.
- Truly technically complex.

Single Stage to Orbit – 4 Schools of Thought

- Some pessimists think it is outright impossible, only two stages will work.
- Structure optimists think that the solution lies in making structures so light that pure rockets become viable options.
- Engine optimists believe that advanced Scramjets can allow to fly to orbit with mass ratios similar to that of a plane.
- System optimists believe that balancing existing technologies will lead a single stage reusable orbital launcher .

Structural Optimism

- For Single Stage to Orbit the rocket equation shows that the vehicle needs to have a 12.7% mass ratio (structure is 12.7% of total mass).
- Basic rocket stages have achieved 10%, but this only leaves 2.7% for payload and all remaining systems.
- Small changes have a big impact on the required specific impulse.
- Never proven possible.



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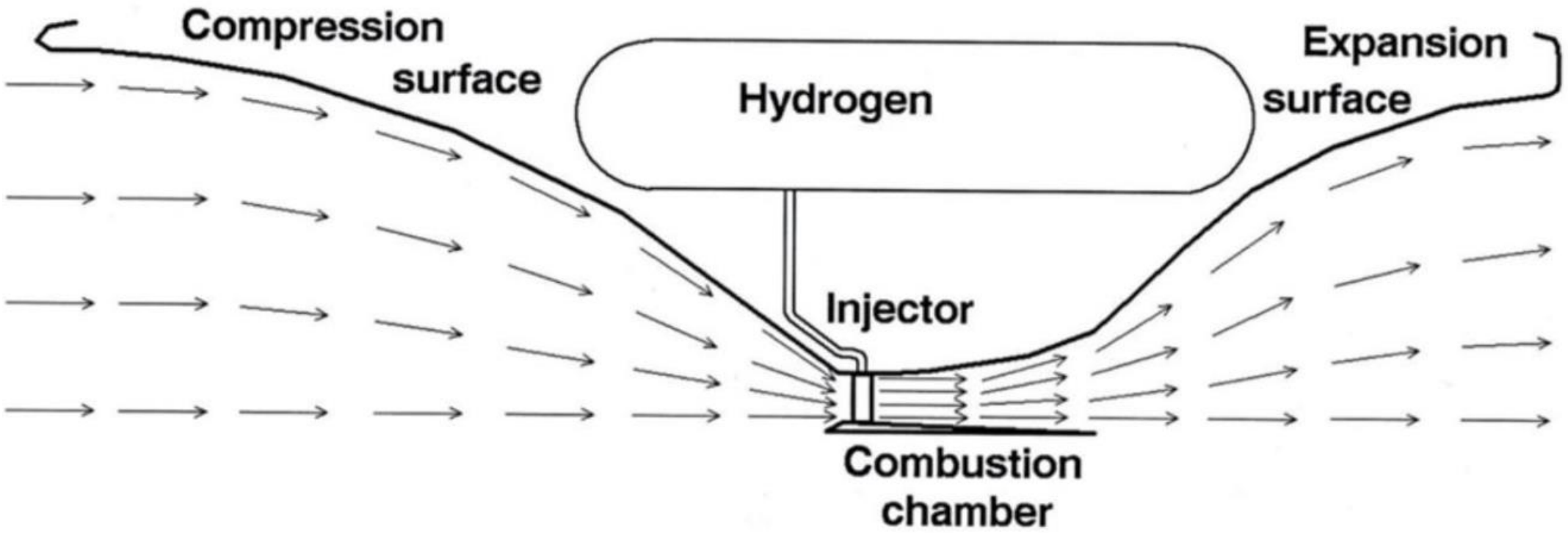
Engine Optimism

- For a typical 40% structure mass, specific impulse needs to average 10,200 m/s.
- Rockets typically offer 4500 m/s but turbojets can go much higher 10,000s m/s.
- The airbreathing options: turbo ramjets, precooled cycles and scramjet.

Scramjets



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Problems with Engine Optimism

- Momentum drag.

- Can only give the spacecraft 20% of the ΔV after which it is deadweight.

- Scramjets can break through the momentum barrier but:
  - Thrust to weight is worse than jet engines.
  - Exhaust velocity is only double that of a rocket.
  - Mach 5 is the minimum speed at which a scramjet will start to work.
  - They would have to work at Mach 15 but already challenging to make them work at Mach 7 and their geometry would need to alter.

System Optimism

- Compromise between mass ratio (22%) and exhaust velocity (6100 m/s) to make it work.

HOTOL

Skylon

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