Simulating Continuously Rotating Detonation Engines

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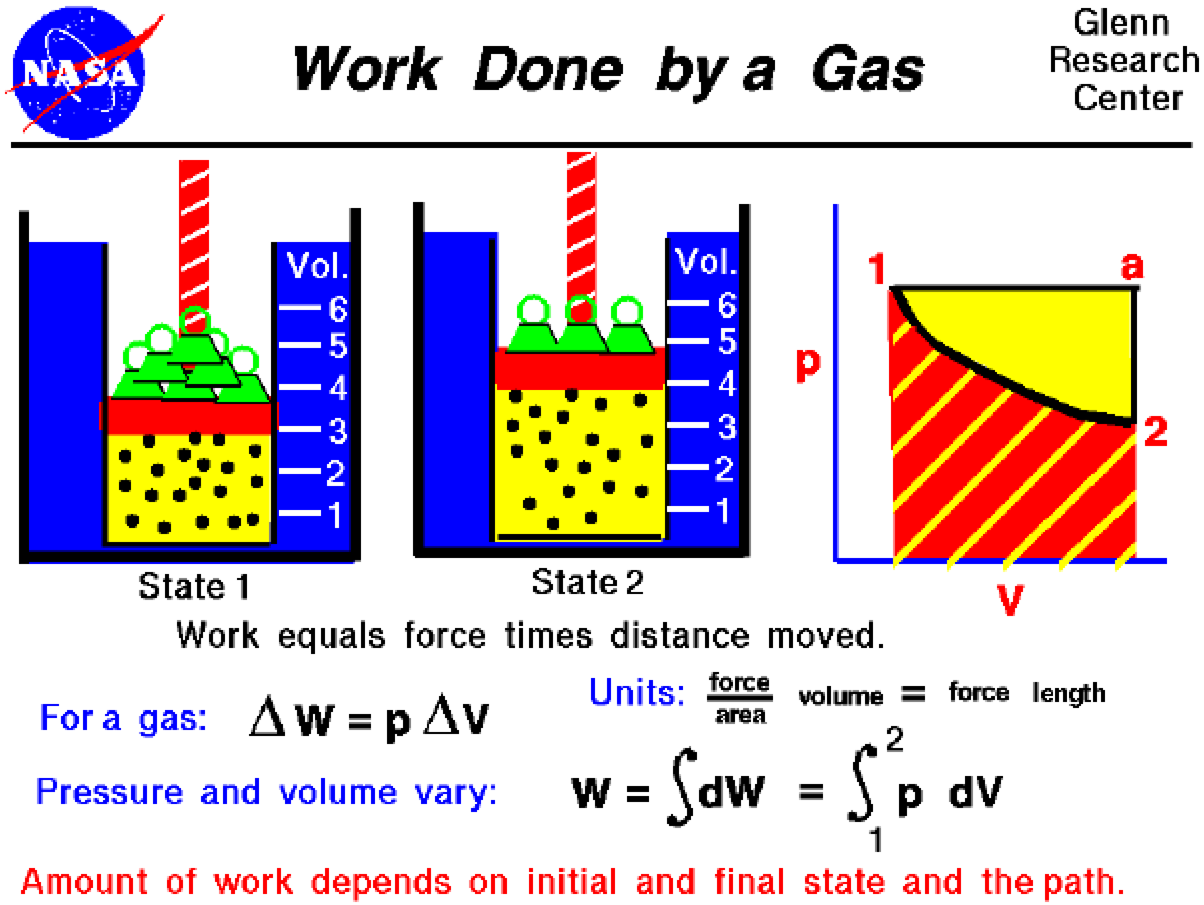
Introduction

- How this research fits in with the NASA goals
  - NASA has an interest in developing its space program in order to put people on Mars. To this end they have developed a series of goals within which interested parties can apply for or inform NASA of their findings. This research project focuses on the propulsion goals by working on improving the modeling of pulse detonation engines.
- Other application of this research
  - The DOE has an interest in using detonation engines for energy harvesting

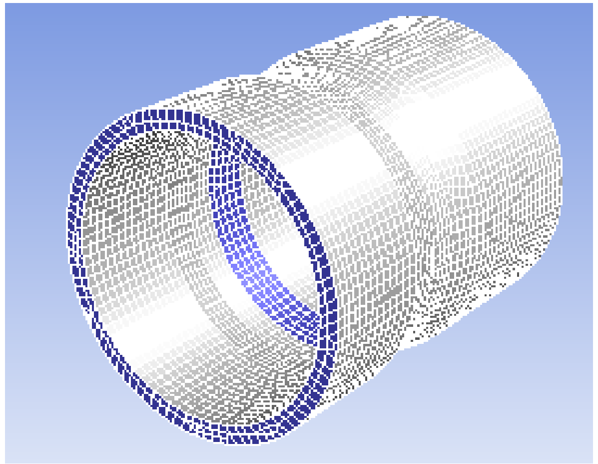
Introduction

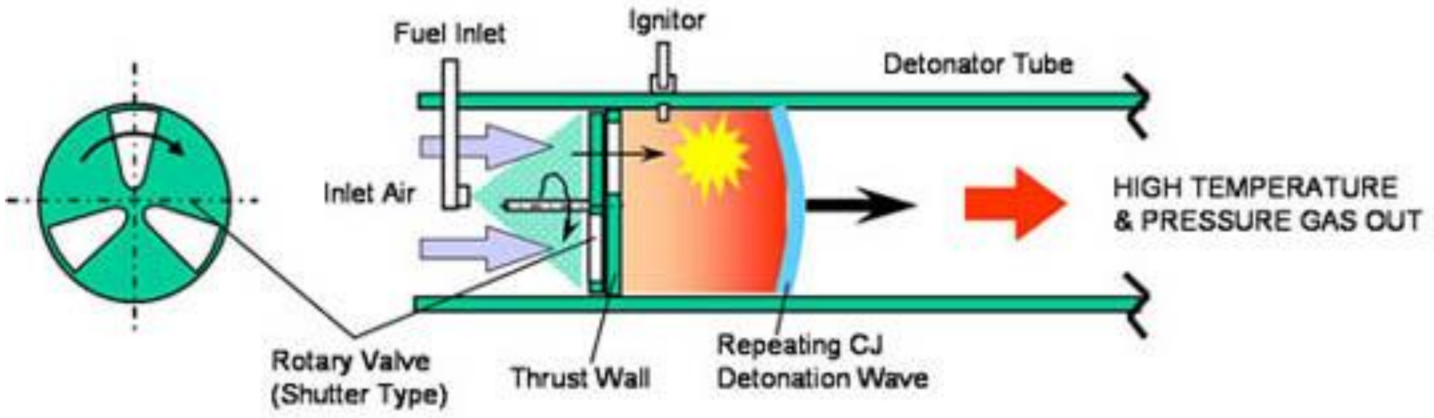
- What is pressure-volume work

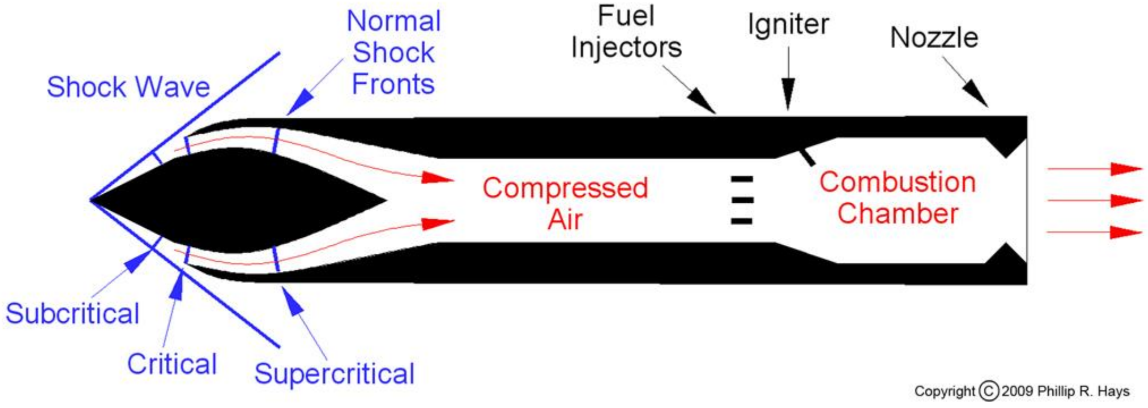


Introduction

- What is an engine?

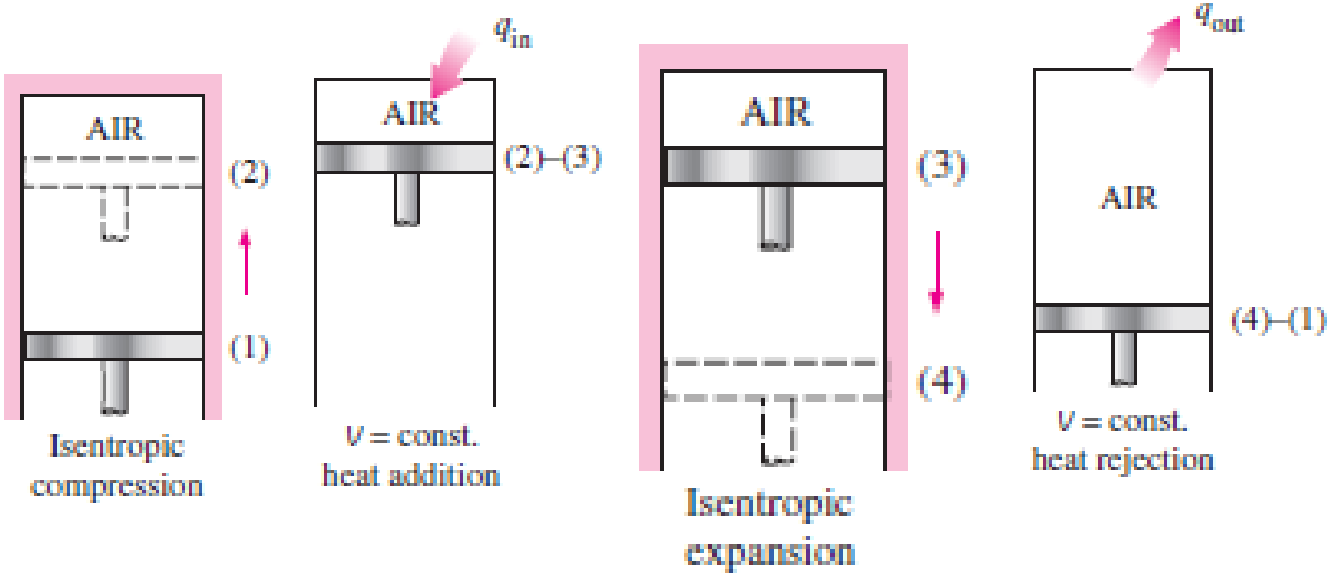


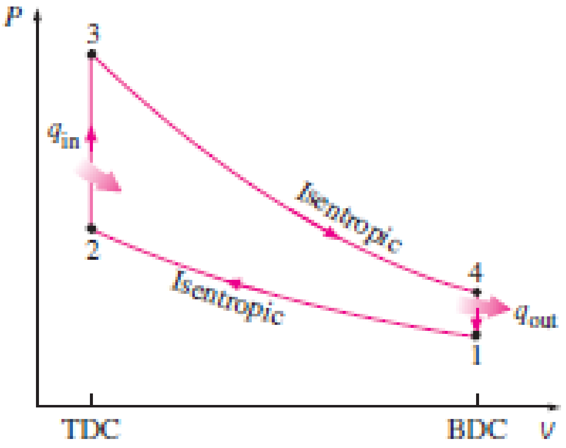




The Otto Cycle (the four-stroke engine)

1. Compression stroke
2. Power stroke
3.Expansion stroke
4.Exhaust stroke

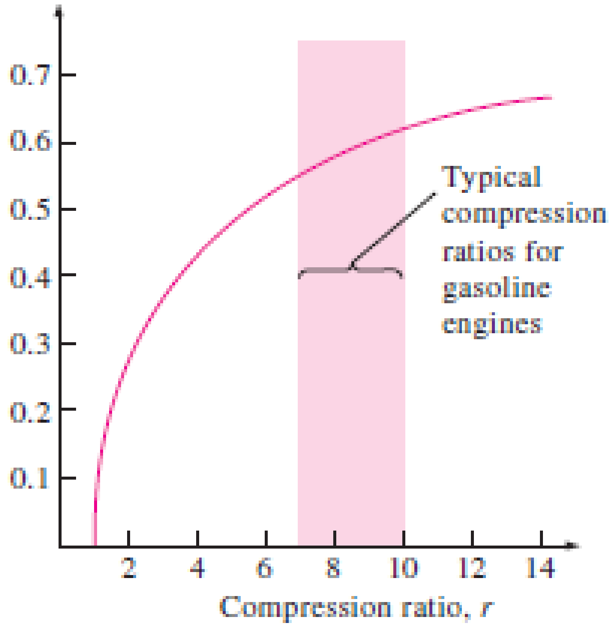




Increasing Otto Cycle efficiency

$$\eta_{th,Otto} = 1 - \frac{T_1}{T_2} = 1 - \left(\frac{v_2}{v_1}\right)^{k-1}$$

$$= 1 - \frac{1}{r^{k-1}}$$



Auto-ignition produces "engine knock" at higher compression ratios

"Octane rating" measure of engine knock resistance

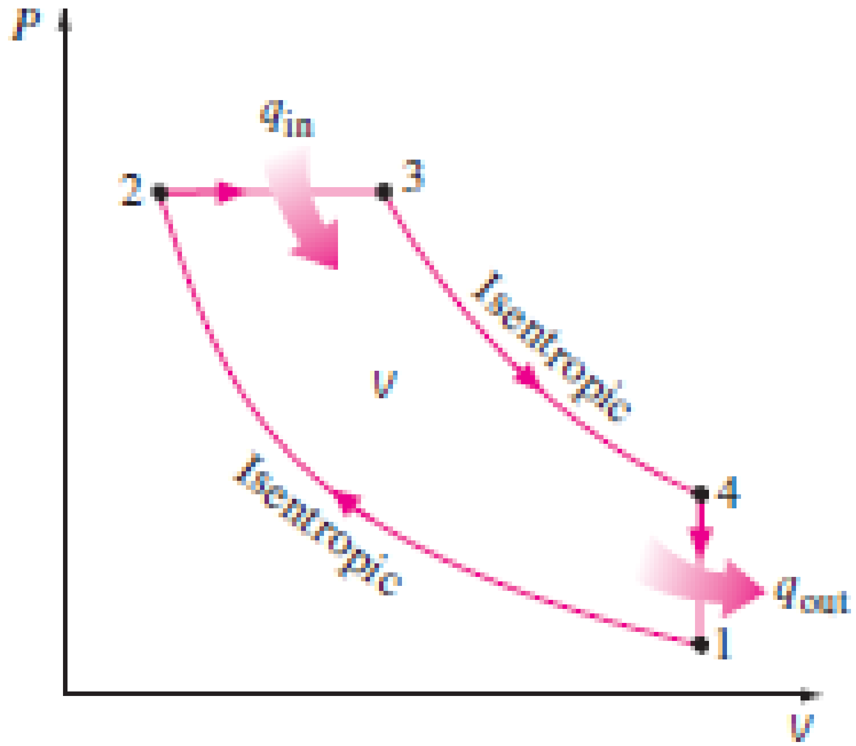
Diesel Cycle

Compression stroke:
The piston moves back up to compress air to a temperature which is higher than the auto ignition temperature of the fuel.

Combustion stroke (power stroke):
When the piston approaches the top of its stroke, fuel starts to be injected from the fuel injector and the combustion occurs spontaneously, driving the piston down. Fuel is injected during the first part of the power stroke, resulting in a longer combustion interval.

Exhaust stroke:
Once the piston hits the bottom of its stroke, the exhaust valve opens and the exhaust leaves the cylinder to go out through the tail pipe.

Intake stroke:
The piston starts at the top dead center, the intake valve opens, and the piston moves down to let the engine take in a cylinder-full of air

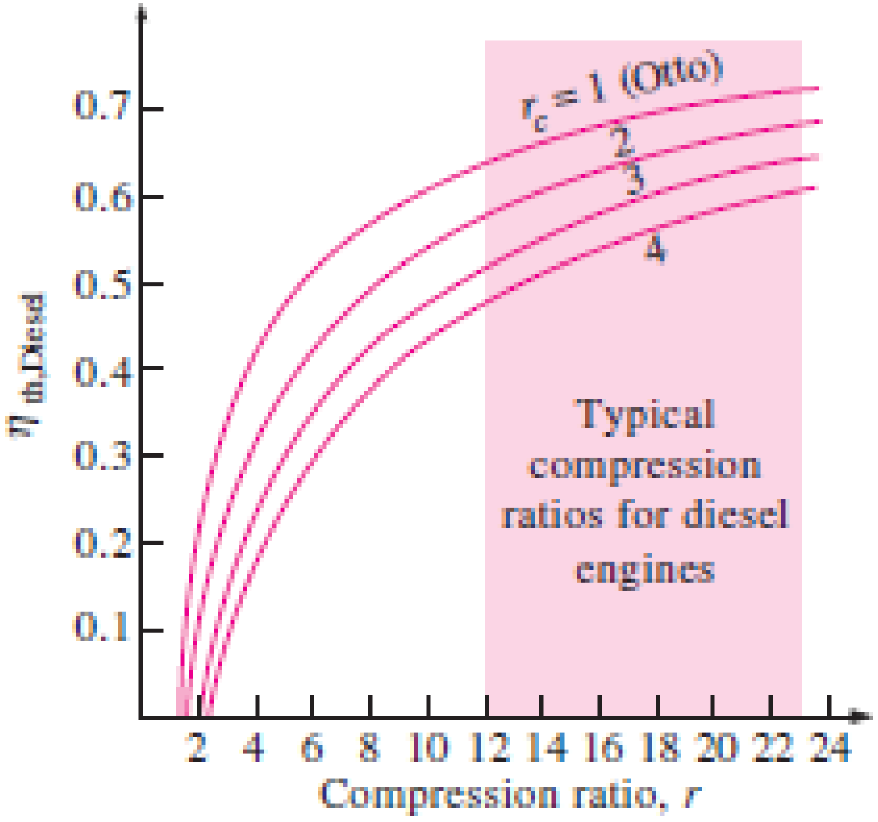


(a) P- v diagram

Summary Diesel Cycle

$$\eta_{th,Diesel} = 1 - \frac{1}{r^{k-1}}\left[\frac{r_c^k - 1}{k(r_c - 1)}\right]$$

$$\eta_{th,Otto} > \eta_{th,Diesel}$$



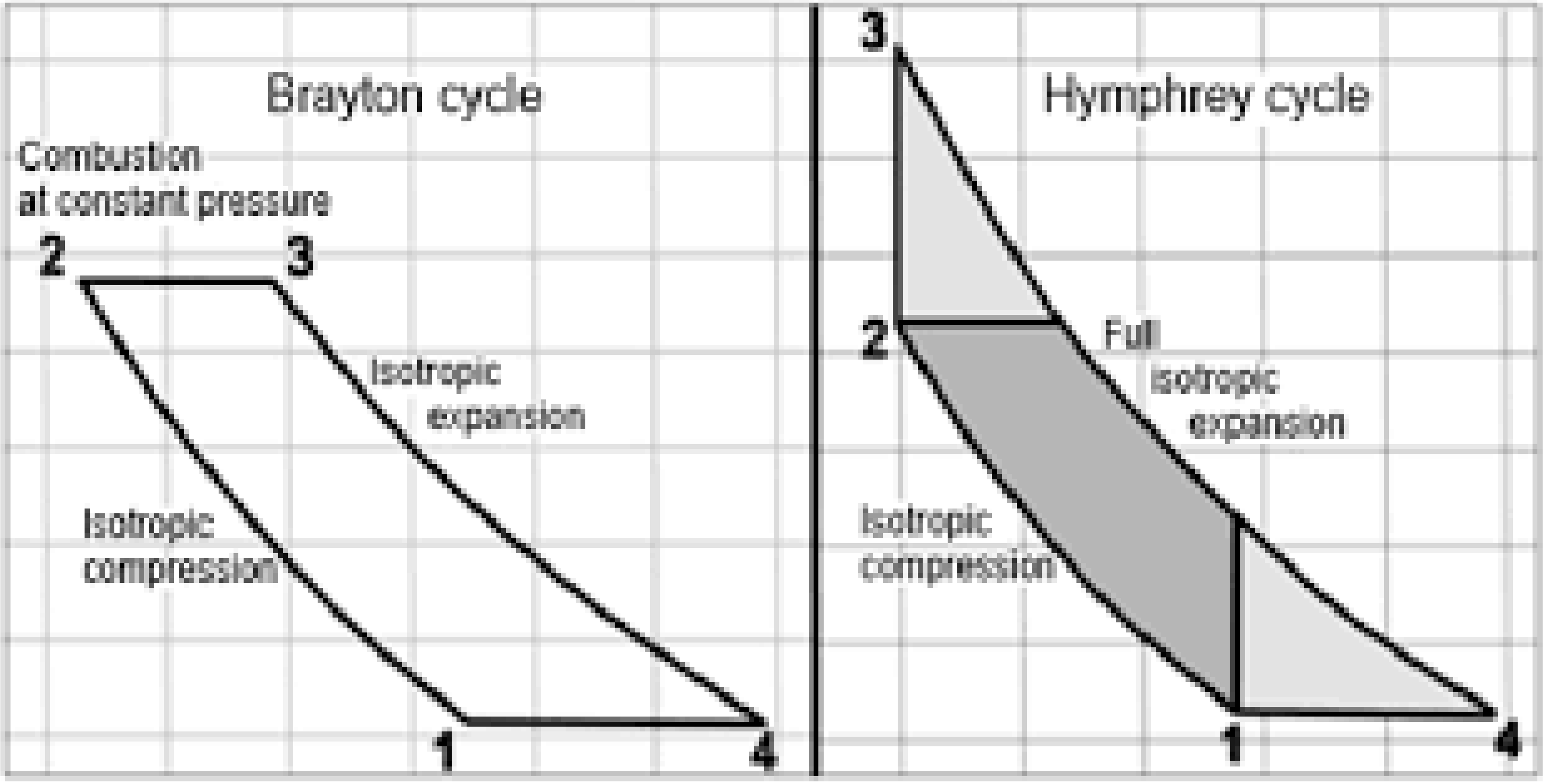
Diesel cycles are attractive because:

They can employ higher compression ratios

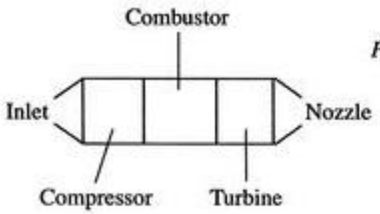
Employ lower grade fuels as the auto-ignition problem is absent (only air is compressed)

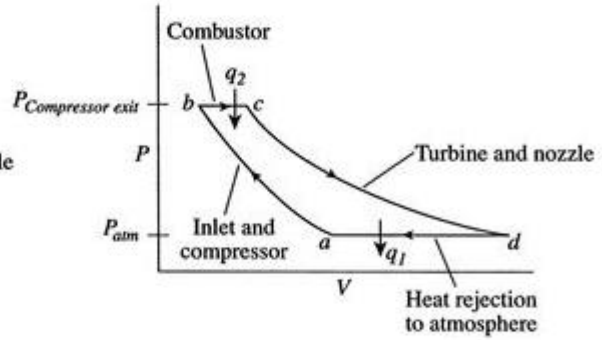
Introduction

- **What is a thermodynamic cycle?**

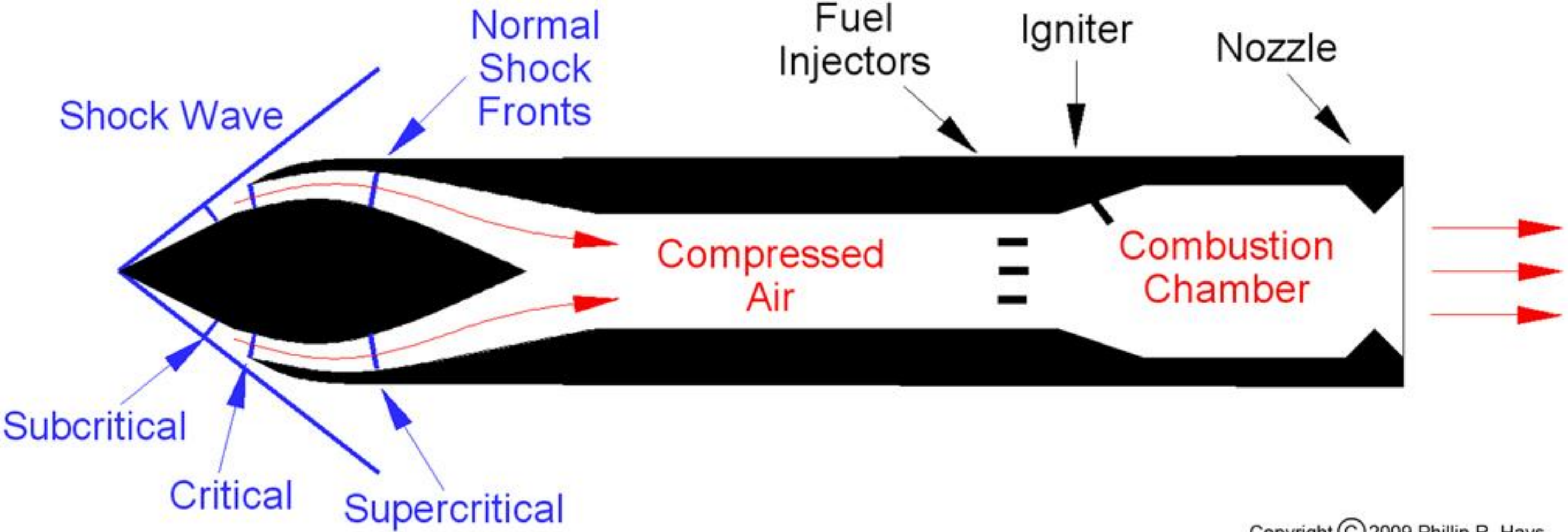


Brayton Cycle

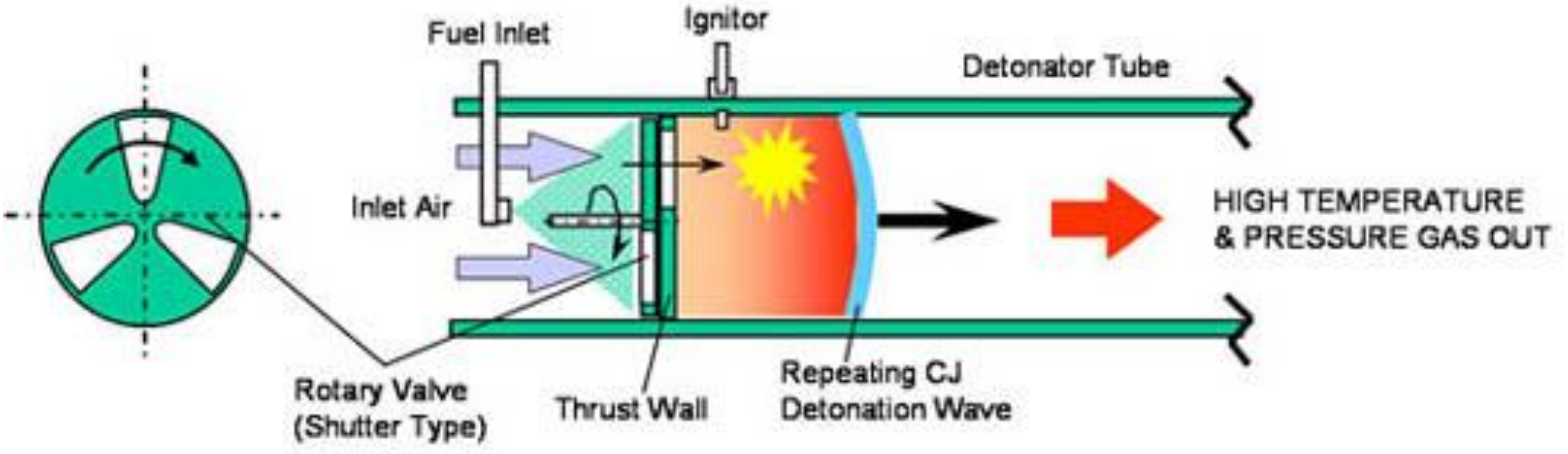




From MIT



Humphrey Cycle

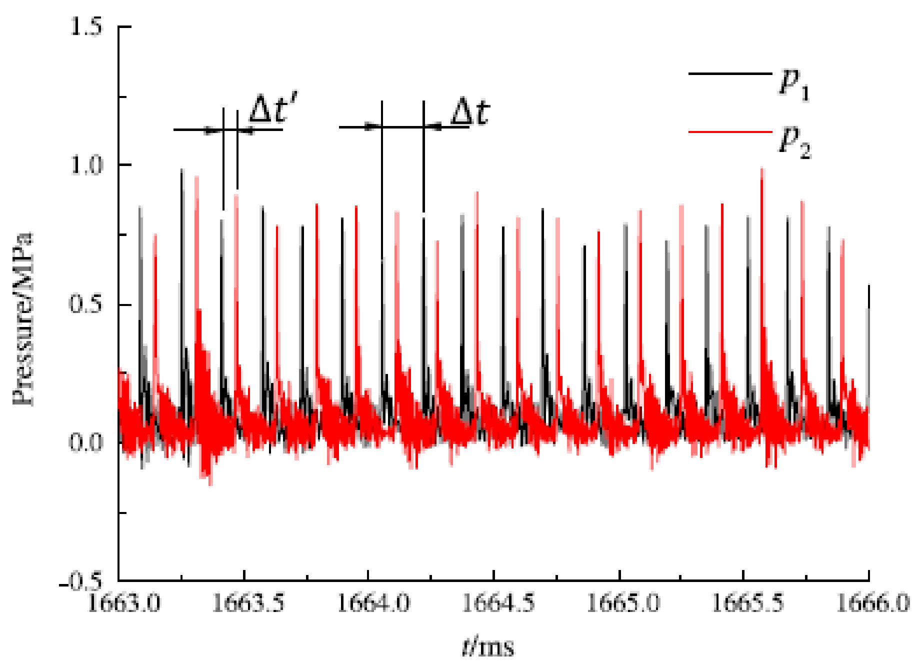


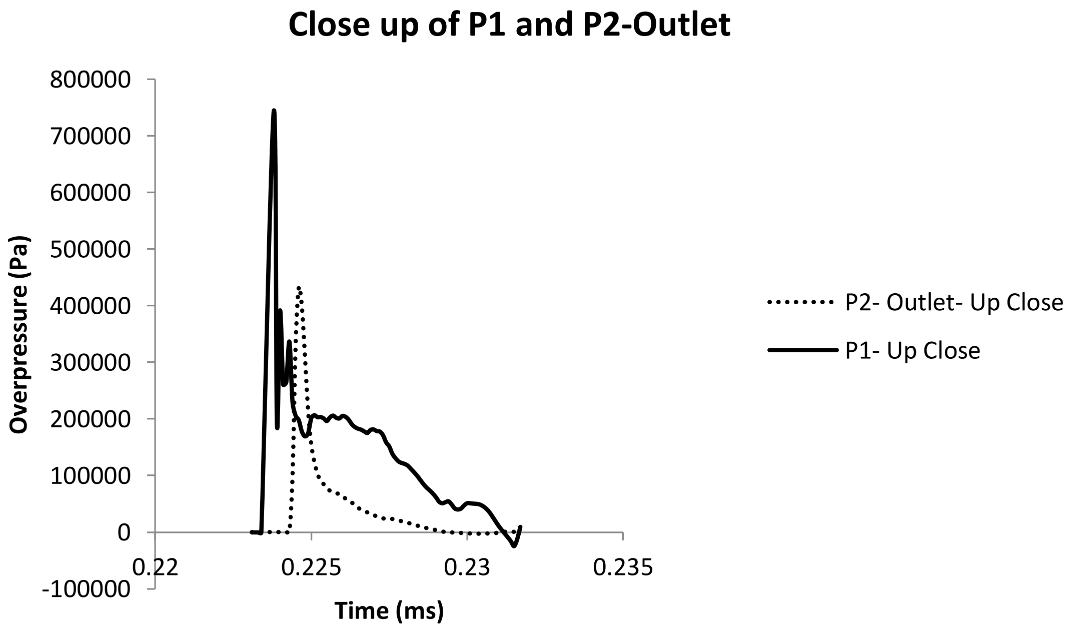
Methods

Used computer simulations
Tried to get similar results as wet lab experiments performed by Yang et al.

Results

- After all the work, was only able to sustain engine for one cycle.
- Very difficult to simulate





Conclusions

- Biggest mistakes I made
  - Getting the right engine design
  - Choosing the right time step to test model
  - Making sure the solution is convergent at smaller time-steps
  - Biggest lessons for future space grant individuals: start early- you run out of time

Impact of my experience on my life

- Career Goals (career interests)
  - Academic Research (manufacturing optimization), Teaching & Service
  - Research & Development (Industry)
  - Engineering consulting
- Level of care
  - Grading my own work,
  - Listening and responding to criticism well
  - Taking pride and ownership of my work
- Should you do this?
  - Yes!