Mars, Machines & Marine Life: Engineering for the 22nd Century

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BE (Mechanical) (Space) Hons./BSc (Physics) (Adv.)

Cambodia/Vietnam 2019

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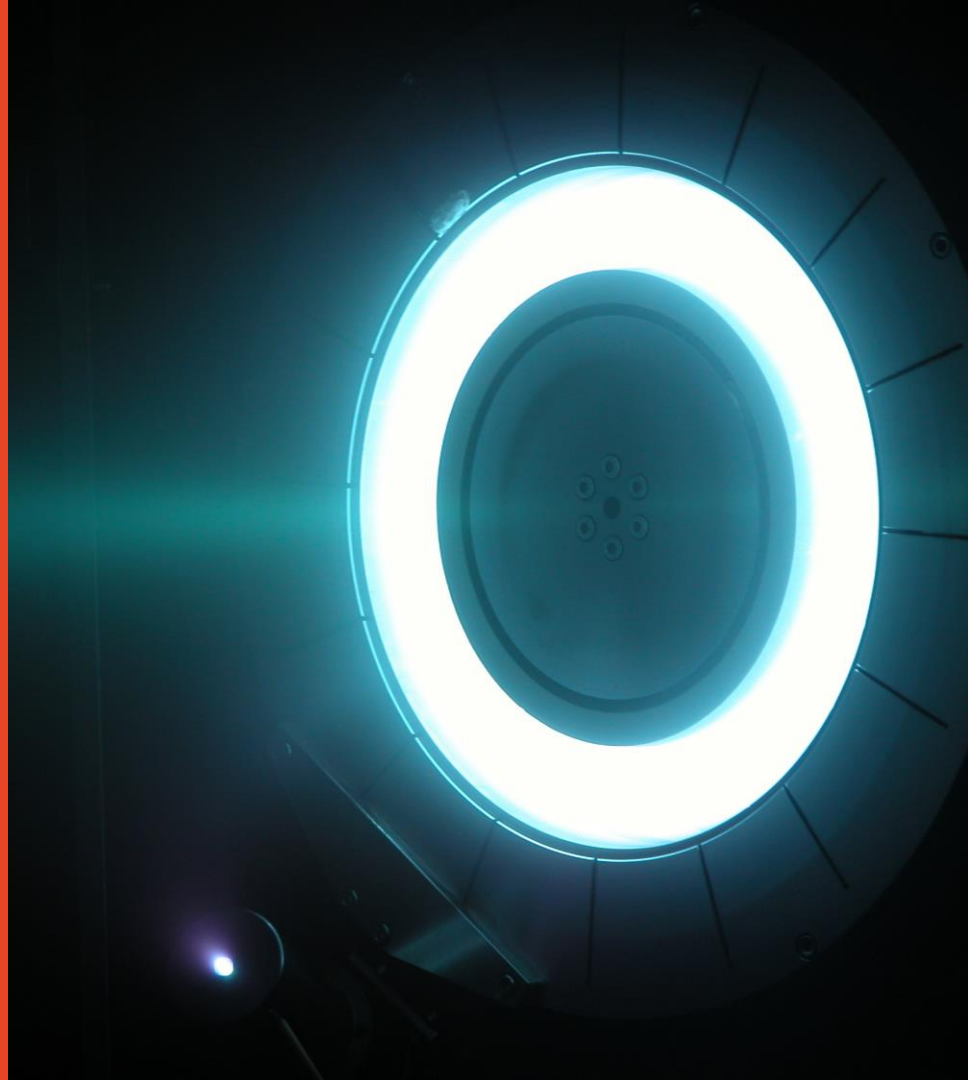
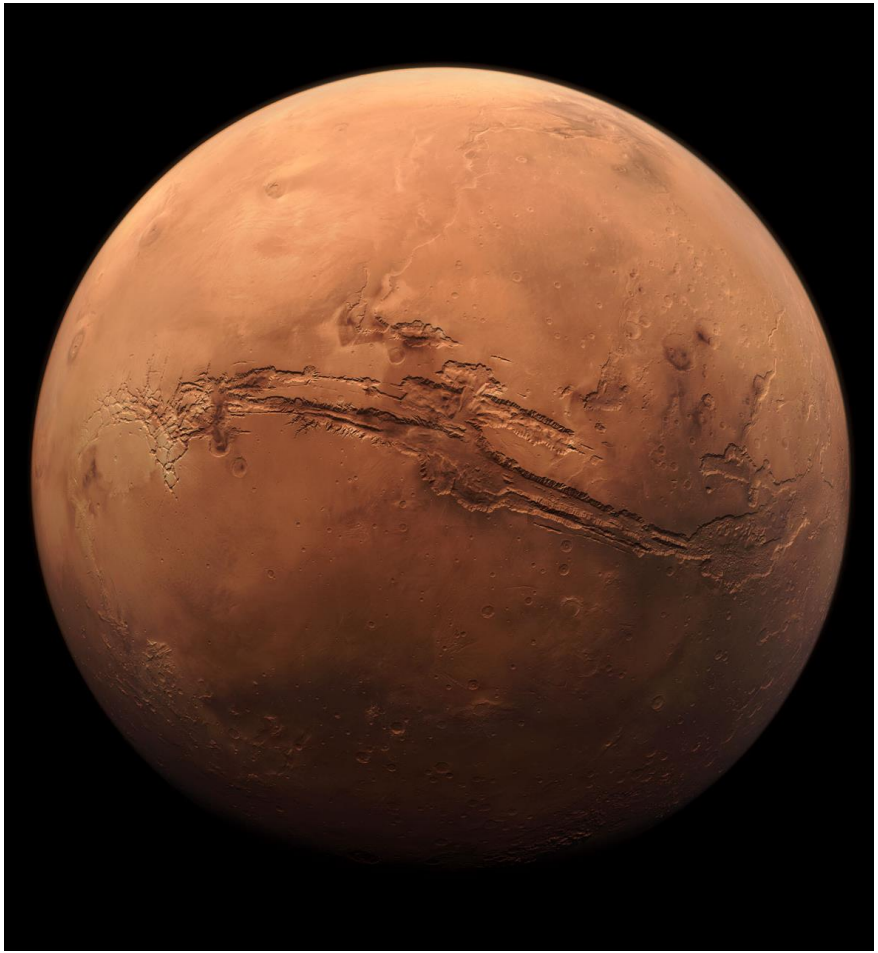


A little about me…

- 3rd Year Mechanical (Space)/Physics Student @ USYD
- Faculty Communicator/Student Ambassador
- Engineering Leadership Scholar
- Immediate-past President of Mechanical Undergraduate Society and Vice-President of Physics Society @ USYD

Mars

The Next Big Challenge in Human Space Exploration



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Space – the next frontier

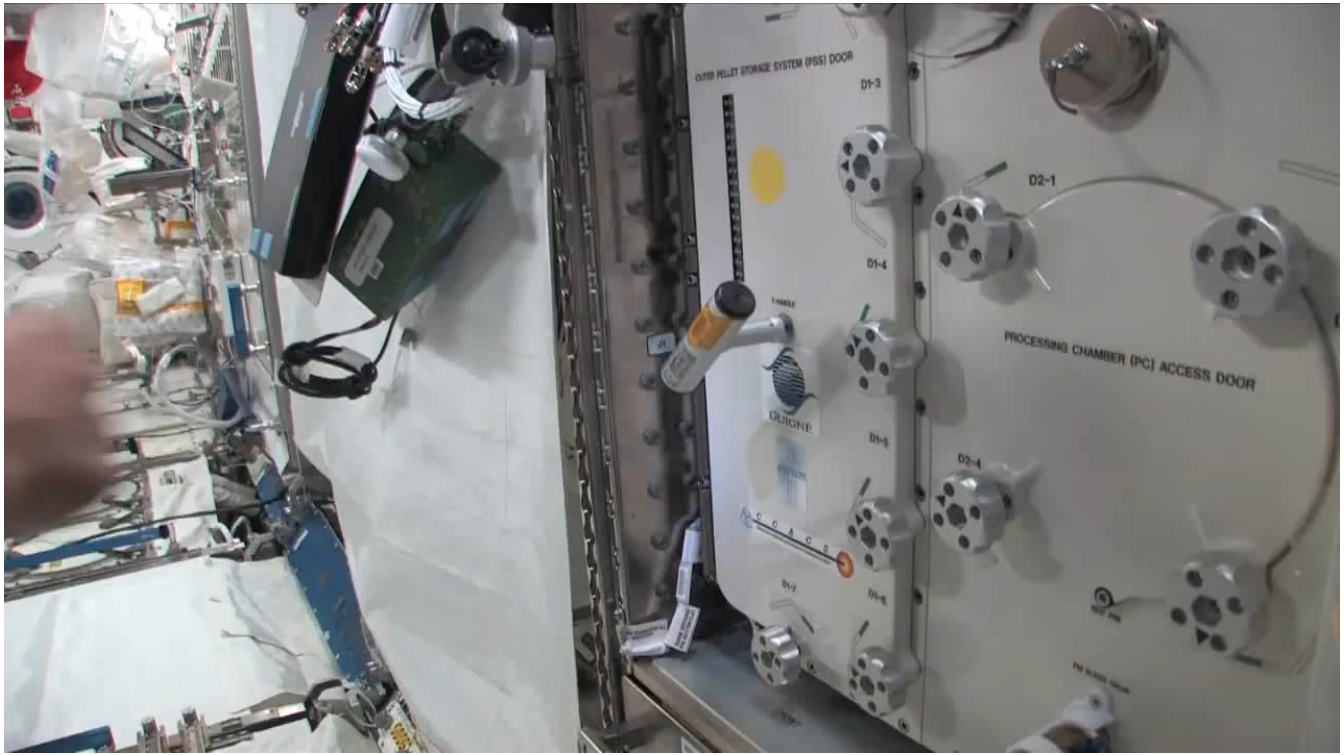
- Putting things into space is extremely hard to do
- Very high cost, small payloads and large amounts of infrastructure

We need to get there, because space is our future.

Designing for Space

- **Space is a really weird environment for engineers:**
  - Metal surfaces cannot rub against each other
  - You constantly have to change the way you're facing
  - Light can change your direction
  - Radio signals change your direction
  - Charge can build up on your spacecraft and cause lightning

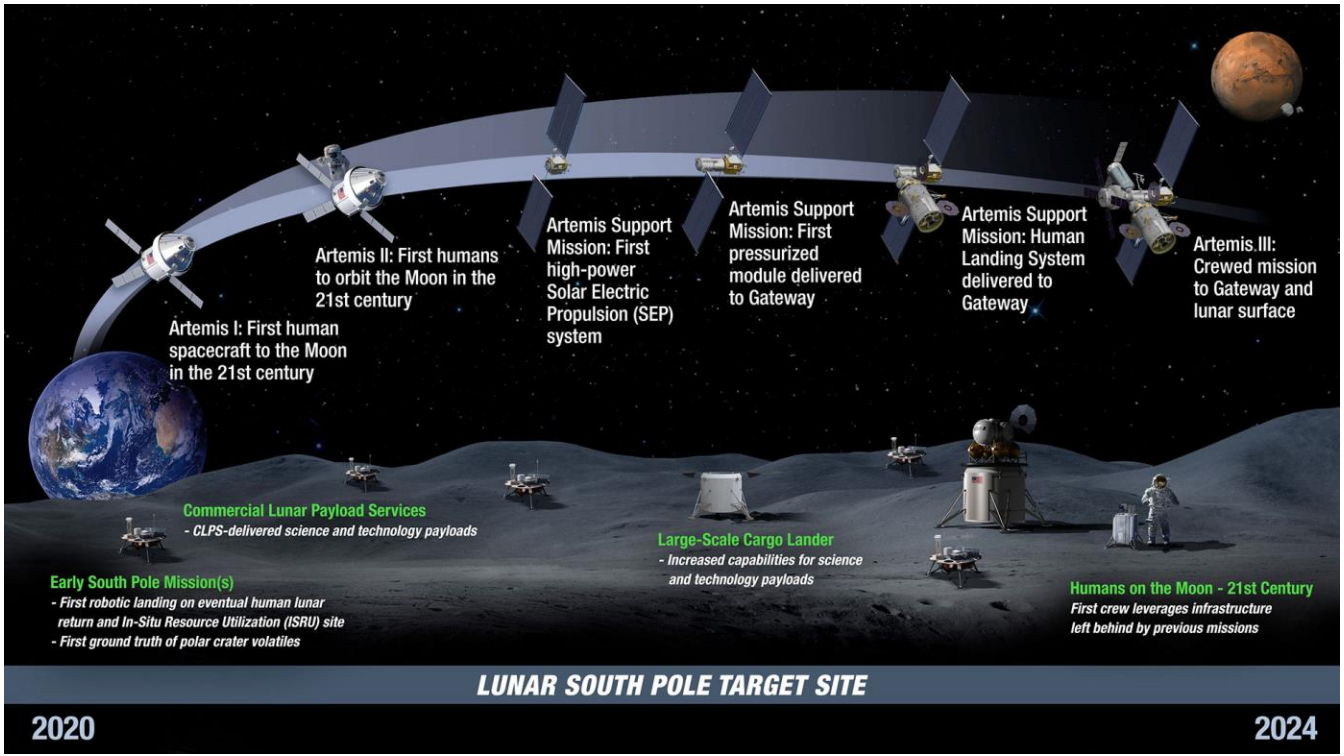
Why it's difficult?



Where do we go next?

- **Back to the moon, as a gateway to beyond**
- **Difficult engineering challenges**
  - Humanity has never designed a space portal before
  - How do we create a permanent “halfway” point to journeys beyond our orbit?
  - Will we need to relay messages?
  - Does this need to be a “service centre” to repair spacecraft mid-journey? (E.g. solar wind/radiation damage)

Artemis


Artemis I: First human spacecraft to the Moon in the 21st century
Artemis II: First humans to orbit the Moon in the 21st century
Artemis Support Mission: First high-power Solar Electric Propulsion (SEP) system
Artemis Support Mission: First pressurized module delivered to Gateway
Artemis Support Mission: Human Landing System delivered to Gateway
Artemis III: Crewed mission to Gateway and lunar surface
Commercial Lunar Payload Services
- CLPS-delivered science and technology payloads
Early South Pole Mission(s)
- First robotic landing on eventual human lunar return and In-Situ Resource Utilization (ISRU) site
- First ground truth of polar crater volatiles
Large-Scale Cargo Lander
- Increased capabilities for science and technology payloads
Humans on the Moon - 21st Century
First crew leverages infrastructure left behind by previous missions
LUNAR SOUTH POLE TARGET SITE
2020
2024

Efficiency

- **Spacecraft are not as efficient as people think**
- **Measured via specific impulse (I_{SP})**
  - The B787 that I flew here on has engines with an I_{SP} of 800 s
  - A plasma thruster has an I_{SP} of 2000 s
  - Most liquid rocket engines are ~200 s
- **Higher I_{SP}, lower thrust – major tradeoff**
- **How can we design more efficient spacecraft?**

Machines

Have we hit the limit of efficiency?

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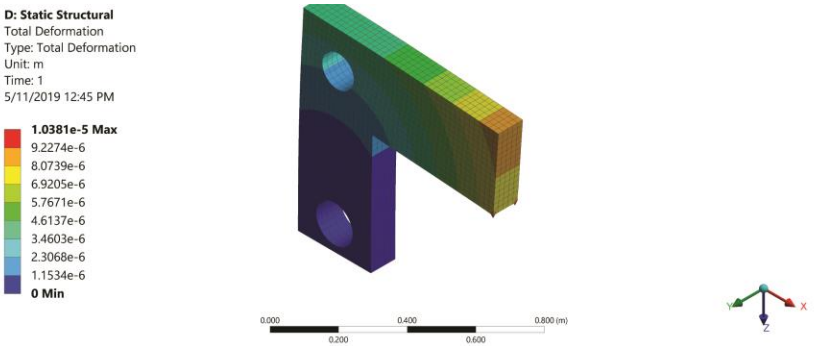
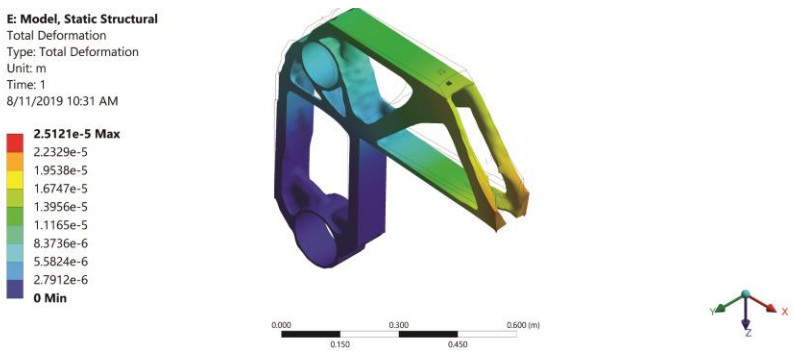
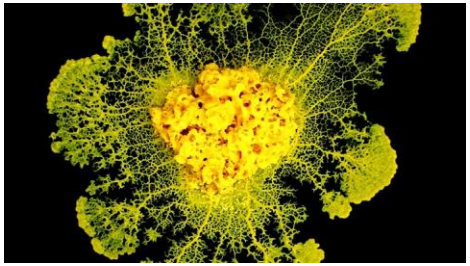
Do we always design the best way?

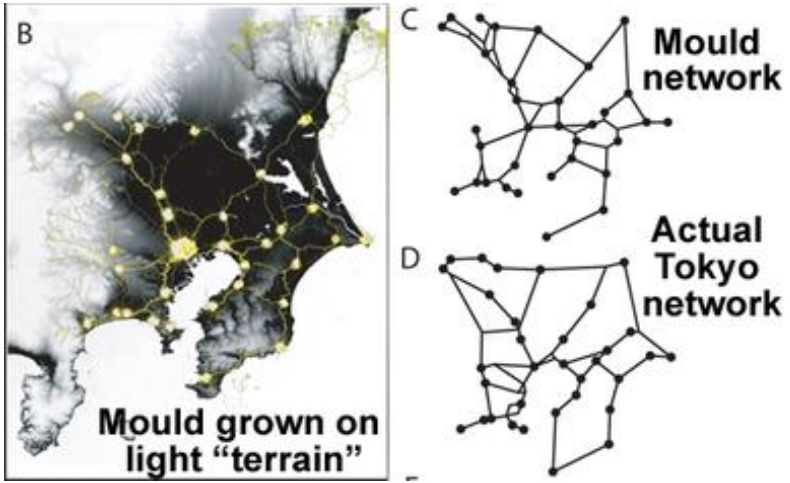




Nature has got efficiency perfected

- **Slime mould was used to model Tokyo's railway system**
- **Matches almost perfectly**
- **Says two things:**
  - Japanese engineers really good at what they do
  - Nature had it right all along!

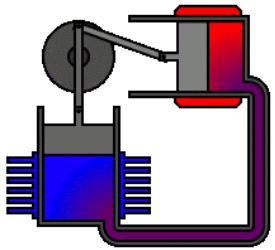




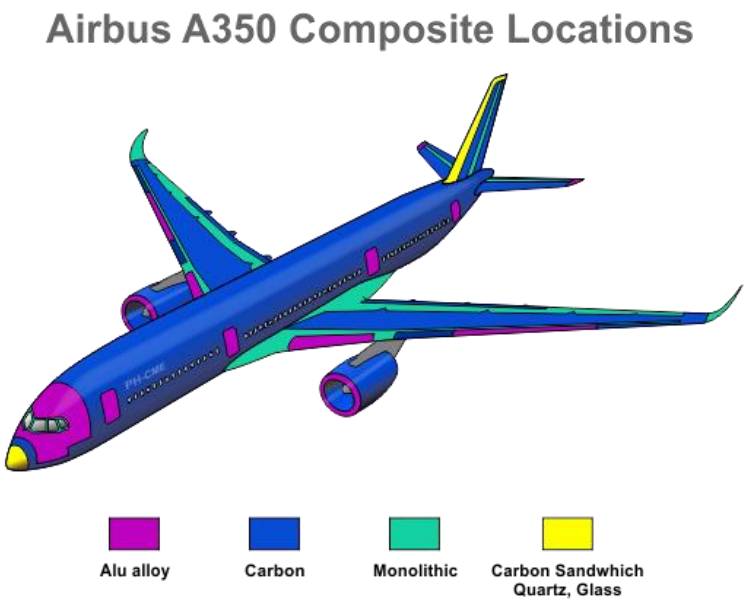
Old tech is the “new” new tech

- **The most efficient submarine propulsion is based on principles from the steam age**
- **Submarines require:**
  - Efficient transfer of energy
  - Quiet operation
  - Cannot fail
- **The result: the Stirling engine first designed in 1816**

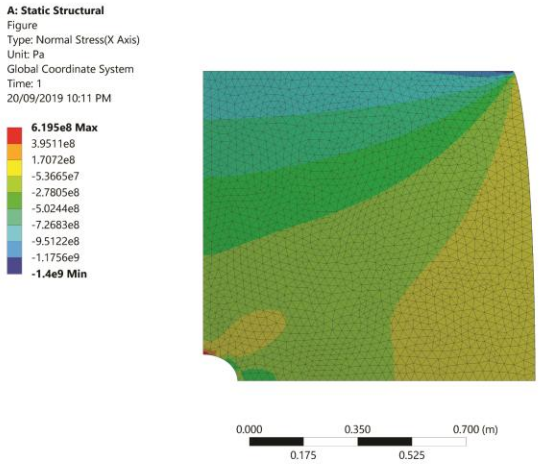
The Stirling Engine

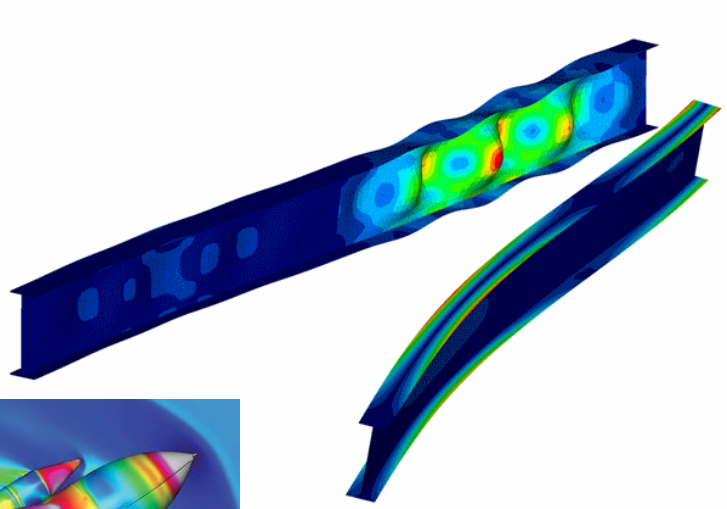


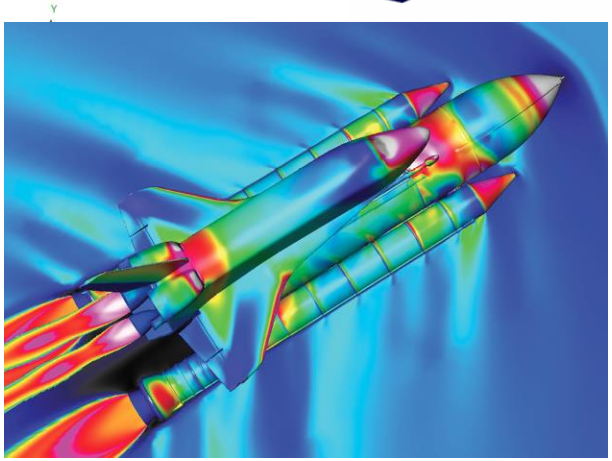
The right materials for the job



Simulations to give what testing cannot







Marine Life

Ocean health as a vital resource

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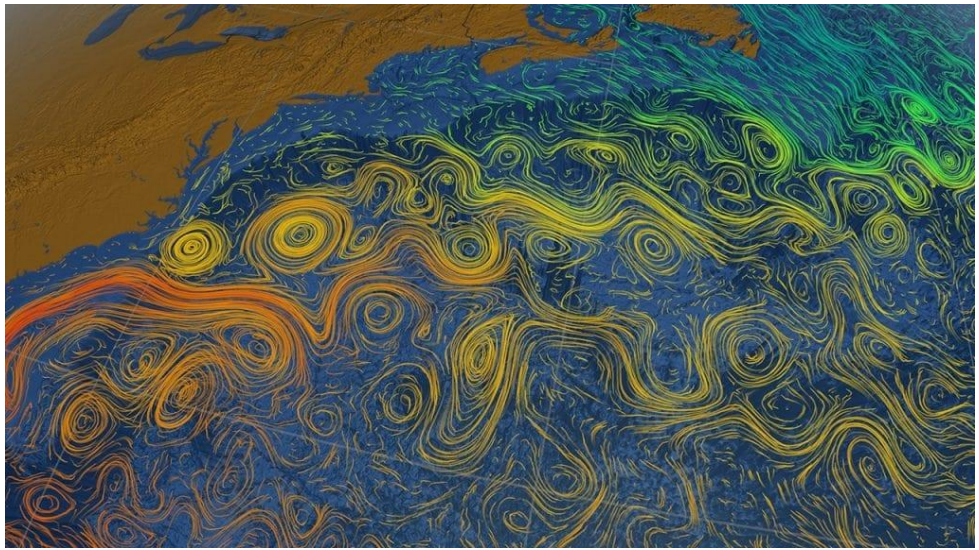
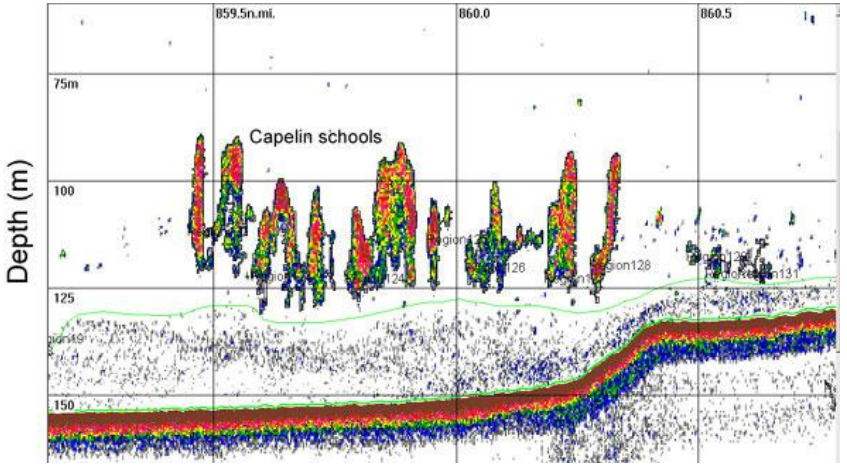
Why should engineers care about the ocean?

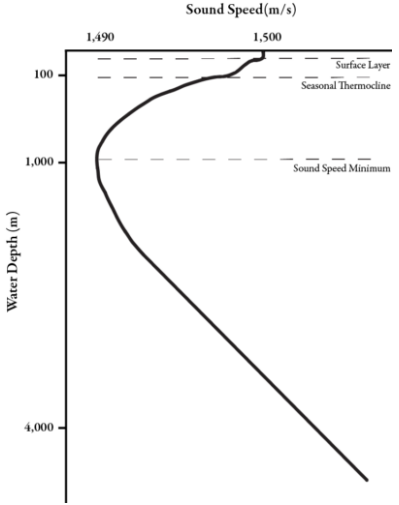
- One of the most valuable resources
- Abundant source of oxygen, hydrogen, water (i.e. the basis for life)
- Stable temperature, chemical composition
- Helps to predict weather



Sounds in the ocean

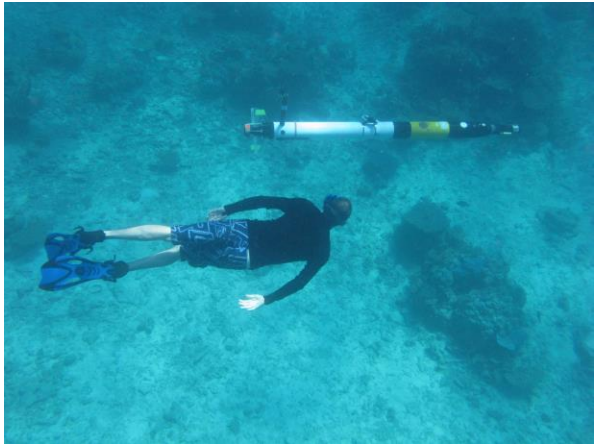
- **The ocean is a very noisy place**
- **The noise is not from us**
  - Millions of creatures are creating their own noise
  - We can listen to this – and actually we can use this
  - By how noisy the ocean is, it tells us how well the ecosystem is doing





Exploring the terrestrial unknown

- Geological information is thousands of feet below
- Give an insight into how our world is evolving but we cannot get to it
- Need to design for crushing depths and pressures.



Some of my current research – Guidance System Designs for Autonomous Underwater Vehicles

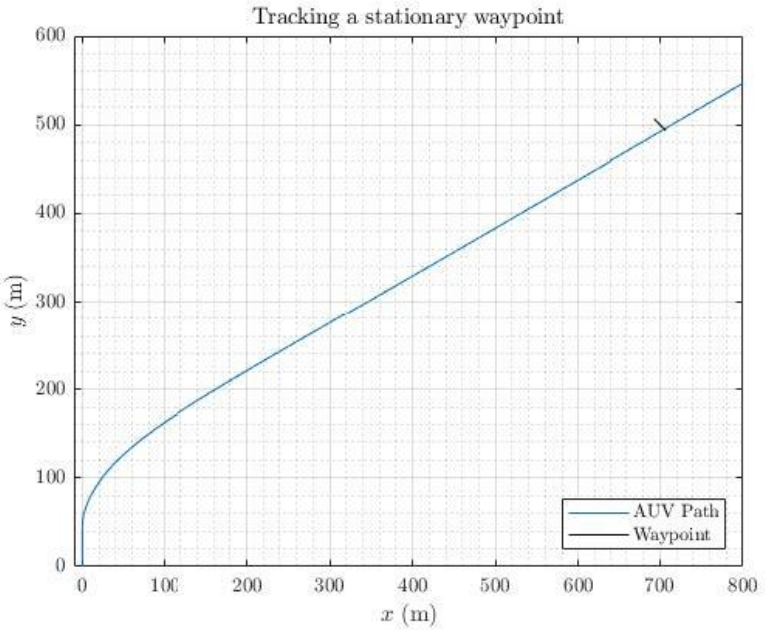
- **Equation does not look difficult, but is (it's a 6x6 matrix!):**

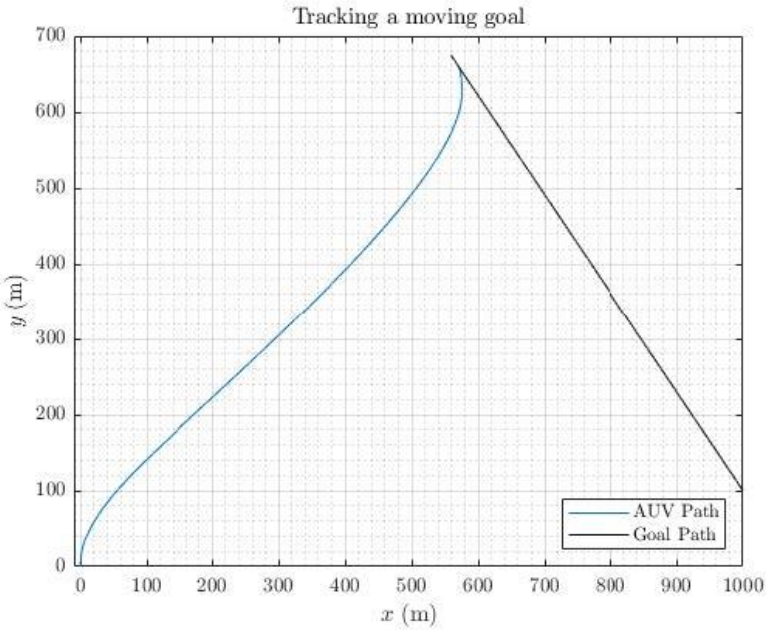
$$\boldsymbol{M}\dot{\boldsymbol{v}}_{\boldsymbol{r}} + \boldsymbol{C}'(\boldsymbol{v}_{\boldsymbol{r}})\boldsymbol{v}_{\boldsymbol{r}} + \boldsymbol{D}(\boldsymbol{v}_{\boldsymbol{r}})\boldsymbol{v}_{\boldsymbol{r}} + \boldsymbol{g}(\boldsymbol{\eta}) = \boldsymbol{\tau}$$

- **Geometrical guidance vector:**

$$\varsigma = \tan^{-1}\frac{x_g - x}{y_g - y}$$

AUV's moving


Tracking a stationary waypoint
y (m)
x (m)
AUV Path
Waypoint

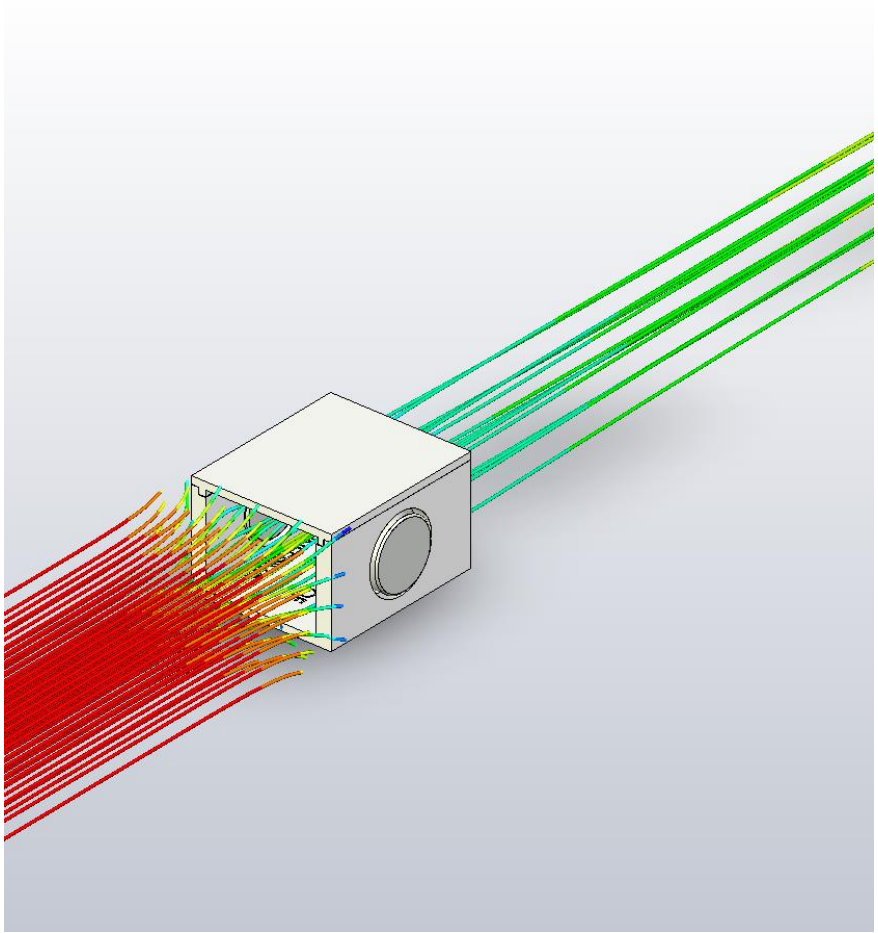

Tracking a moving goal
y (m)
x (m)
AUV Path
Goal Path

Sustainable engineering is key

- **The skillset of an engineer is applied to human problems**
- **Sometimes these are not easily solved:**
  - Rising sea levels
  - Pollution
- **Need to develop innovative and sustainable solutions**

Magnetohydrodynamic (MHD) Thrusters

Who said you couldn't build a propulsion system in under 10 mins?



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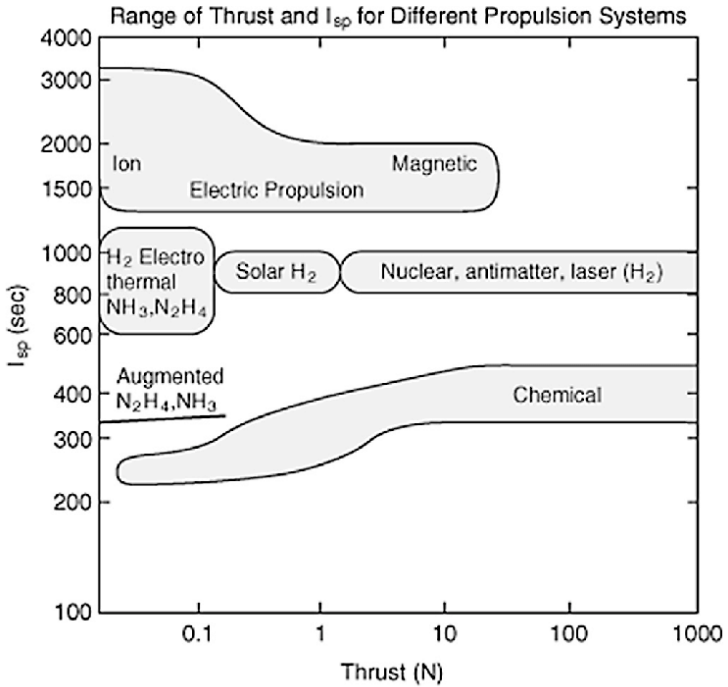
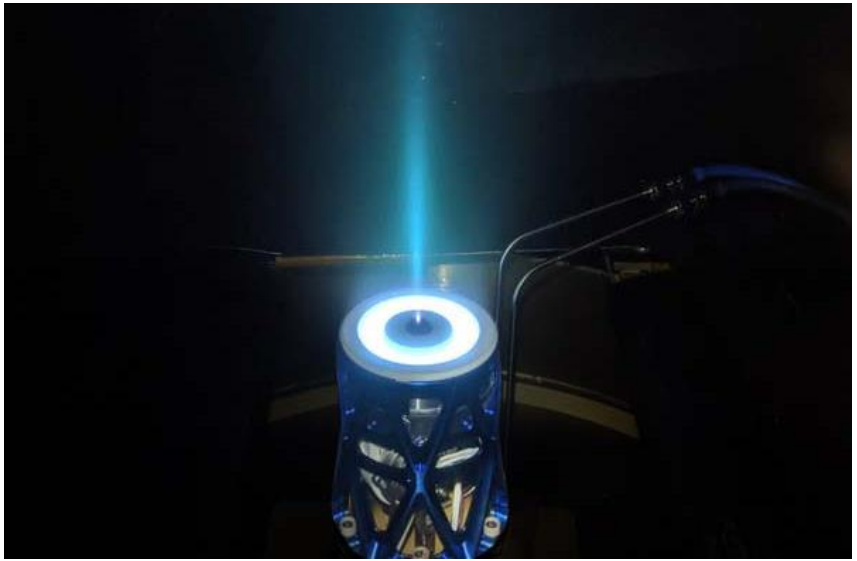
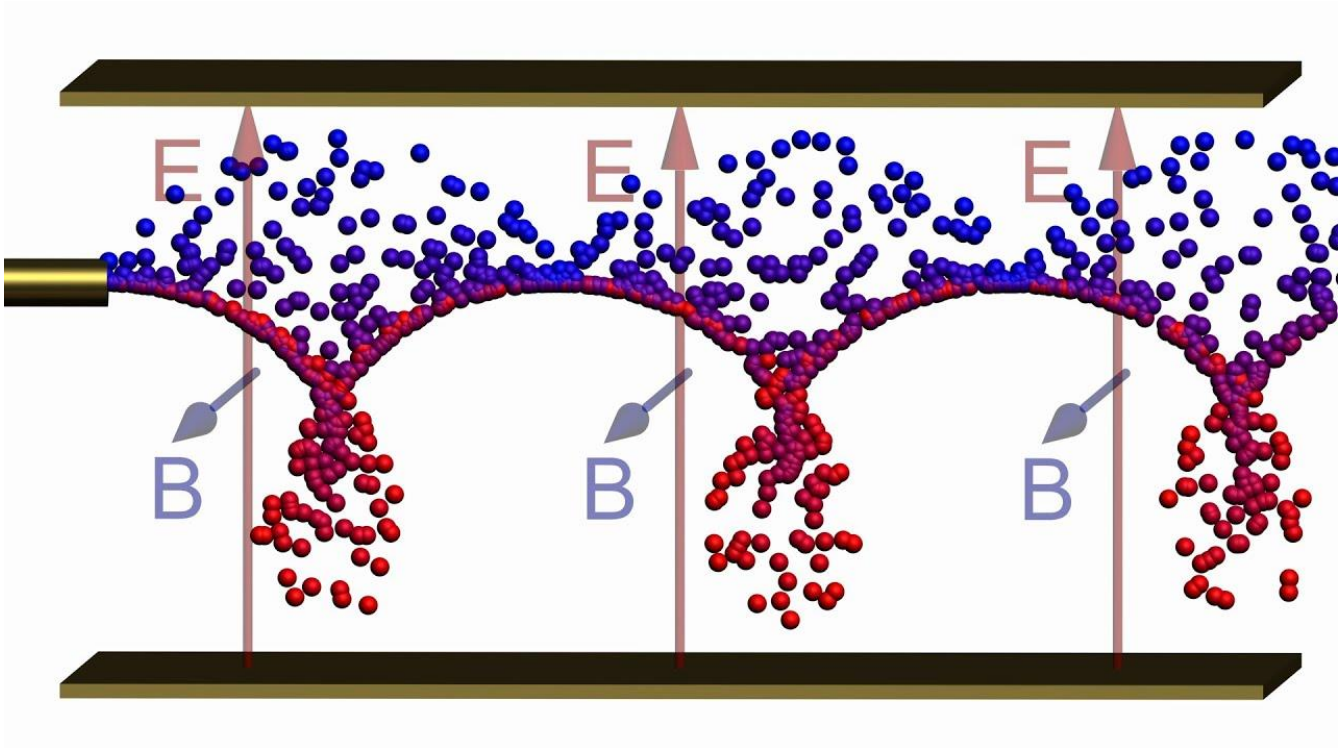
MHD Thrusters

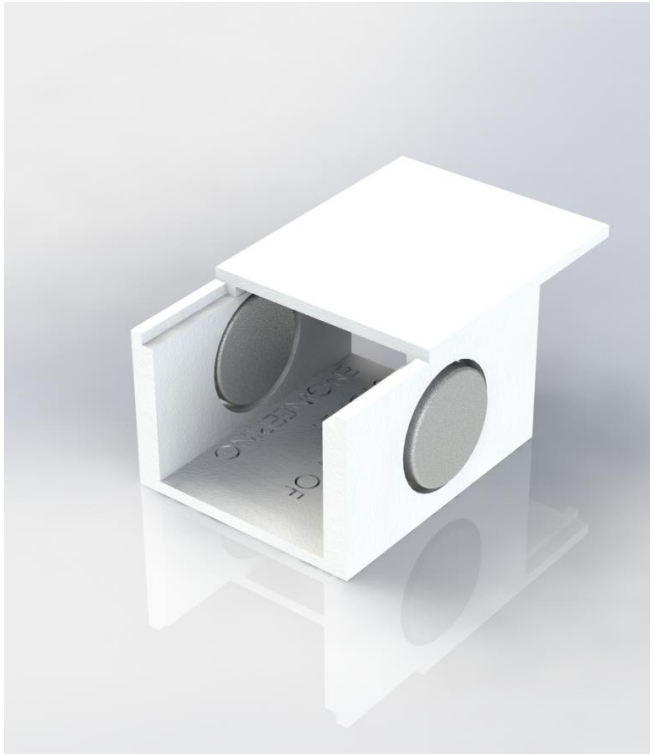




How does it work?



Constructing the models



- Sticky tape magnets inside holes
- Cut a desired size of aluminium foil (hint: how big should this be given magnet size)
- Stick aluminium foil on bottom and top of cavity
- Bring up the front

Q&A

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