Engineering Portfolio

Attila Haas – 14.11.2023

Imperial College London

Battery Pack for hybrid Go-Kart

Result: A

Third year design make and test project – Click here to see full report

Teammates: Aditya Vencatesan Basu, Edward Lee, Edward Wang

My Roles:

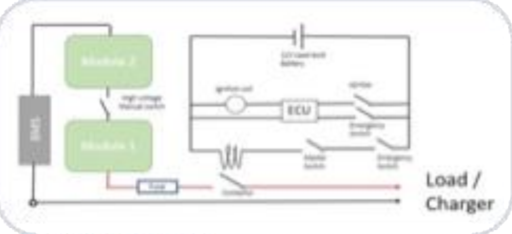
- Project Management
- Mechanical design
- Engineering Analysis
- Reporting

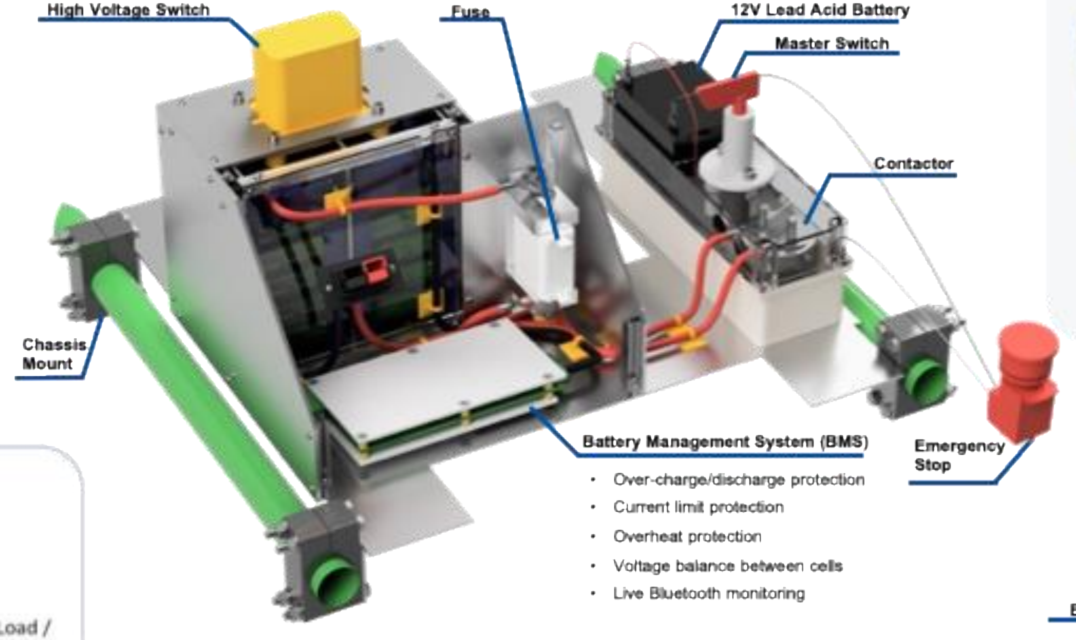
Technical Requirements

1. **Life**: Battery needs to last 30 minutes on the track.
2. **Safety**: Withstand debris and vibration; fully insulated
3. **Battery Voltages**: In range 50-120V for motor controller and 12V battery for engine control
4. **Temperature**: To operate within 10°C to 60°C
5. **Cost**: £1000 allocated

Molicel INR-21700-P42A

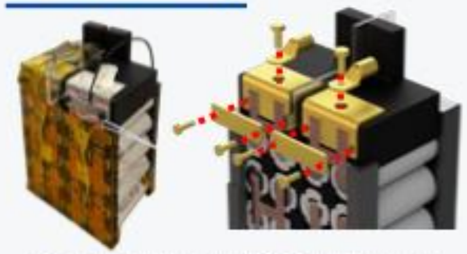
- Nominal voltage: 3.6V
- Capacity: 4200mAh
- Maximum current: 45A



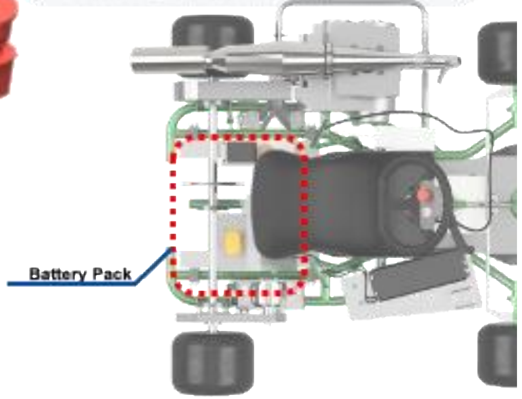


- Over-charge/discharge protection
- Current limit protection
- Overheat protection
- Voltage balance between cells
- Live Bluetooth monitoring

Module Assembly

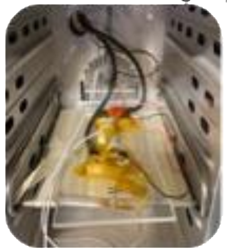


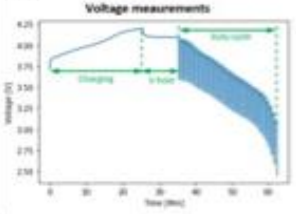
- 2 identical modules of 10S 2P connected using bolted aluminium clamps.
- TIG Welded H shaped Copper busbars were used for cell connections to minimise contact resistances.
- 3D Printed insulation coupled with acrylic sheets for constraining and additional safety.

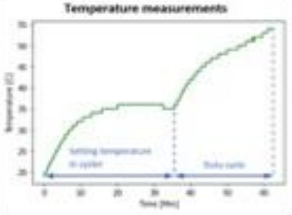


Single Cell test

Single-cell discharge tests were conducted to verify the cell's ability to meet the power delivery requirements and to gain insights into the cell's thermal behaviour during high current draw contingency situations.

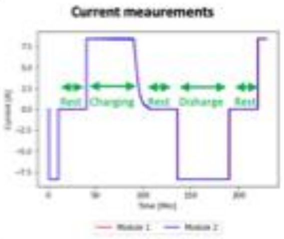


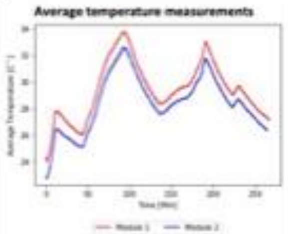




Module test

Module discharge tests were conducted on both modules separately to examine their manufacturing quality and thermal characteristics.





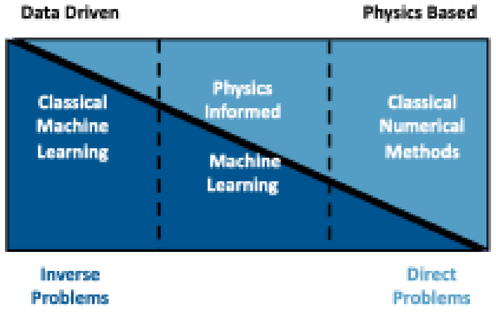
Result: A

Physics Informed Machine Learning

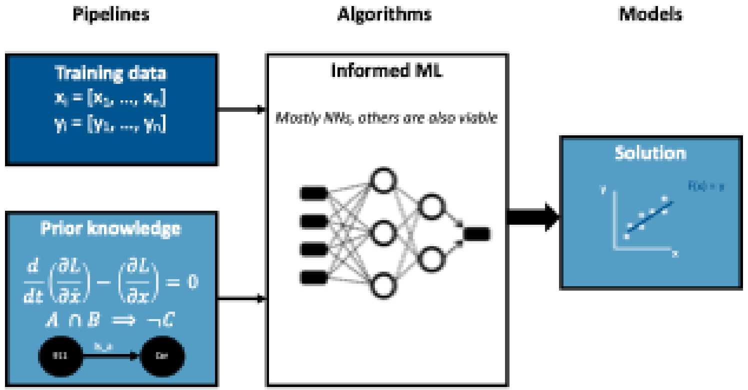
Third year literature review – [Click here to see full report]

What is PIML?

Physics Informed Machine Learning (PIML) is the middle ground between classic numerical methods and "black box" ML methods.



Rueden et al. (2021) *define Informed Machine Learning as an ML algorithm that learns from multiple, independent pipelines consisting of both training data and prior knowledge.*



von Rueden, L., Mayer, S., Beckh, K., Georgiev, B., Giesselbach, S., Heese, R., Kirsch, B., Pfrommer, J., Pick, A., Ramamurthy, R., Walczak, M., Garcke, J., Bauckhage, C. & Schuecker, J. (2021), 'Informed Machine Learning – A Taxonomy and Survey of Integrating Knowledge into Learning Systems', IEEE Transactions on Knowledge and Data Engineering pp. 1–1.

How can Physics be incorporated?

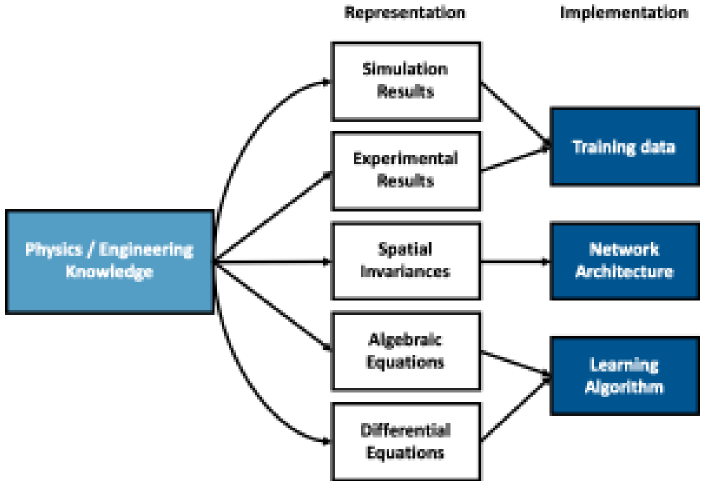
Firstly, the most straightforward method is to convey information in the training data itself. This quintessentially does not differ from a traditional ML approach, however with physics for example, multiple pipelines of data can be considered. One could use a hybrid of both experimental and simulation results as training data, thus relying on both previously discovered physical rules and measurements. This not only allows for significant cost reductions in data acquisition, but also to reduce noise.

Secondly, the ANNs architecture can be altered to help it better optimise for certain solutions. Only changes that have real world meaning are considered a second pipeline. Mapping certain neurons that are known to represent parts of a logic statement to particular neurons is a prime example. CNNs used to add translation invariance is another.

Thirdly, the learning algorithm can be tweaked. The cost function of a NN can usually be altered

in a way for the results to conform to known algebraic or differential equations. As one would

expect this is the most widely used method in PIML, as most systems can be described by known relationships.



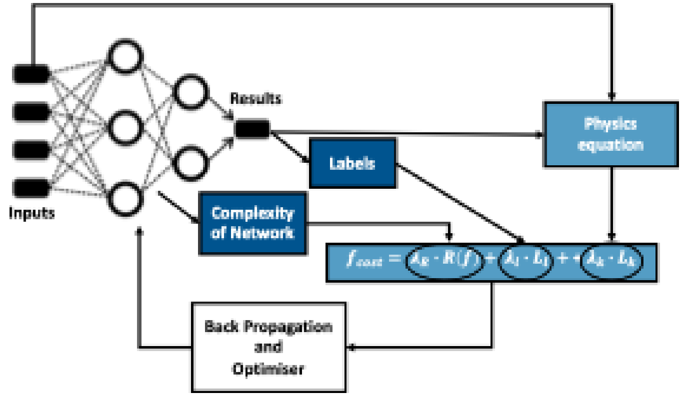
The most common method for NNs

The full report goes into many sub-variants of PIML implementations, see the link.
For the sake of conciseness, here only the most common NN solution will be showcased

As common with NNs there is a set of training data to which the network will be trained with a cost function.

In examples involving physics, a results accuracy can be judged on existing laws. For example, if the energy isn't conserved, during a process, the output is known to be false. To guide the NN towards solutions that obey the known physical laws, the cost function is expanded with a term which penalises deviations from the known relationships.
This allows the NN to not only confirm to measured data, which is subject to noise, but also follow laws of nature.

(Diligenti et al. 2017)



Diligenti, M., Roychowdhury, S. & Gori, M. (2017), Integrating Prior Knowledge into Deep Learning, in '2017 16th IEEE International Conference on Machine Learning and Applications (ICMLA)', pp. 920–923.

My Roles:

Research

Reporting

Result: A

Sailing Vessel Energy Harvester

Second year design project – Spring

Teammates: Alexander Christopherson, Jansen Papworth, Kayman Krishnamohan

Aim

Develop a sailing vessel energy harvester which powers onboard electrical systems including navigation, lights and a laptop while also charging a battery to allow continued use of electronics while stationary.

Target Market & Expected Use

Initially designed for 30+ ft sailboats (14% of US sailboat market). Boats this size are often used for day trips with pauses at tourist locations or scenic spots.

- In use during comfort sailing, i.e. 5-10 knots (2.57- 5.14 m/s)
- Suitable for use in both fresh and saltwater conditions
- Used for 12 hours a day, 30 weeks of the year; 30ft+ sailboats often chartered for trips so in continuous use
- Must power navigational systems (110W, 12V), lighting (122W, 12V) and a laptop (60W, 19.5V)
- Can be mounted easily and safely by 2 people (18kg)
- Retail price approximately £3000

Technical Specifications

- 290 W generated at 5 knots, 440 W at 10 knots using 4 RS-655VA-28118 motors.
- Battery capacity of 81 Ah.
- Made up of 81 18650 cells, in a hexagonally close packed arrangement.
- 4 stage reduction gear box using helical gears
- Total reduction ratio of 1:525.
- Bearing L_{10} life 82000 hours, 33 years of expected use

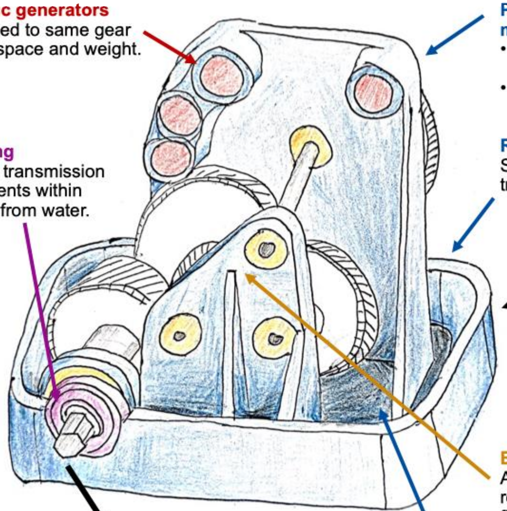
Embodiment Design

4 electric generators
Connected to same gear to save space and weight.

Seal Ring
Protects transmission components within housing from water.

Polyster (UP) Injection moulded housing Blue
- Same material as most boat hulls,fits into the aesthetic.
- Provides protection, sealing and electrical insulation.

Rubber Gasket
Seals off the inside of the transmission box.



Bearings
All bearings are angular contact rolling element bearings, press fitted into the polyester housing.

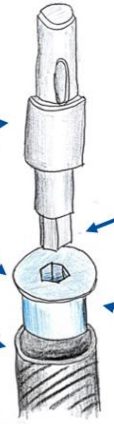
Casing Design Sketch
Colours for illustrative purposes only

Electronics
Battery and electronics systems mounted in this space, between ribs.

Stainless steel input shaft (CNC machined) resistant to corrosion, high strength.

Stainless steel insert bonded with epoxy adhesive to carbon fibre shaft.

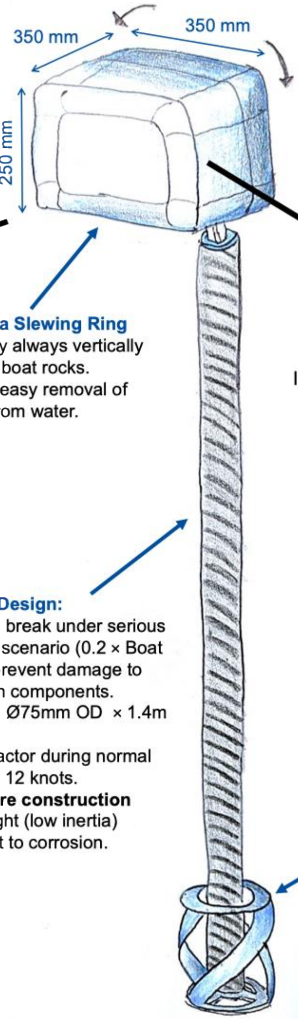
Shafts of different lengths can be purchased and swapped to account for different boat sizes.



Hexagonal sections interlock to transmit high torques.

Pin through assembly to secure vertically- not used for torque transmission.

Torque Transmission Coupling

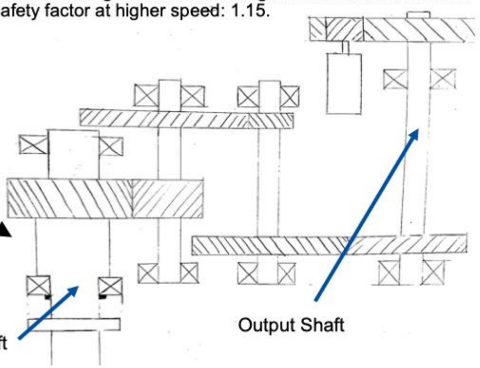


Mounted via Slewing Ring
- Assembly always vertically down as boat rocks.
- Enables easy removal of turbine from water.

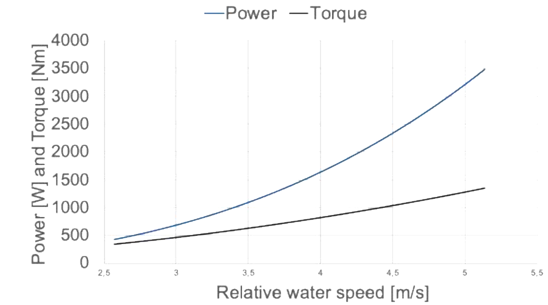
Lower Shaft Design:
- Designed to break under serious rock impact scenario (0.2 × Boat Weight) to prevent damage to transmission components.
- Ø 55mm ID, Ø75mm OD × 1.4m length.
- 8.3 Safety factor during normal operation at 12 knots.
- **Carbon Fibre construction**
  - Low weight (low inertia)
  - Resistant to corrosion.

Assembly drawing
Colours for illustrative purposes only

Layout of Transmission
- Detailed arrangement of the 4 stage reduction transmission.
- Safety factor at higher speed: 1.15.



Graph of Turbine Power & Torque vs water speed:
Variation of the power and torque produced by the turbine over the range of operating speed specified (5-10 knots).



Darrieus Helix Turbine Design:
- Hydrofoil fins at 40° azimuthal angle minimises the initial torque required to start rotation.
- Ø 0.2m × 0.2m height to minimise cross sectional area and increase ease of handling when removing from water or cleaning.
- **Fibre glass construction**
  - Easily moulded to create complex shapes.
  - Inexpensive relative to other composites or polymers; cheap to replace if damaged or lost when lower shaft snaps.
  - Resistant to corrosion.

My Roles:

Mechanical design

Engineering Analysis

Reporting

Result: A-

Gravity light

Second year design project – Autumn

Teammates: Ore Pelumi, Ashay Dhingra, Diego Sanchez Loarte, Suheyb Adam

Problem:

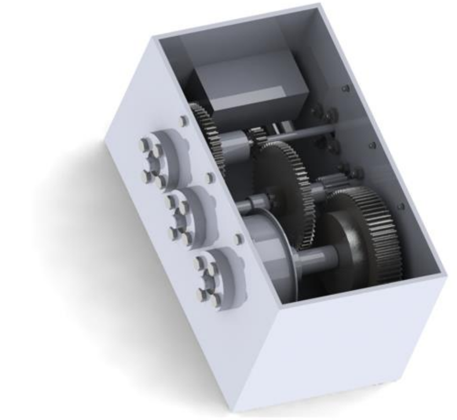
"Design, build, and test a so-called gravity-light: a reading light powered by a suspended mass that is slowly lowered, for use in locations where access to mains power and/or batteries is limited."

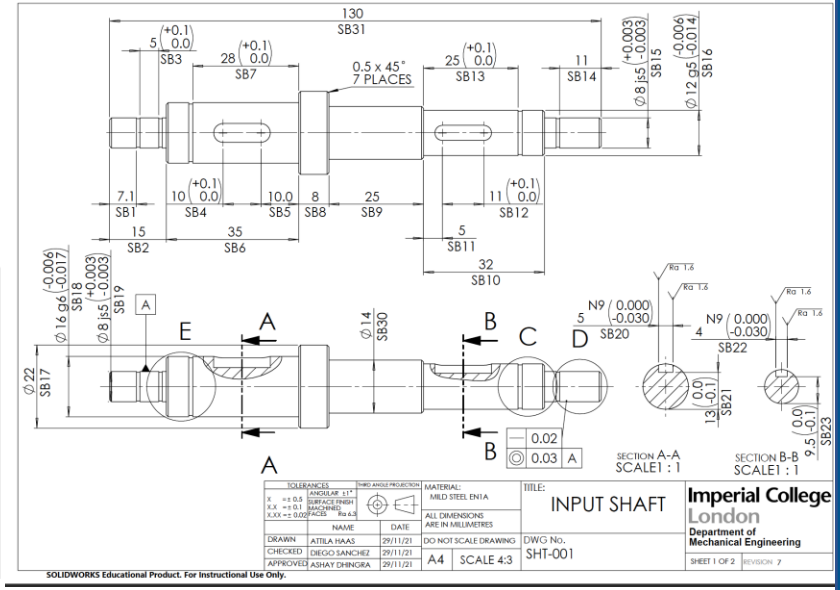
- Group 3-month project

Solution:

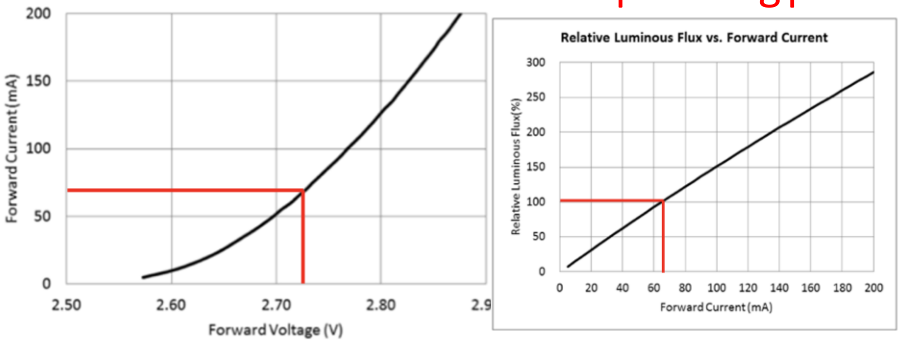
Sheet metal box houses the generator, transmission and pulley to release potential energy at an optimal pace:

- Provides about 6 minutes of light
- Simplistic design allows for cheap manufacturing methods
- A prototype has been built in the workshop





LED and Generator operating point



My Roles:

Project Management

Mechanical design

Engineering Analysis

Reporting

Brick Hoist

First year design project

Problem:

“Given a support structure and motor, design an actuation method and transmission to raise 50 bricks between single floors of a house!”

- Individual, 3-month project

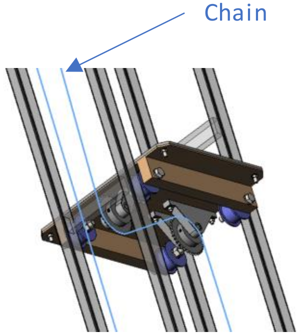
Solution:

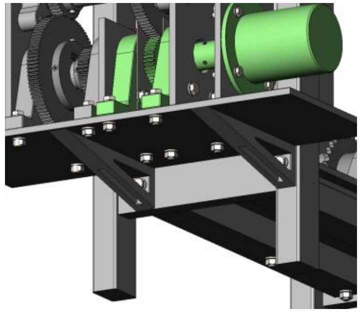
H-bridge inspired chain drive drives the platform

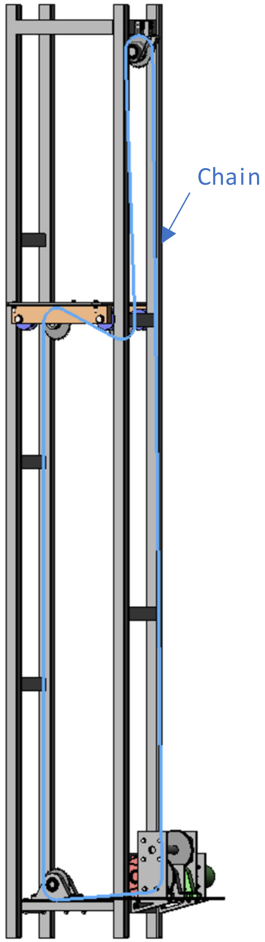
- Leaves the packing area open, and allows for fully lowering

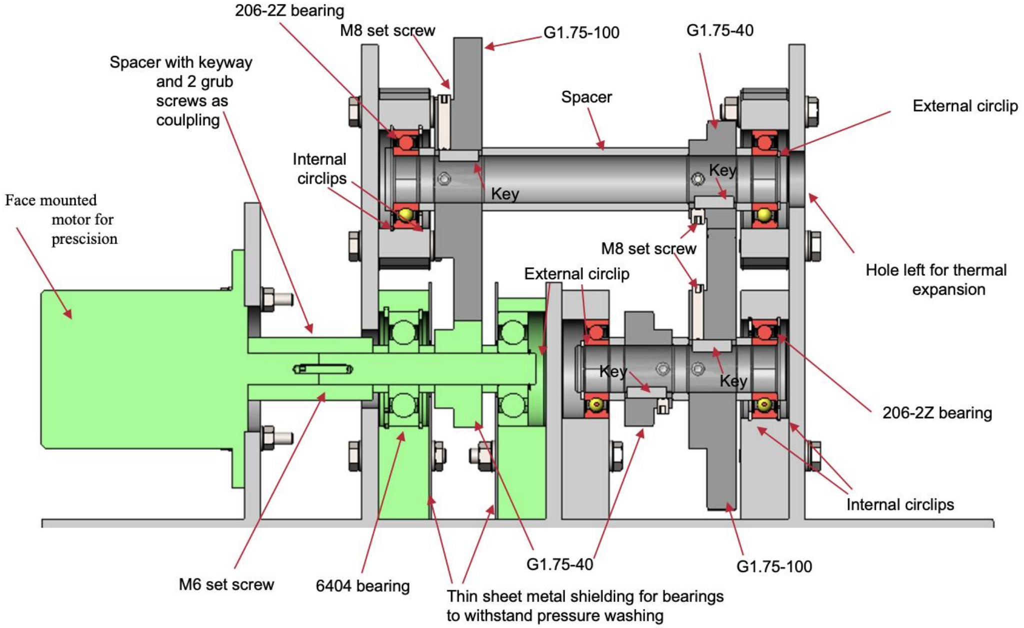
Triple reduction gearbox provides the coupling between motor and the chain

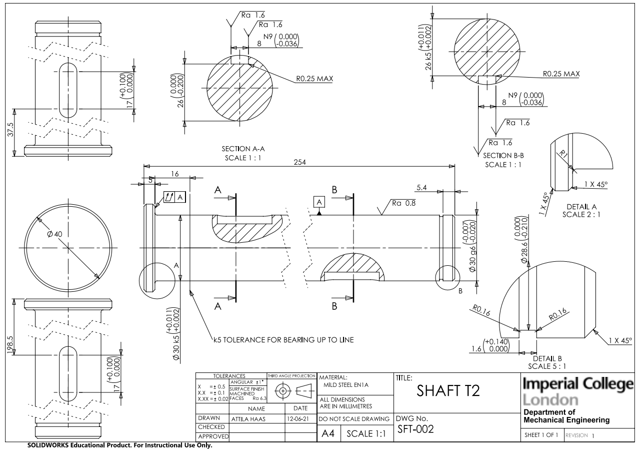
- Compact, cheap design, easy to maintain











My Roles:

- Mechanical design
- Engineering Analysis
- Presenting