Engineering: You're Hired Project Submission Form

Please use this template for your submission, outlining your design and your plan for a project to take it to proof of concept stage.

Hub: Z

Group: 4

__Technical Design__

1) Aim, Impact & Commercial Implications

This section should state what your proposal aims to develop, the impact this will have on key stakeholders (e.g. the company, customers and society at large), what the route for commercialisation of your proposal is and what the competing technologies are.

The main aim is to reduce the risk of people in hazardous environments when measuring pipeline conditions. This would be done by introducing a consistent automatic system that will reduce the overall cost and improve efficiency in safety inspections of plants. We focused more towards the inspection of underwater pipeline conditions due to the lack of current AUV's that can maneuver with a battery life long enough for it to return on it's own, which brings about a need to research more into. This should remove or drastically reduce the amount of people that are required to carry out these inspections, in addition to reducing time taken for these inspections. Currently there are land based semi-automatic robots for scanning through the use of ultrasound on pipes which require human interaction, and there are also two companies that specialise in underwater AUV's that are Technip and Subsea 7.

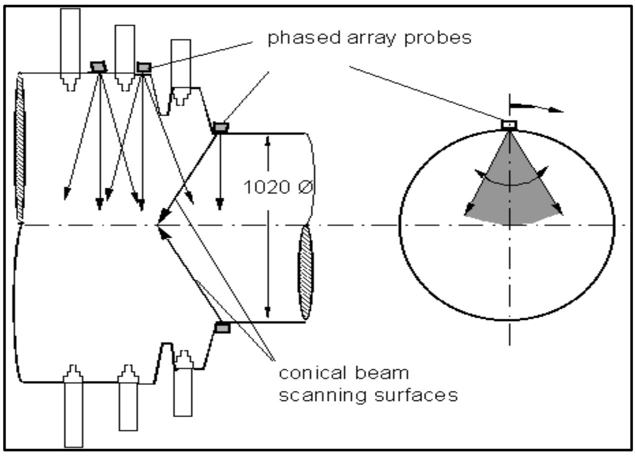
2) Outline description of ideas considered and justification of the proposal

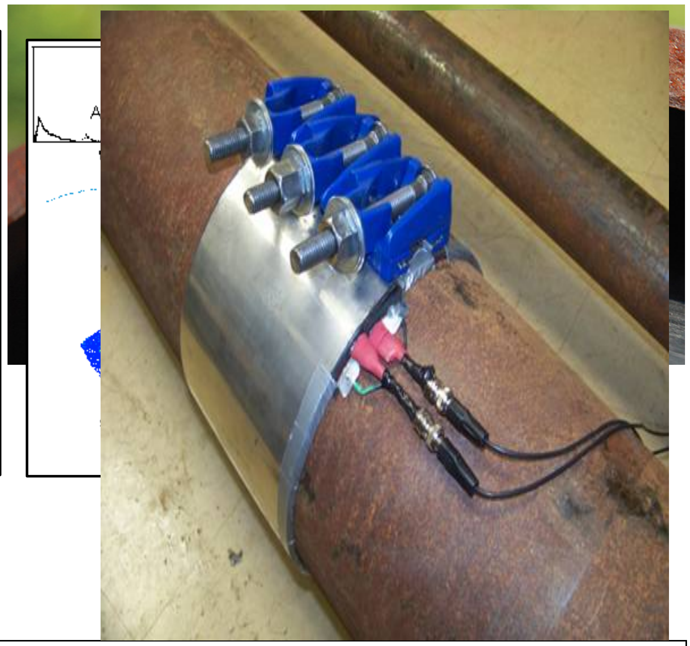
Describe the outline ideas that you generated and your reasons for selecting your proposal.

1) __Remote- Controlled Robot__

- Semi-autonomous so required to be controlled by trained personnel. Adapted from micro-magnetic cased pipeline inspection robot (ULC Robotics).
- Idea: To inspect inner and outer pipeline conditions without putting someone at risk and accessible in hard to reach places.
- Able to:
    - Measure integrity of pipeline coating including delamination, holes and other defects.
    - Alter outer shell models for different harsh environments including deep underwater, underground, high temperature pipelines, high levels of radiation.
    - Scale pipe walls with magnetic technology with pitch and roll sensors allowing for remote navigation and provide the precise location of defects and anomalies.
    - Monitor temperature and humidity pipe environment with sensors.

Disadvantages:





- o Requires total shutdown of pipelines if inner annular inspections are performed, increasing downtime and losing production.
- o Require multiple trained personnel and robots to cover elongated pipe network.

Figure 1 : Micro-magnetic Pipeline Inspection Robot

2) <u>Amplified Phase Array Equipment</u>

- Position independent beam sweeping approach. Adapted from using special software package to present results as an echotomography. Triggered by a pulse repetition rate frequency low enough to suppress interferences by late returning echoes determines inner pipe conditions and its location.
- Typically an angular increment of 2° and a rotating speed of 0.5 to 1 rpm must be used. By the storage procedure the A-scan data are linked to the actual probe position.
- Disadvantages :
  - o Requires multiple probes to scan and compare multiple location
  - Requires large amount of power and high costs

Figure 2 : In-service inspection of pipe using phased array probes (Left)

Results from an A-scan. 2 single inclusions can clearly be separated via A-scan and echotomogram (Right)

3) <u>System of Collaborated Sensors</u>

- AI monitoring equipped with temperature, pressure, voltage, pH and flow rate sensors
- Installed at regular intervals throughout pipe network to monitor conditions and transmits collected data to a CPU to be calibrated.
- Able to detect corrosion and disintegration level based on loss of flow rate over time as an early indication.

- Disadvantages :
    - Requires a combination of different types of sensors placed at regular distance intervals
    - Cost of maintenance is high as some sensors cannot withstand certain conditions

Figure 3: Example of a PVDF sensor measuring pipe wall cross from reduction in cross sectional area

4) Combination of Time-of-Flight Diffraction (TOFD) + Map scan

- Using longitudinal waves with ultrasonic sensors placed on each side of pipe section.
- Uses time of arrival of signals received from crack tips for accurate defect positioning and sizing map scan for geographical movements
- Quick to set up and perform an inspection, as a single beam offers a large area of coverage
- Rapid scanning with imaging and full data recording
- Can also be used for corrosion inspections
- Required equipment is more economical than phased array, due to conventional nature (single pulser and receiver) and use of conventional probes.

Figure 4 : OmniScan model used for TOFD inspections. (OLYMPUS CORPORATION)

3) The chosen design

Including:

a) Detailed design; Provide design specifications justifying the choices you have made. Demonstrate where possible that your idea is feasible with outline calculations. This could include materials selection, limitation of the design, health and safety issues. You should also indicate how the design choices of different disciplines have been integrated.

b) Design development; Indicate any design aspects that will require further development. This should form the basis of your project management plan.

Place your text here (maximum of 800 words and 12 figures)

The finalised design for the Pipeline Inspection Submersible Sentry (P.I.S.S.) is presented in figure 5. Figure 6 illustrates the layout of the electrical equipment inside the device.

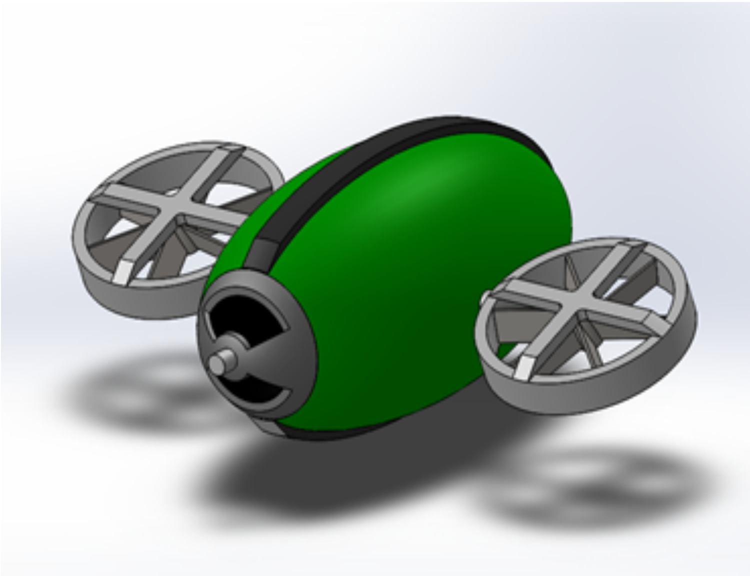


Figure 5 : Illustration of the final design in CAD

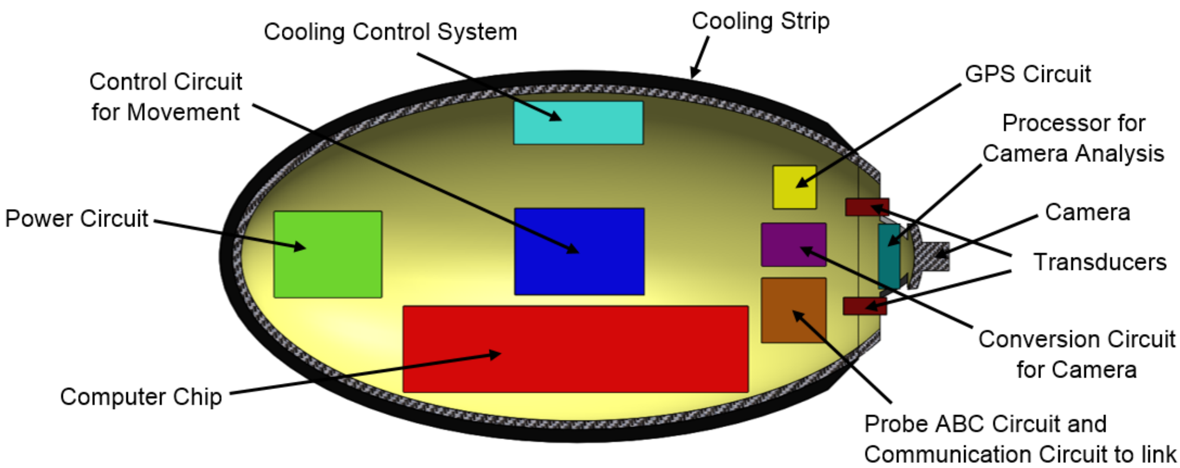


Figure 6 : Illustrates the layout of the electrical equipment inside the Pipeline Inspection Submersible Sentry (P.I.S.S.)

Separately controlled twin propellers give P.I.S.S. excellent maneuverability in the water.

The main body of the robot is an ellipsoid as this shape has a very low drag coefficient because it prevents flow separation. This minimises drag losses making P.I.S.S. very efficient and improving battery life. The body is 800mm long and has a maximum diameter of 400mm this gives a frontal area of 0.126 square metres. Calculations show that at the intended scanning speed of 1 meter per second the flow over the body in sea water is turbulent so the drag coefficient is 0.13. Drag on the body at this speed was calculated to be just 8.2N.

$$\square = 0.5 * \square * \square^2 * \square * \square_{\square} = 0.5 * 1000 * 1^2 * 0.126 * 0.13 = 8.19\square$$

The black strip over the body is the cooling strip. It uses the concept of having a temperature gradient between the heating electrical components and outer seawater running continuously in a channel through it.

Recommended Materials

i) Body Core and Propellers

We recommended to use **Carbon Fibre Reinforced Plastic** where carbon fibre is woven into an elliptical shape and resin is applied and allowed to cure.

Advantages :

- Chemically inert and corrosion resistant
- High Tensile Strength of 200 GPa, so not susceptible to high differences in pressure underwater
- Low coefficient of thermal expansion thus material would not expand or contract much with varying temperatures due to conditions
- Relatively low density of 1600 kg/m^3 compared to that of steel which is 8050 kg/m^3 thus being light and not contributing to overall drag.
- Maximum temperature up to 300 degree Celcius.

However, carbon fibre is electrically conductive making it dangerous underwater in addition with contact with the electrical components in the core. Therefore, to counter this, we would need to apply a very thin insulating layer between the outer core and the inner core where the electrical components are. This can easily be epoxy resin which was to be originally applied to the carbon fibre to polymerise it and molded into shape.

ii) Cooling Unit Strip

The material recommended is **Stainless steel**. Justifications for choosing this material are as followed:

- High Cryogenic resistance and Hot Strength thus able to withstand low temperatures of seawater as well as high temperatures due to excessive heating from electrical components and batteries.
- Good heat conductivity helps the strip act as a heat exchanger by absorbing heat from the electrical components through a seawater medium inside flowing in and out of the core.
- Very low corrosion rate of 0.005 compared to carbon steel of 9.5 (Abuqir, 2008)
- Although being a heavy material in general, the product would only require a small thin strip across the body core to allow the passage of water coolant and therefore would not contribute too much to the weight
- Being expensive, it would have a high initial cost but would require extremely little to no maintenance due to its high durability to withstand corrosion due to high water velocities.

Project Management

1) Project planning and cost

Indicate the planned duration of your project, the principal activities and resources (people, equipment and materials) required for the design and development of your proposal up to prototype. Include an estimate of the costs of the personnel and a Gantt chart showing the principal activities.

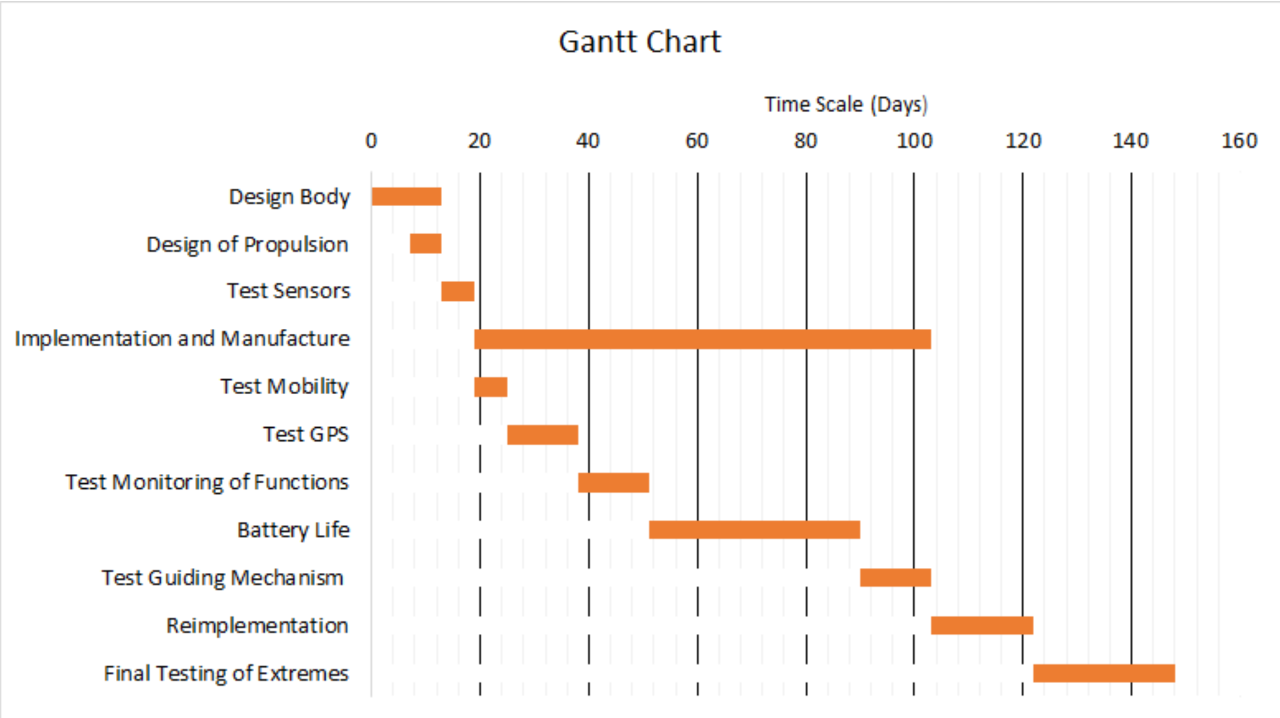


Chart 1 : Gantt Chart for the proposed design and development of the Pipeline Inspection Submersible Sentry (P.I.S.S.)

Duration: Project would take approximately 4 months (122 days).

Material: carbon fiber w/ polymer reinforced plastic : $22 USD per kilogram (2013 source)

Equipment: Advanced Camera, GPS Receivers, Transducers

Software: Robotics Software (Mapper3, Mobile Eyes)

Human Resources: 2 senior engineers (due to the specific nature and requirements of the proposed model), 1 manager, 1 accountant, 2 junior technicians, 2 experienced software engineer.

Personnel Cost: 348K per annum

Technical Cost: 130K (estimated number for buying third part components and building/coding the submersible)

Additional Cost: 50K

End of line Production cost estimate: 3k per robotic submersible

Total Cost: 326K(Actual cost for finished in 4 months)

2) Project risk management

Identify what could go wrong with the PLAN of your project (commercially, technically, timescale etc) and how you will mitigate these risks.

Power Efficiency: Digital Control Loop, better components, innovative packaging, soft-switching techniques, optimise thermal management.

Battery Life cycle Supply: Breakdown/failure of battery, backup batteries, charging times, unintentional discharges, reverse currents and circuit faults/general protection.

Circuit/Mechanic interactions: Flux overlap, magnetic interference, temperature interference, noise interference, cross-talk, friction and damage from environment

Incorrect identified and analysed collected data(images): Improve software testing process, increase algorithms and classifiers to identify images.

Unavoidable design flaws

3) Patent Implications

Identify any areas of your proposal that you feel may be commercially sensitive or may require protection, and any areas where you reply on already protected technology.

From our research it appears that no underwater drone currently on the market is laid out in the same way as P.I.S.S. Our innovative low drag ellipsoid shaped body may require patent protection to prevent other companies from copying our design. Otherwise there isn't much else that can be patented as we use a lot of existing technology deployed in a new way.

We will need to seek permission to use the patents on some of the sensor equipment we have used.