PES UNIVERSITY
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100-ft Ring Road, Bengaluru – 560 085, Karnataka, India

Summer Internship Report

on

‘Development of Data Acquisition System for Thrust Bench’

Submitted by

Siddharth D Srinivas (PES1UG21EC283)

June - July 2023

Carried under the guidance of

Prof. Suresh Sundaram,

Associate Professor, Department of Aerospace Engg.,

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CERTIFICATE

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Date: 3rd August 2023

Certificate

To whomever it may concern

This is to confirm that the student Mr. Siddharth D Srinivas, bearing SRN PES1UG21EC283 of IV Semester ECE of PES University underwent a summer internship project titled "Development of Data Acquisition System for Thrust Bench" in the Department of Aerospace Engineering located at Indian Institute of Science, Bangalore for a duration of two months from 01 June 2023 till 31 July 2023.

We wish him all the very best for his future endeavours.

Suresh Sundaram

Prof. Suresh Sundaram
Associate Professor
Department of Aerospace Engineering
Indian Institute of Science, B'lore - 12.

DECLARATION

I, (*Siddharth D Srinivas*), hereby declare that the work entitled, ***'Development of Data Acquisition System for Thrust Bench',*** was carried out under the guidance of Prof. Suresh Sundaram, Associate Professor, Department of Aerospace Engg., Indian Institute of Science, Blore – 12**.** This report is being submitted in partial fulfillment of the requirements for completion of 8^{th} Semester course work in the Program of Study, B.Tech in Electronics and Communication Engineering.

PLACE: Bengaluru
DATE: 09-08-2023

NAME AND SIGNATURE OF THE CANDIDATE
Siddharth D Srinivas

ABSTRACT

This project was a successful attempt at developing an indigenous version of the popular Thrust Bench and Data Acquisition Software for drones, a necessity in every drone lab and the ideal tool for optimizing the performances of drones, robots and radio-controlled vehicles. It was assigned to a 2-member team which included me.

Our goal was to build a modularised Thrust Bench which could replace the existing Series 1585 Thrust Stand by Tyto Robotics, Canada, the value addition was its ability to switch between multiple required torque and thrust measuring capacities instead of having to buy a new product every time there was a requirement for different specifications.

The thrust stand for drone propulsion systems measures the thrust, torque and motor RPM with a measurement rate of up to 50 Hz. It is specifically developed to allow drone designers to improve the efficiency of their propulsion systems. The test stand connects to your computer via USB. The DAQ software with the developed UI and backend compatible with any Arduino microcontroller provides sensor calibration instructions and status, controls the ESC manually or automatically with custom scripts as well as performs automated tests including step and ramp tests. It displays logged motor and propeller data in real-time and exports to .CSV file once completed. Many visual graphs are provided for the interpretation of system efficiency and power consumption results. For a smooth transition from the existing RCbenchmark Data-Acquisition Software of Tyto Robotics made for their PCB to our software, we mimicked the UI exactly along with adding more beneficial features.

ACKNOWLEDGEMENTS

I would like to express my profound gratitude to Prof. Suresh Sundaram, Associate Professor, Department of Aerospace Engg., Indian Institute of Science, Blore – 12, for his guidance for my project titled 'Development of Data Acquisition System for Thrust Bench'.

I would like to express my special thanks to the project staff, Mr. Mohammed Naveed Shaikh for the time and efforts he provided throughout the internship. His useful advice and suggestions were helpful during the project's completion.

I would like to thank Dr. Anuradha M, Chairperson, Dept of ECE, PES University, for encouraging me and giving me this opportunity to take up a summer internship which provided knowledge and practical research experience.

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BRIEF WRITEUP OF THE WORK

The first week consisted of the selection and ordering of the appropriate electrical components including sensors, microcontroller and power supply, and the presentation of the project plan to our guide.

Table 1: Bill of Materials

Sl No	Category	Item	Vendors	Cost per item (₹)	Quantity	Total (₹)	Part Links
1	Load cell	SEN-14729 Miniature Load Cell - 5 kg (Parallelogram Bending beam type)	Digikey	1086.86	6	6521.16	https://www.digikey.in/en/products/detail/sparkfun-electronics/SEN-14729/9555603
		SEN-14729 Miniature Load Cell - 2 kg (Parallelogram Bending beam type)	Digikey	1086.86	4	4347.44	https://www.digikey.in/en/products/detail/sparkfun-electronics/SEN-14729/9555603
		SEN-14729 Miniature Load Cell - 10 kg (Parallelogram Bending beam type)	Digikey	1086.86	2	2173.72	https://www.digikey.in/en/products/detail/sparkfun-electronics/SEN-14729/9555603
		SEN-14729 Miniature Load Cell - 20 kg (Parallelogram Bending beam type)	Digikey	1086.86	2	2173.72	https://www.digikey.in/en/products/detail/sparkfun-electronics/SEN-14729/9555603

2	Load Cell Amplifier HX711	SEN-13879	Digikey	907.10	6	5442.60	https://www.digikey.in/en/products/detail/sparkfun-electronics/SEN-13879/6202732
3	Hall Effect RPM Sensor	A3144 Hall Effect Sensor Module	Robu	39.00	2	78.00	https://robu.in/product/hall-magnetic-sensor-module/
4	Reflective Tapes		Amazon	150.00	3	450.00	https://www.amazon.in/dp/B0C5VMMDSR/ref=sspa_dk_detail_1?ie=UTF8&psc=1&pd_rd_i=&pd_rd_i=B0C5VMMDSRp13NParams&sp_csd=d2lkZ2V0TmFtZT1zcF9kZXRhaWxfdGhlbWF0aWM
5	Arduino Microcontroller	Arduino Mega	Robu	3,299.00	2	6598.00	hhttps://robu.in/product/original-arduino-mega-2560-atmega2560-mcu-rev3/
6	PCB Prototype Board	4 x 6 cm Universal PCB Prototype Board Double-Side - 2pcs	Robu	40.00	2	80.00	https://robu.in/product/46-cm-universal-pcb-prototype-board-double-sided/

7	Ammeter - Hall Sensor	WCS1700 Hall Current Sensor	Digikey	725.00	2	1450.00	https://robu.in/product/wcs1700-hall-current-sensor-with-over-current-protection/?gclid=Cj0KCQjwtamlBhD3ARIsAARoaEy_-T2Zl_6zt_0ixB05F0_py1oPJN6jVJ61rcu0cR83EAGk2c4H0JEaAn8xEALw_wcB
8	Jumper Wires	M/M, M/F	Digikey	173.96	4	695.84	https://www.digikey.in/en/products/detail/sparkfun-electronics/PRT-12795/5993860?s=N4IgTCBcDaIAoCUAqBaAjGA7ATgKwgF0BfIA
9	Male Headers Pack-Break-Away		Digikey	54.67	2	109.34	https://www.digikey.in/en/products/detail/sullins-connector-solutions/PRPC040SAAN-RC/2775214?s=N4IgTCBcDaIAoCU4GEAMAWVBlAgjgcgLQLIgC6AvkA
10	Solderless Breadb	GS-830	Digikey	766.27	2	1532.54	https://www.digikey.in/en/products/d

	oard						etail/global-specialties/GS-830/5231309
11	Temperature Sensors	DS18B20 Temperature Sensor with Arduino	Robu	94	8	752	https://robu.in/product/ds18b20-temperature-sensor-module/ https://robu.in/product/ds18b20-waterproof-temperature-sensor-for-sonoff-th10a-th16a/
12	Benchtop supply	FSP1200-50ADB	Digikey	23857.92	1	23857.92	https://www.digikey.in/en/products/detail/fsp-technology-inc/FSP1200-50ADB/16164267?s=N4IgTCBcDaIEYFMB2BjAFgFwPYAcAEAzgK444A2AnngIxgAMdeA6iALoC%2BQA

Then, a modular flowchart was prepared and the circuit with the fundamental components was designed and simulated.

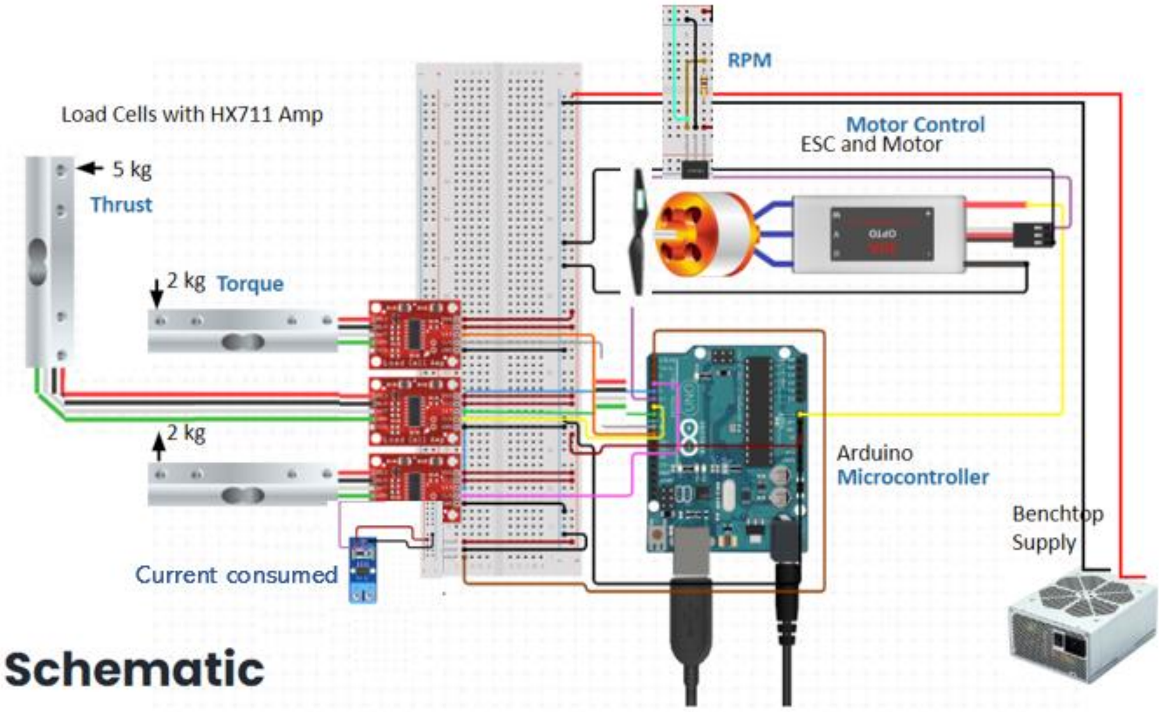

Figure 1: Circuit Schematic

Figure 2: Hardware setup at the start of internship – 3 load cells and stand

Once the components were sought, we made a prototype circuit board for the sensors, microcontroller and pin connections.

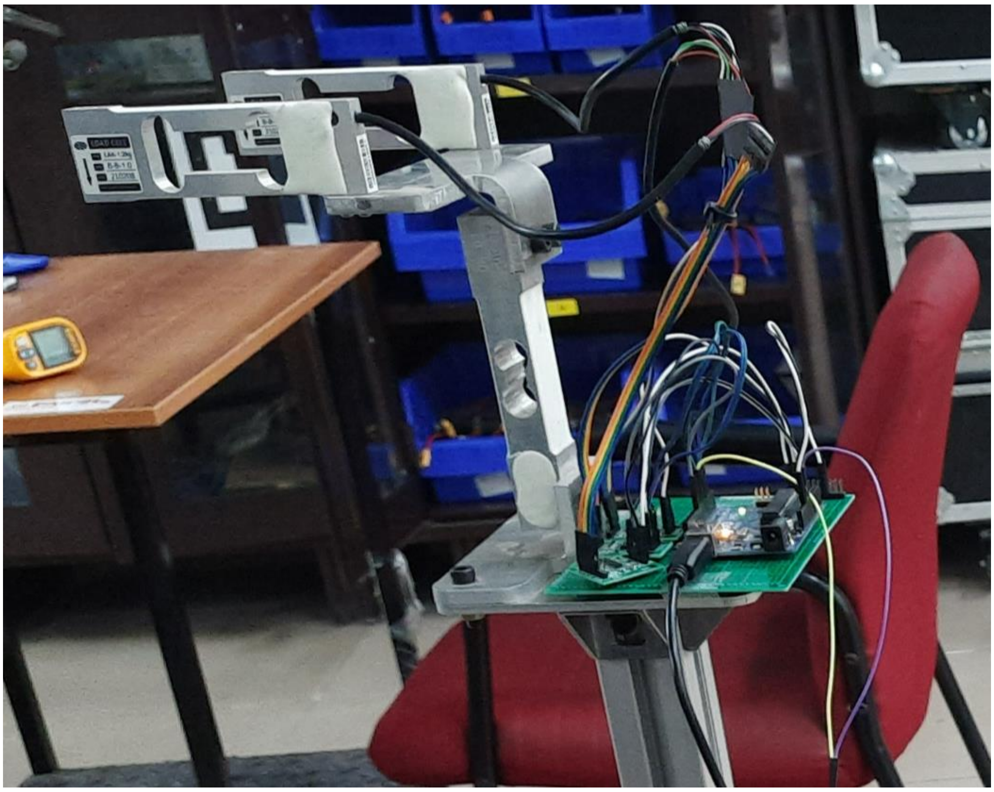

Figure 3: Prototype circuit board with sensors, load cell amplifiers and microcontroller board

To measure motor and propeller torque, two load cells were oriented horizontally at a known distance, fixed on one end, to sense the vertical forces applied to the other ends. In tandem, to measure thrust exerted by the motor and propeller, a single load cell was mounted vertically and fixed at the bottom end to measure the horizontal force of the setup.

For the purpose of gauging RPM, our approach involved incorporating a hall sensor that detects the presence of magnetic field of the poles in the motor. By utilizing interrupts and dividing them to account for number of poles, we monitored pulse counts to continuously update and log the averaged RPM values. We also alternatively employed an optical tachometer with reflective tape adhered to the motor.

For measuring current, we passed the cable connecting ESC and power supply through a Hall effect sensor. The current to be measured flows through a conductor that is inside a magnetic core. In this way, the current creates a magnetic field inside the core. This field is measured by a Hall effect sensor placed in the core air gap.
For power and efficiency analysis, we made use of the following formulae:

- Mechanical power (Watts) = Torque (Nm) * Speed (rad/s)
- Electrical power (Watts) = Voltage (V) * Current (A)
- Motor Efficiency = Mechanical power / Electrical power
- Propeller efficiency (g/Watts) = Thrust (g) / Mechanical power (Watts)
- System efficiency (g/Watts) = Propeller efficiency (g/Watts) * Motor Efficiency

After this, began the development of software. This included the preparation of a user interface for ease of use by the lab staff and the backend of the data acquisition system for effective functionality as well as the speed control of ESC of motor and propeller. We achieved accurate logging and display of sensor measurements graphically in real time.

Each piece of code was tested with the corresponding sensor to make sure that the code would work in a modular way. Then it was integrated with the UI to achieve the same functionality. For smooth transition from the existing RCbenchmark Data-Acquisition Software of Tyto Robotics to ours, our next step was to fine-tune our software to mimic it exactly. Many new elements of VBA programming language were learnt and implemented for the best performance of the UI.

Figure 5: Developed Welcome page

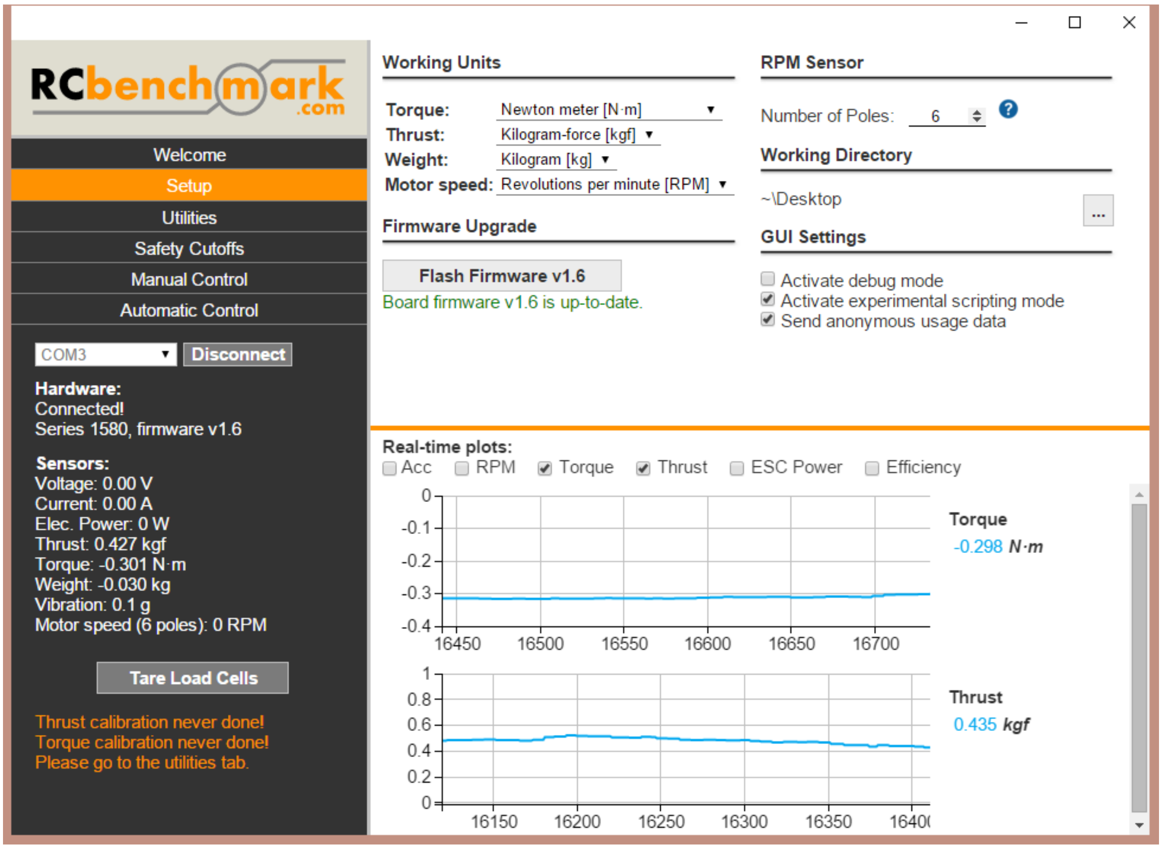

Figure 4: RCBenchmark Setup page

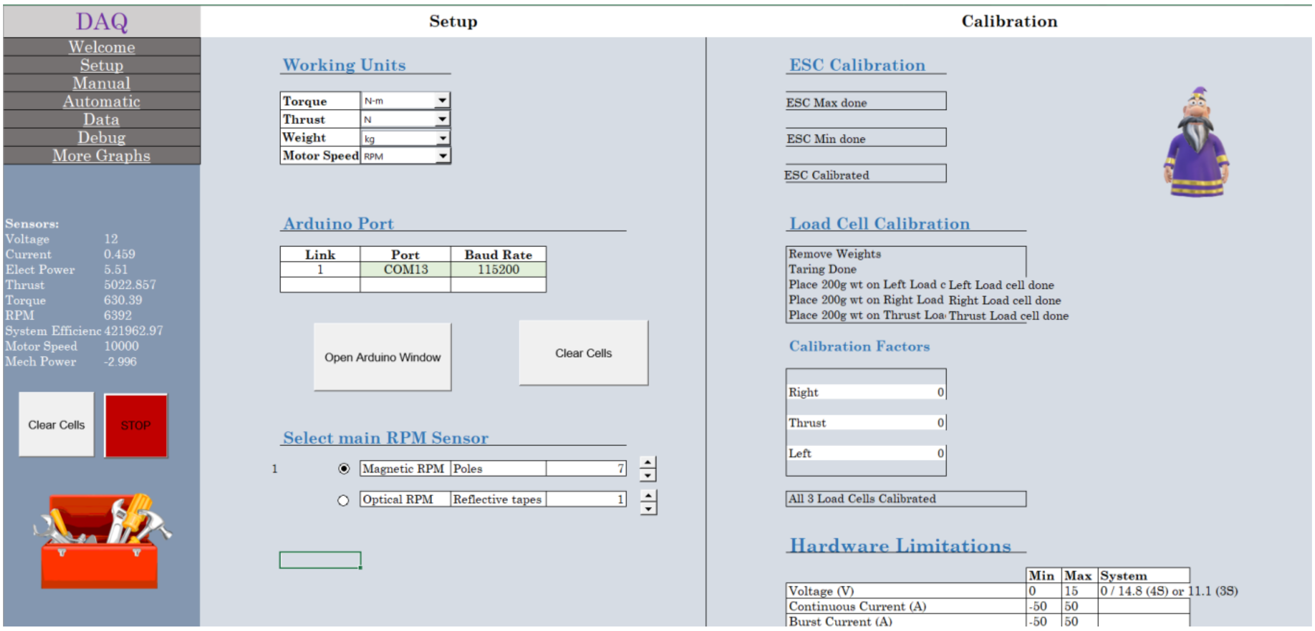

Figure 6: Developed Setup and Calibration page with multiple options for working units, selection of main RPM sensor display of calibration status in real time and set up of safety cutoffs for the connected devices.

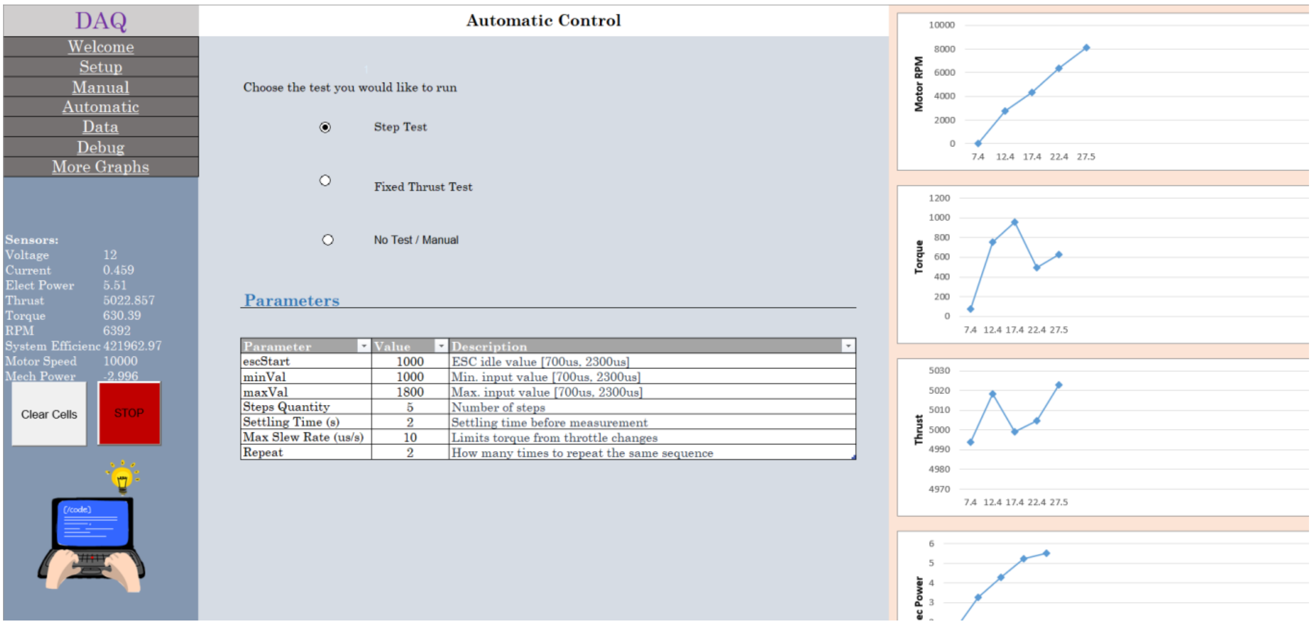

Figure 7: Developed Automatic page to run automated tests such as a simple step motor test and fixed thrust test on the motor.

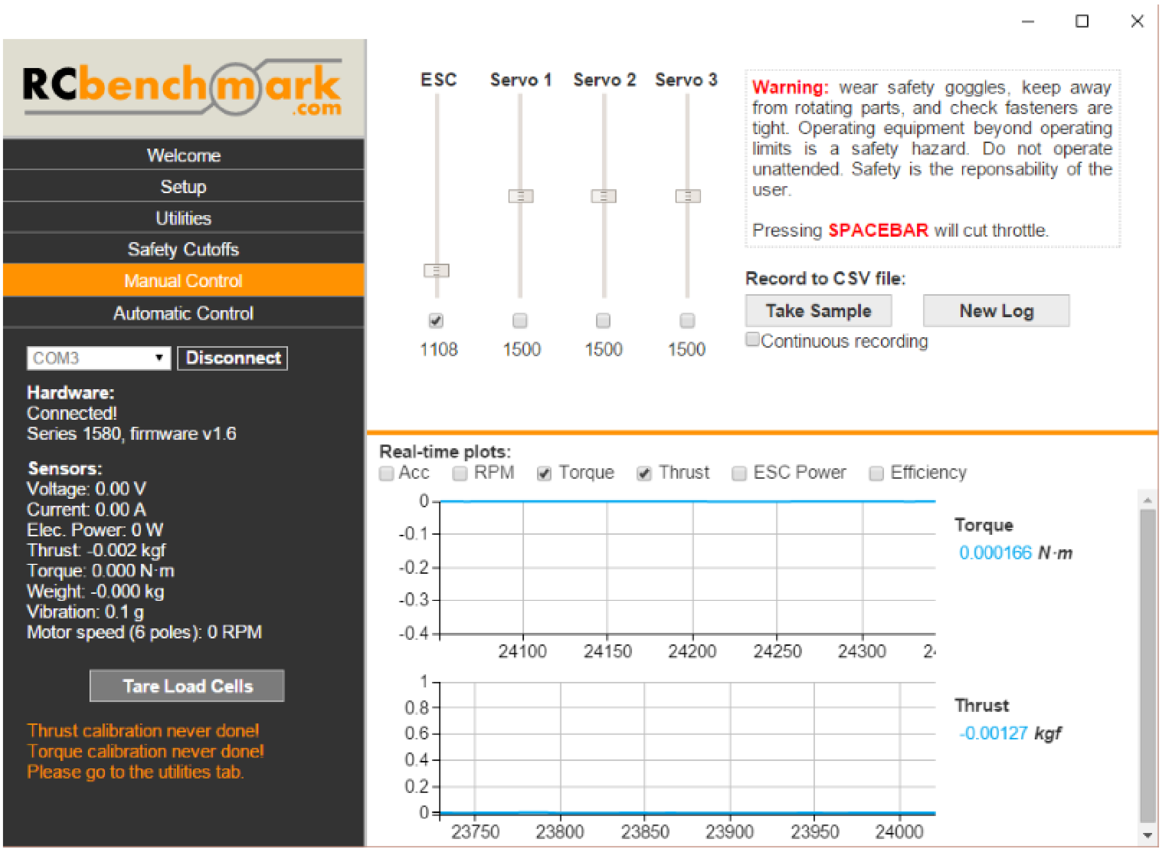

Figure 9: RCbenchmark Manual Control page (Existing software compatible only with its PCB)

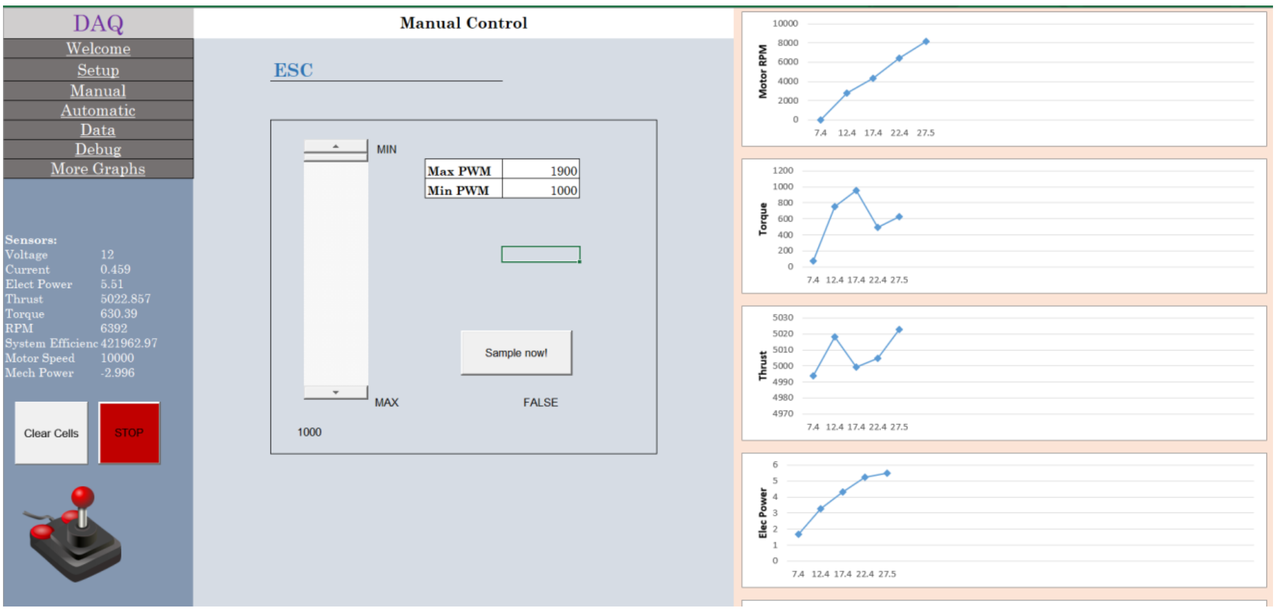

Figure 8: Developed Manual page with control of motor ESC, graphs, current data on the left and an emergency stop button on every page.

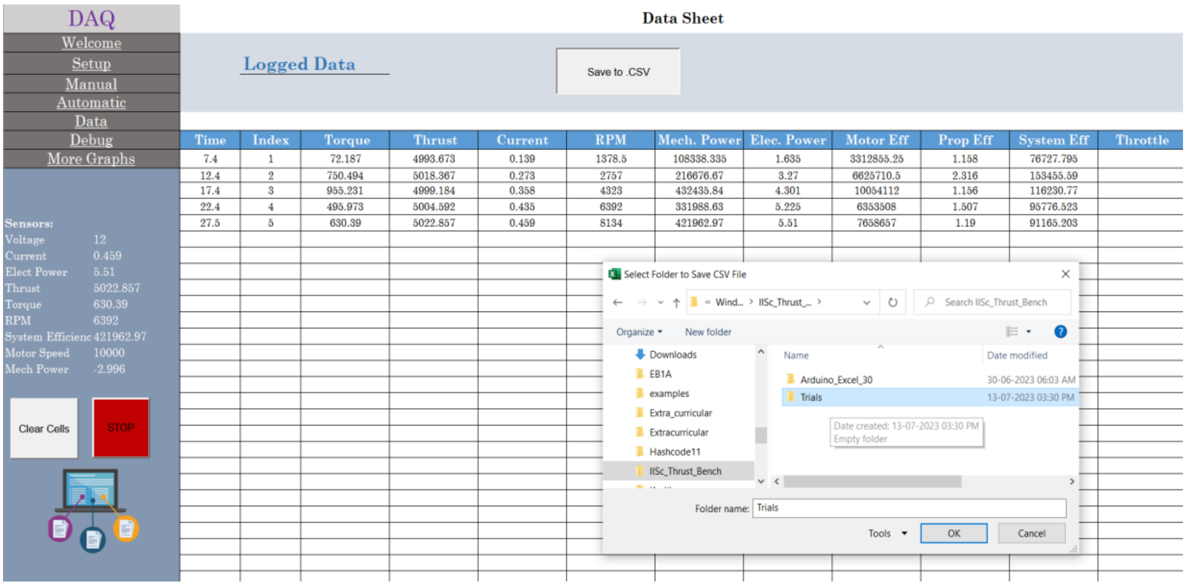

Figure 10: Developed Data page with logged data that can be saved as a .csv file.

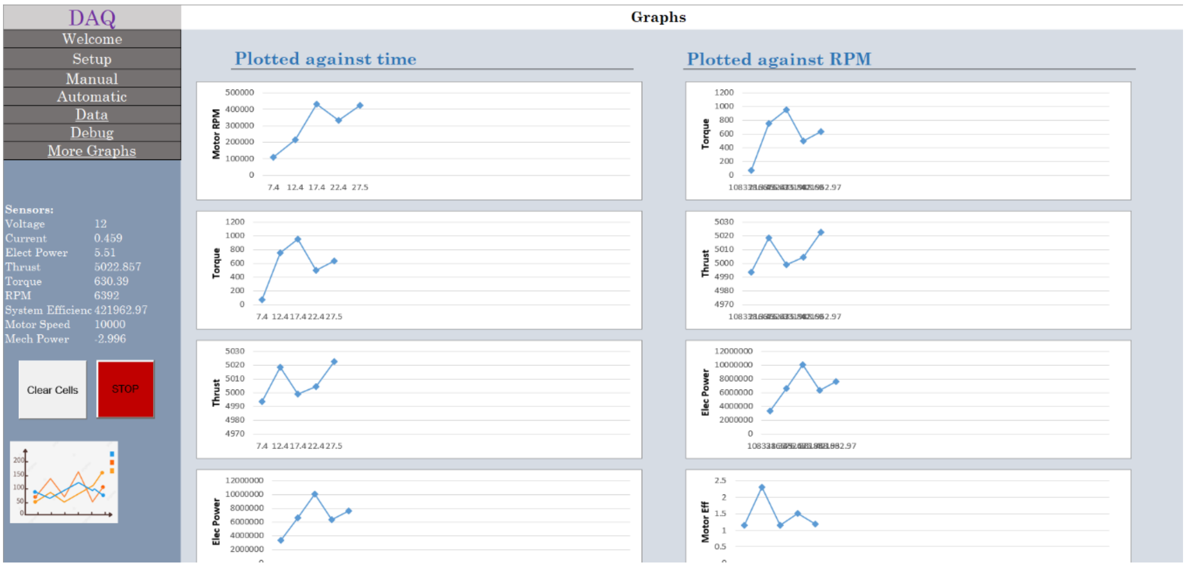

Figure 11: Developed Graphs page containing graphical visualisation of data.

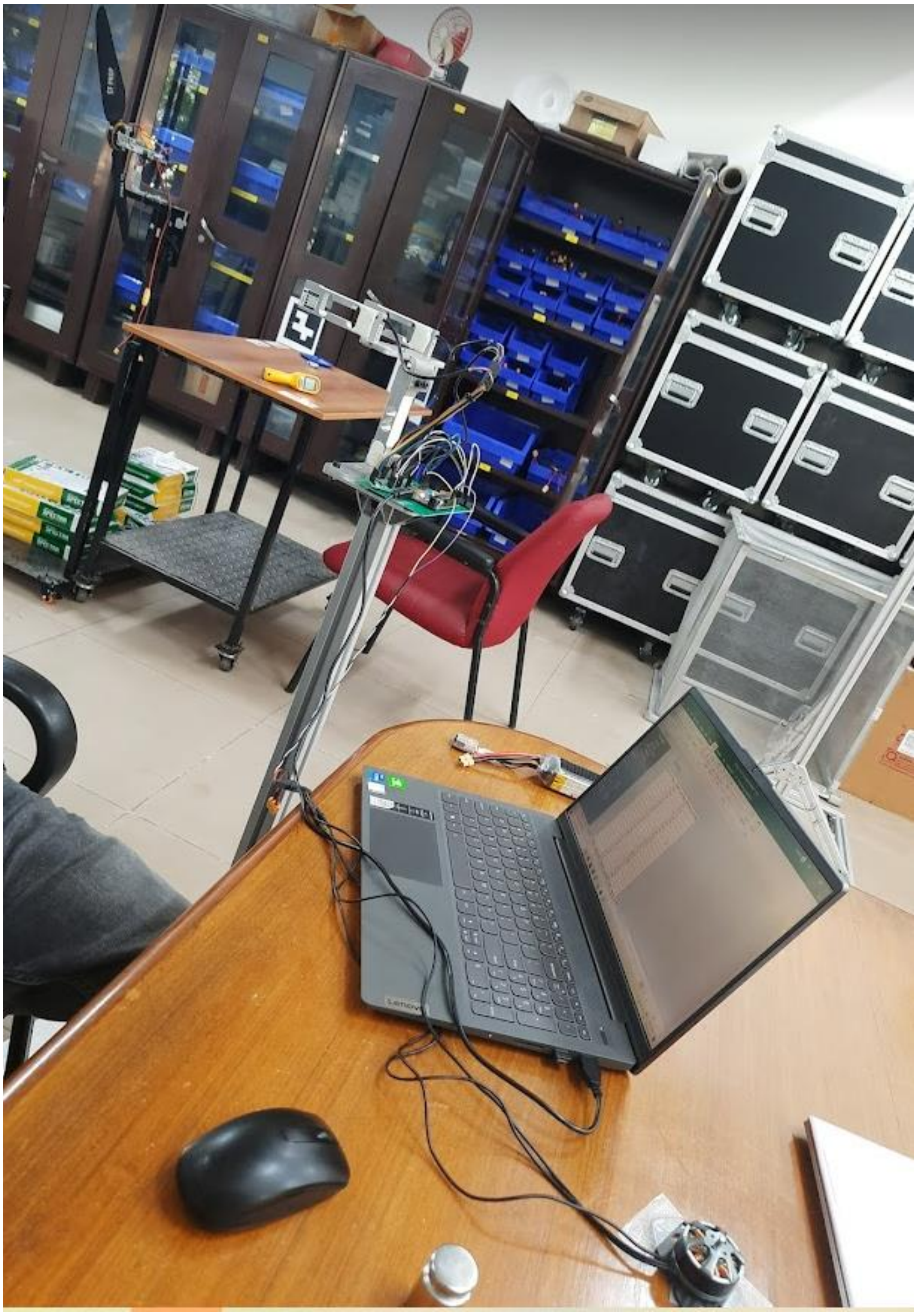

Figure 12: Fully functional indigenous Thrust Stand and Tyto Robotics Thrust Stand side by side

Figure 13: Successful trials after integration of our hardware and software even with the Tyto Robotics Thrust stand

CONCLUSION

The accomplishment of this project stands as an insightful learning experience of building an industry solution from scratch. Fundamentally, our project has achieved its objective of creating a homegrown substitute for the existing setup.

Our work is now at the disposal of the laboratory, enabling the selection and optimization of drone motors and propellers, along with conducting efficiency calculations, eliminating the limitations that the Tyto Thrust Stand and RC benchmark imposed.

Future Work:

- Conduction of Trials and Validation
- Integration of Temperature and Vibration sensors
- Implementation of more automated tests
- Utilisation of Windshapers
- Design of PCB to replace prototype

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6. https://www.tytorobotics.com/blogs/manuals-and-datasheets/rcbenchmark-software-overview
7. https://www.wingflyingtech.com/motor-test/Drone-Test-Equipment.html

Datasheets:

1. Arduino Mega Datasheet
2. HX711 Datasheet
3. Load Cell Datasheet
4. WCS1700 Datasheet
5. A3144 Datasheet

Publications:

G. Avanzini, A. D. Nisio, A. M. L. Lanzolla and D. Stigliano, "A test-bench for battery-motor-propeller assemblies designed for multirotor vehicles," 2020 IEEE 7th International Workshop on Metrology for AeroSpace (MetroAeroSpace), Pisa, Italy, 2020, pp. 600-605, doi: 10.1109/MetroAeroSpace48742.2020.9160320.

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