Technical Design Report for Bestagon

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Abstract— **With interdisciplinary cooperation between team members, the Kennesaw State University Autonomous Underwater Vehicle Team (KSU AUV) has designed and built a new AUV that is designed to be our most lightweight, cost-effective, and robust design yet for the 2026 RoboSub competition. Following the robust hexagon shape with interlocking parts, Bestagon will have a low drag and low buoyancy design. The motor configurations and new control systems allow for absolute control and flexibility. This vehicle utilizes a custom electrical and software architecture to allow for ease of modifications and control of movements within the water. This paper discusses the 2026 KSU AUV competition strategy and highlights the technical attributes of Bestagon.**

Keywords—autonomy, underwater, vision, machine learning

I. Competition Strategy

A. Preface

The KSU AUV team is a student led student organization sponsored by Kennesaw State University that competes yearly in the RoboSub competition. For the 2025-2026 competition season, the KSU AUV team has redesigned our AUV to improve on our faults from the Type X 2024-2025 design. The Bestagon is a robust and versatile platform developed during the 2026 season. Our team consists of three major sub-groups - mechanical, electrical, and software - which collaborate to design and integrate the necessary systems required to form a working autonomous architecture. The technical attributes of the Bestagon in Fig.1 are found in Sections II and III of this report, in addition to the hardware and software specifications provided in the appendices. The team has collaborated for design work, integration, and testing while meeting appropriate safety guidelines.

B. Competition Strategy

Post-RoboSub 2025, the team identified numerous potential improvements from the Type-X design shown in Fig. 1a. Notable examples would be the continued design to utilize 3D printed parts. Utilizing FDM printing reduces cost and weight of the AUV, while including a new design to interlock the parts of the AUV without the use of screws and bolts. Continuing to design the open-frame design for accessibility of the AUV components.

For the 2026 RoboSub competition, the team identified three primary challenges to pursue:

1. Buoyancy control of the AUV.
2. Modular in-house designs for the new electrical system.
3. Improved accuracy of autonomous control software.

To meet these objectives, the team sub-groups focused efforts on improving movement-critical and task identification systems from the 2025-2026 season and developing a new AUV from the ground up.

II. Design Creativity

A. Mechanical Design

1) Outer Structure and Component Housing

After the 2025 competition, the team has solved the greatest time-sink involved in interaction with the AUV, in which the team did not have quick and easy access to the electrical housing. The solution is to house the electrical components in an Apache 2800 case, providing easier access to the electrical components with a quick unlatch of the case. This year the team leadership identified several issues with the current submarine frame that required attention. Through in-depth discussions and proposals, it was decided that designing a new frame would be more efficient than adjusting the current frame. This would also allow the team to use the previous design as a backup submarine if needed. The main issues that required attention were difficulty in transporting the AUV, un-distributed buoyancy throughout the AUV due to high displacement of certain parts, and the amount of time and energy to flip the AUV over and undo ties to access the electrical housing.

To address the first design concern, the mechanical team made a new design in which handles are within the frame of the design. The design implements large shrouds which include areas to grab and transport the AUV from the sides in an easier manner, as well as a width which fits well into a venue supplied cart for easier transportation.

The second issue was caused by the size of the Apache case that makes up the electrical housing. The previous

Apache case was a Apache 3800 31.6in^3 case. To reduce the amount of air trapped in the case, the electrical housing is now housed in a 26.2in^3 Apache 2800 case. The 17% reduction in displacement dramatically reduces the amount of buoyancy that needs to be offset, reducing the dry weight of the sub.

The third issue was solved by continuing an open frame design, then placing the electrical housing on the top of the AUV with spacing for easier access to unlatch the case and a window at the top of the case for visuals of the electrical components without having to open the housing case.

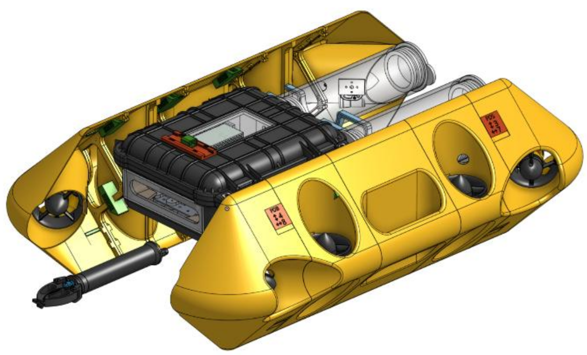

Figure 1. Bestagon 2026 Build Year

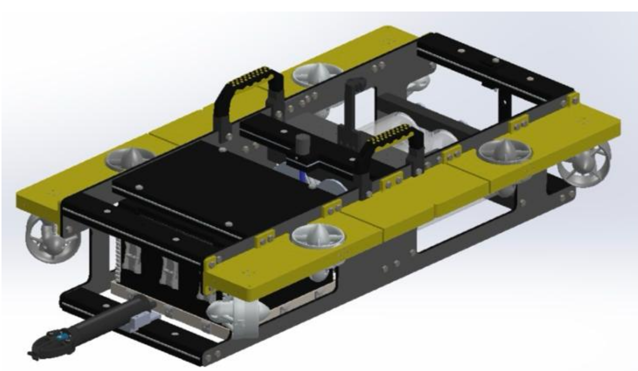

Figure 1a. Type-X 2025 Build Year

2) Control Electronics Housing:

All of Bestagon's control electronics are located in the central housing. The components are mounted on a non-conductive base plate that is then mounted to the bottom of the housing. Last year's design, Type-X, had the mounting of components oriented to the roof of the housing because it would allow the electrical boards to be suspended in case of a leak in the main enclosure. Although this design had great safety considerations, in practice, it was difficult to access the electrical housing due to having to flip the sub every time. This year we decided to have the housing oriented so that it can be opened with the sub right-side up.

All of the components within are mounted onto a plastic plate, which is then itself mounted to the bottom main housing. Furthermore, all the electronics are located on one board, allowing for easy removal of all components for troubleshooting without a lengthy disassembly process. This mounting plate also helps to ensure all electrical components are electrically isolated from the metal housing.

3) External Battery Packs

The purpose of the External battery packs was to allow for more of the weight to be placed on the rear of the frame to make the weight distribution more balanced and to allow easy change-out of low-power batteries with fully charred batteries without needing to open the main electrical enclosure. This also isolates the heat the batteries produce during operation from the main electrical housing. Through several rounds of testing, we have verified that the battery housing itself provides more than adequate cooling to all the batteries to prevent them from overheating during operation.

4*) Robotic Arm and Torpedo Design*

The mechanical team spent many months researching and designing various iterations of sub-systems to complete competition tasks. The robotic arm proved the most complex to design and operate. The team has several Robotics and Mechatronics Engineering students who helped with this project and are experienced with operating robotics equipment such as Festo and Fanuc automation systems. A two-axis arm was decided upon with a Blue Robotics end effector due to its simplicity and time restrictions for the project. The arm is primarily servo-actuated on the bending axis while the end effector is actuated with a DC motor and a stop switch. This system is controlled and linked to the software and is visible from the front-facing camera.

Figure 2. Robotic Arm End Effector Testing

Multiple torpedo launcher and propulsion designs were considered and tested thoroughly, leveraging the SolidWorks computational fluid dynamics (CFD) simulation package. Each torpedo design was run through a series of simulations in an attempt to evaluate the performance of the torpedo before production. Several variations of the torpedo launching mechanism went through multiple rounds of revisions to select the final design. The final launcher utilizes an elastic band to propel the torpedo out of the launcher. This design was chosen for its simple and robust design.

The torpedo is a simple, solid torpedo design. The body is made from a steel bar to give the torpedo the needed inertia to reach the target. The rear fins are 3d printed to allow for ease of manufacturing. The tip is made of a pointed rubber to prevent injury to divers while helping to maintain a hydrodynamic design.

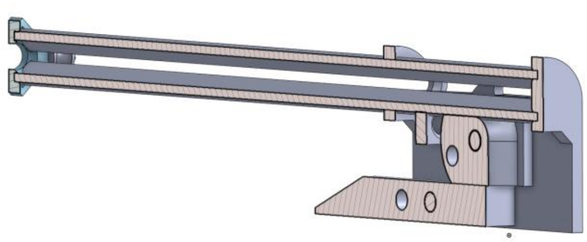

Figure 3. Torpedo Launching Mechanism

B. Electrical Design

1) Standardized Card-Based Architecture: The electrical system was redesigned around a unified daughterboard layout that slots directly into the motherboard through PCIe-style connectors. Each card handles a specific subsystem: Arm Controller, Battery Monitor, Display, MMU, ESC Controller, ESC Carrier, Orin Interface, and Power Safety, while also sharing identical footprints for power, CAN, I²C communication, and programming headers. This modular approach improves from last year's design, Type-X, by standardizing our designs for consistent signal integrity, maintainability of board components, and debugging across Bestagon's electrical system. Furthermore, individual board sizes were consolidated and given design guidelines to optimize our use of board space and maintain consistent size measurements between all of our daughterboards. This makes it easier to slot in and take out each individual board, which was a quality Type-X's electrical system lacked.

2) Microcontroller Platform: All boards, excluding the ESC Carrier and Orin Interface, employ the STM32G431KBT6 Cortex-M4 MCU with a 16 MHz Avracon ABM8 crystal oscillator for stable timing. Each board integrates a custom 14-pin ST-Link MINIE programming header that supports SWDIO, SWCLK, SWO, USART, and reset control. This common interface is an improvement from last year's design, as it establishes a unified standard for embedded programming that prevents the potential for mistakes when exposing pins in the design phase.

3) Sensor and Actuator Integration: The connections between sub-electronics are shown in Fig. 4. Like Type-X, Bestagon utilizes eight Blue Robotics thrusters for maneuverability. Eight electronic speed controllers (ESCs) regulate the speed of the thrusters. The ESCs receive instructions by pulse width modulation from the ESC Controller and give the ability to control the level of thrust. The MMU integrates a 9-axis IMU and a pressure/humidity/temperature sensor to provide the Orin with continuous motion and environmental data. It collects linear acceleration, angular velocity, magnetic heading, and depth and ambient temperature readings.

4) Power Distribution and Regulation: Three lithium polymer batteries power the sub's motors, onboard computer, and sensors. Power distribution is managed through the Power Safety Module, which manages isolation, soft-kill control, and over-current protection. Furthermore, each daughterboard uses MIC5207regulators to step +12V down to +3.3V logic and, where required, +5V analog rails. Status LEDs for power and MCU activity provide instant visual diagnostics for each board.

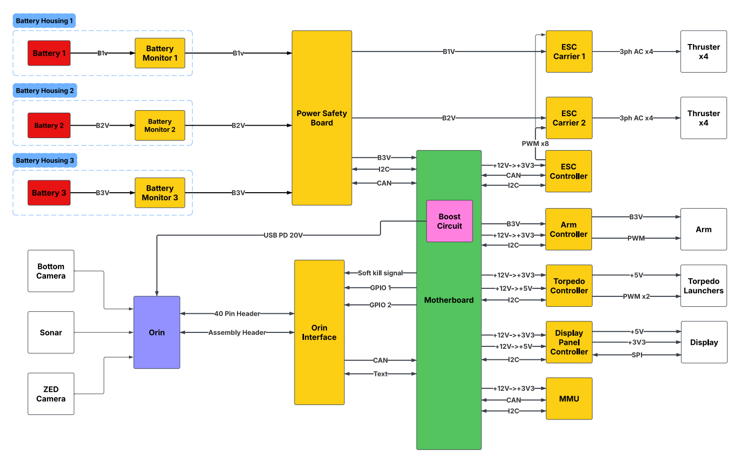

Figure 4. Electrical System Overview

5) Kill Switch: The kill switch, part of the Power Safety Module, controls the distribution of power from the batteries to the rest of our subsystems. It implements a dual-stage protection measures that consist of a soft-kill and a hard-kill mechanism to ensure fail-safe operation under both electrical and environmental fault conditions. The soft-kill stage uses a series of three P-channel MOSFETs configured as high-side switches for each battery. Each MOSFET gate is controlled by the Power Safety Board's microcontroller through dedicated NPN transistor drivers, allowing the Orin to command an immediate cutoff of power to all thrusters and other subsystems. The hard-kill circuit acts as a physical failsafe independent of software control. It uses low-value sense resistors and a magnetic reed switch positioned with the electrical housing. The hard-kill pulls the gate control lines to ground, forcing the MOSFETs into a non-conductive state. Together, these two layers provide both a controlled shutdown and guaranteed absolute method of killing power to protect our electrical system. It ensures Bestagon remains electrically secure under all operating and fault conditions.

6) Connector Standardization: Reflecting on Type-X's use of Anderson connectors for most of our electrical connections, the AMASS XT150 connectors were integrated into its design to improve assembly efficiency and reliability across its high-current interfaces. The Anderson connectors required precise crimping and forceful insertion of metal contacts into their housings; thus, the process not only consumed a great deal of time but also risked damaging insulation and deforming large-gauge wiring. The XT150 connectors use solder-on termination, providing cleaner, more secure mechanical joints – reducing integration time. This change aligned with the system's broader push toward modularity and maintainability.

C. Computer and Software Design

1) Hardware: Our vehicle this year utilizes the Nvidia AGX Orin 32 GB Developer Model as the core processing unit. This model boasts strong performance, allowing for effective operation of our AI algorithms within the competition course. We are also utilizing the ZED 2i stereographic camera and the Anker Power Conf C200 2K camera for our Camera package. These cameras allow us to get both front-facing and bottom-facing views, and in the case of the ZED camera, allow us to perform depth sensing. This grants our sub strong perception capabilities, providing effective navigation and task recognition capabilities.

2) Software Architecture: The software architecture of Bestagon is built upon the Python Programming language (version 3.10.2). Python is chosen as the backbone for the software architecture for ease of use and simple integration with existing AI libraries. The architecture consists of one main process with five sub-processes linked together with multiple relational databases. The five sub-processes are as follows:

- Hardware Interface
- Movement Package
- Camera Package
- AI Package
- Sonar Package

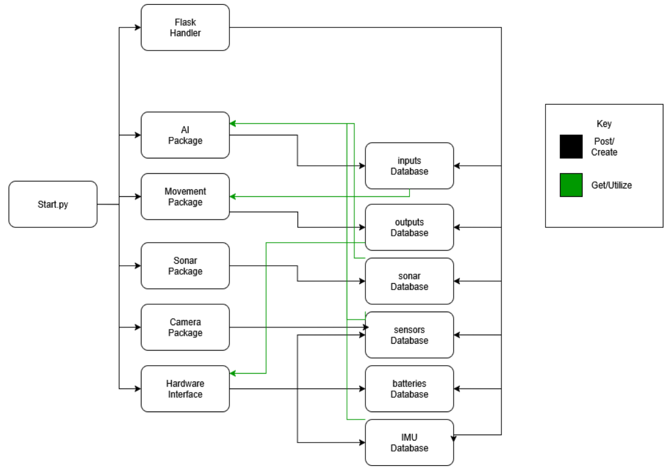

Figure 5. Software Architecture

3) High-level Control: Bestagon is controlled by the AI package, which allows for real-time autonomous decision-making of the submarine. Imitation learning - a machine learning algorithm based on teaching an agent to tackle a task based on expert demonstrations - is used to control the submarine. We utilize pool tests based off of competition scenarios to collect data and train the model to navigate the competition course.

4) Cameras: Bestagon utilizes one ZED 2i depth sensing camera and one Anker Power Conference C200 camera. The ZED camera is used to provide a front-facing view and allows for distance measurements to detect objects in front of the sub. This is crucial for performance in several of the competition tasks, as this allows for accurate detection of obstacles and necessary visuals for tasks.

5) Hardware Interface: The hardware interface sub-process handles all communication between the electrical system and the Orin. Written in Python, the subprocess communicates with the electrical system over I2C communication lines, ensuring accurate and fast communications between them. All sensor data is stored within the relational database, and all of the movement data is queried from the same database and sent to the necessary electrical hardware. This allows for rapid and seamless control of the sub both manually and autonomously.

6) Simulation: For this season, we used HoloOcean, a high-fidelity underwater vehicle simulator constructed by Brigham Young University's Field Robotic Systems Lab. The use of this simulator allows for us to visualize sub behavior in a virtual environment and train our AI algorithms. In addition, HoloOcean is constructed off of Unreal Engine, allowing us to construct the pre-qualification and main courses in simulation. This makes it so that we can train the AI models for imitation learning in simulation before deploying them in the real world and further refining them, leading to quicker development and testing of Bestagon's autonomous capabilities.

Figure 6. Pre-qualification Simulation

III. Experimental Results

A. Simulation Testing

Prior to testing the vehicle in the pool, several simulations are run in HoloOcean to understand submarine dynamics and understand software and AI performance in competition-like environments. To do this, specific scenarios similar to competition conditions are created. Once factors such as autonomous and control algorithms are validated in simulation, testing in the pool is performed.

B. In-Pool Testing

Our pool testing focused on verifying that the elements of the sub worked correctly, specifically the updated frame, wiring, and neural network architecture. While limited testing was conducted in both the fall and early spring semesters, our primary testing period was cut short due to delays in material shipping. In response to this challenge, the software team focused on using the previously developed simulation to virtually test novel project aspects and to train the AI model as discussed in Section II.C.6.

C. Design of the Internals

The design of the interior was a complicated problem. It had been "solved" several times, but while each design looked great in CAD, the solutions proved too complicated or cluttered in real life.

To better understand how components would fit in person, the mechanical team decided to subvert the traditional use of computer-aided design and instead, implemented "cardboard-aided design" to create mock-ups of the sheet metal front tube racks. This was done by cutting sheets of cardboard and laying out scale models of the computer components. The team produced four competing ideas to find traits that would benefit the sub: an improved, removable version of the current rack, a trifold design, a "T" shaped design, and an "I" shaped design. The cardboard mockups were given to the electrical team to get feedback on what traits work and what traits hinder.

IV. Acknowledgments

The team would like to thank Dr. Muhammad Tanveer and Dr. Razvan Voicu for acting as our faculty advisors, all our engineering and technology professors for their instruction, the KSU Student Activities Board Advisory Committee, the KSU Alumni Association, and all of our generous sponsors who helped make the Bestagon platform a reality.

V. References

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Appendix A: Component and PCB board Specifications

Component	Vendor	Model/Type	Specs	Cost (if new)
Buoyancy Control	N/A			
Frame	eSun	PETG	1.75mm PETG filament	$131.94
Waterproof Housing	Apache	2800 Rugged Mobility	11-7/8 in. x 9 in. x 5-5/16 in. (interior) and 13-1/2 in. x 11-3/8 in. x 6 in. (exterior)	$35.00
Waterproof Connectors	Blue Trail Engineering	Cobalt Series 8 - Pin Connector	600m depth	$260.00
Thrusters	Blue Robotics	T200	17 A @ 12 v	$ 1760
Motor Control	JLCPCB	Custom ESC Controller PCB	45A	$120.00
High-Level Control	Nvidia	Jetson AGX Orin	Quad-core ARM Cortex-A57 MPCore processor (1.43 GHz)	$3,200
Propellers	Blue Robotics	T200	N/A	$8
Battery	Zeee	High performance Lithium Polymer Battery 120C 14.8V 148Wh 4S 10000mAh	10000mAh, 4S	$97.20
Embedded System	Nvidia	Jetson AGX Orin	Quad-core ARM Cortex-A57 MPCore processor (1.43 GHz)	$99
Internal Comm Network	N/A	N/A	I2C	$10
External Comm Interface	Blue Trail Engineering	Cobalt Series 8 - Pin Connector	600m depth	$234.00
Programming Language 1	Python			
Programming Language 2	C++			
Inertial Measurement Unit (IMU)	N/A	Custom	BNO086 with Custom Circuitry	15.00
Camera(s)	ZED Amazon	ZED 2I C200	Dual 1080p @ 60fps Single 2k @ 60fps	$519 $59.99
Hydrophones	Teledyne Marine	RESON TC4013	N/A	$1500
Manipulator	Blue Robotics	Newton Subsea Gripper	14.8V DC Motor Based manipulator waterproof up to 300m	$680
Algorithms: vision	Tensorflow	Custom	N/A	$0
Algorithms: autonomy	KSU AUV	Custom	N/A	$0
Open source software	Python, Flask, Flask SQLAlchemy, Python State Machine, Tensorflow			
Team size (number of people)	15			
HW/SW expertise ratio	2 HW: 1 SW			
Testing time: simulation	500+ hrs.			
Testing time: in-water	30+ hrs.			

Motherboard Dimension Specifications		
Dimension	Length (mm)	Note
Y	75.057 mm	HEIGHT
X	125.095 mm	WIDTH
R	0.0 mm	RADIUS OF CORNERS

Daughterboards Dimention Specifications		
Dimension	Length (mm)	Note
Y	~75 mm	MAXIMUM HEIGHT OF DAUGHTERBOARDS (excludes PDB, Motherboard, ESC Carrier)
X	40 – 100 mm	AS LONG AS NEEDED
R	0.254 mm	RADIUS OF CORNERS

Standardized PCB Board Component Specifications				
	Component	Specification	Coord X	Coord Y
1	PCIe Card Edge	64 pin PCIe card edge connector	Aligned at the origin	Aligned at the origin
2	Programming Header - SWD	14 Pin IDC 1.27 mm Pitch	54.966 mm	68.402 mm
3	USB-C Connector	16 Contact SMD	53.556 mm	56.410 mm
4	Reset Button	SPST Right Angle Keypad Switch SMD	54.915 mm	45.237 mm
5	Boot Button	PST Right Angle Keypad Switch SMD	38.608 mm	72.923 mm
6	Power LED	SMD LED Green 2V 30 mA	45.647 mm	46.790 mm
7	Status LED	SMD LED BLUE 3V2 30 mA	45.339 mm	32.283 mm

PCB LED Indicator Specifications		
Color	State	Cause
Green	Steady	Device is powered
Blue	Steady	Device is receiving signal
Blue	Flashing	Device is being programmed (flashed)
Red	Steady	Device has run into an error

APPENDIX B: STANDARD OPERATION PROCEDURE

Kennesaw State University Autonomous Underwater Vehicle Team

Testing for Water Tightness

Standard Operating Procedure

#	Step	Name	Complete
1	Empty housing of water sensitive parts		
2	Place paper towels inside to indicate source of leak		
3	Ensure all penetrators are properly seated and tightened using dedicated penetrator wrench		
4	Ensure housing is fully closed and latched		
5	Ensure water is clear and free of debris that could become tangled		
6	Place housing in water and ballast appropriately		
7	Set timer for 10 minutes		
8	Remove housing from water before drying exterior		
9	Open housing slowly. Check all surfaces and paper towels for moisture		
10	Repeat as needed for testing times of 30mins, 1hr, overnight		
11	Switch off tools and put all equipment away in original configuration		

Place initials of the person who completed a task in “Name”
Place initials of the person who certified a task is complete in “Completed”

APPENDIX C: STANDARD LEAK TEST PROCEDURE

Kennesaw State University Autonomous Underwater Vehicle Team

Testing for Water Tightness

Standard Operating Procedure

#	Step	Name	Complete
1	Empty housing of water sensitive parts		
2	Place paper towels inside to indicate source of leak		
3	Ensure all penetrators are properly seated and tightened using dedicated penetrator wrench		
4	Ensure housing is fully closed and latched		
5	Ensure water is clear and free of debris that could become tangled		
6	Place housing in water and ballast appropriately		
7	Set timer for 10 minutes		
8	Remove housing from water before drying exterior		
9	Open housing slowly. Check all surfaces and paper towels for moisture		
10	Repeat as needed for testing times of 30mins, 1hr, overnight		
11	Switch off tools and put all equipment away in original configuration		

Place initials of the person who completed a task in “Name”
Place initials of the person who certified a task is complete in “Completed”

APPENDIX D: PICTURES

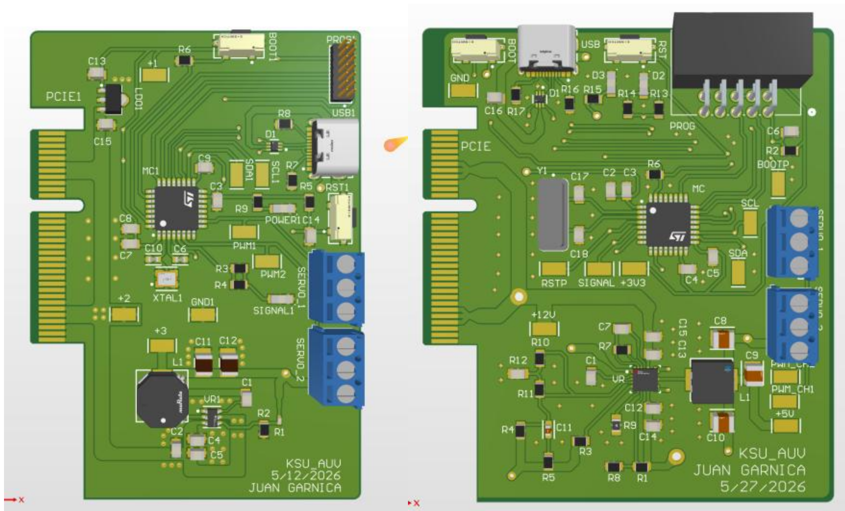

Figure 5. Example of PCB board size, and layout consolidation