TECHNICAL REPORT
CRUSH DEPTH

MATE ROV 2025
EXPLORER CLASS

SCYLLA
feat. Charybdis

CLOVIS COMMUNITY COLLEGE
10309 N WILLOW
FRESNO, CA USA

TEAM MEMBERS

MENTORS GURINDER KHAIRA & BENJAMIN BOHAN

25’ ROBERT VOSS – CEO
26’ OLAF MARTINEZ – COO
25’ DECLAN DOSS – CTO
26’ MAXINE CATAHAN – CLO
25’ RANA EYIT – CCO
26’ GEVORG KAREYAN – CDO
25’ TEMILADE FAGBULE – CMO
25’ ESTEBAN VALENCIA GARCIA – CQO
26’ JULIA TAYLOR – CQO
25’ JULIAN LAXAMANA – ROV PROGRAMMING LEAD
25’ JACK JACKSON – FLOAT PROGRAMMING LEAD
25’ ISABELLE ONG – SURFACE SIDE LEAD
25’ LUKE SALAZAR – ROV DESIGN LEAD
26’ DANIEL LARRALDE – FLOAT DESIGN LEAD
26’ ISHAN ARORA – ROV PROGRAMMING TEAM
25’ CORBEN BEATY – ROV PROGRAMMING TEAM
25’ DONALD LI – ROV PROGRAMMING TEAM
26’ DIEGO HIDALGO – ROV PROGRAMMING TEAM
25’ VOLODYMIR SURIN – ROV PROGRAMMING TEAM
26’ JAKE DUDLEY – FLOAT PROGRAMMING TEAM
26’ KAITLYN FONTANILLA – FLOAT PROGRAMMING TEAM
25’ MASON LIU – FLOAT PROGRAMMING TEAM
25’ AARON SNELL – FLOAT PROGRAMMING TEAM
26’ ELIZABETH FAGBULE – LOGISTICS TEAM
26’ ADRIANA FONTANEZ – LOGISTICS TEAM
25’ SYDNEY HICKEY – LOGISTICS TEAM
25’ JAZMIN JOY – LOGISTICS TEAM
26’ BRI LOGAN – LOGISTICS TEAM
25’ FRANCO LOZADA – LOGISTICS TEAM
25’ FRANCES MEDINA – LOGISTICS TEAM
26’ TYLER BRIDGES – QUALITY CONTROL TEAM
26’ ADDISON HICKEY – QUALITY CONTROL TEAM
25’ KATHERINE HERNANDEZ – ROV DESIGN TEAM
26’ CECILIA URBIETA – ROV DESIGN TEAM
25’ ARMAAN DHAH – FLOAT DESIGN TEAM
26’ KEVIN YAZON – FLOAT DESIGN TEAM
26’ SOLOMON TESFAI – SURFACE SIDE TEAM
26’ JOREL ABRANTES – SURFACE SIDE TEAM
26’ JEREMY CORTEZ – SURFACE SIDE TEAM
26’ JACKSON DOUGLASS – SURFACE SIDE TEAM
26’ ENRICK MANANSALA – SURFACE SIDE TEAM
27’ JHAN PADUA – SURFACE SIDE TEAM
26’ ELLA SIADTO – SURFACE SIDE TEAM

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ABSTRACT

CRUSH DEPTH, AN ENGINEERING-BASED COMPANY SUPPORTED BY THE GRIT OF ITS MEMBERS, OPERATES UNDER THIS MISSION: STRENGTHEN THE VISION OF PURSUING STEM IN THE CENTRAL VALLEY BY PROVIDING STUDENTS WITH OPPORTUNITIES TO TAKE INITIATIVE IN SOLVING THE WORLD'S MOST DAUNTING PROBLEMS.

LAST YEAR, WE TOOK OUR FIRST STEP TOWARDS THIS WITH OUR ROV, PERCY, WHICH HAD A VERSATILE CLAW AND COULD MOVE WITH FIVE DEGREES OF FREEDOM. THIS YEAR, WE PLAN TO REACH GREATER HEIGHTS WITH THE SUCCESSFUL DEPLOYMENT AND USE OF OUR IMPROVED ROV, SCYLLA. THIS YEAR'S COMPANY IS COMPRISED OF A CAPABLE TEAM AMASSING OVER 30 MEMBERS, SPLIT INTO 5 RESPECTIVE DEPARTMENTS: ROV, FLOAT, LOGISTICS, SURFACE SIDE, AND QUALITY CONTROL & COMPLIANCE.

THE COMBINED EFFORTS OF OUR EMPLOYEES HAS ALLOWED US THE PRIVILEGE TO BUILD SCYLLA, AN ROV THAT IS EQUIPPED WITH TWO VERSATILE MANIPULATORS AND CAPABLE OF MOVING WITH A FULL SIX DEGREES OF FREEDOM. THESE SKILLS ARE TOOLS THAT CAN AND WILL BE UTILIZED IN THE BETTERMENT OF THE OCEANS WE HOLD NEAR AND DEAR.

Clovis Community College

FIGURE 1. CRUSH DEPTH TEAM MEMBERS TAKEN BY ALEC HAYASHI

ELECTRICAL DESIGN RATIONALE

SCYLLA OPERATES ON A POWER SUPPLY UNIT THAT CONVERTS 120V AC TO 48V DC. THE 48V IS TRANSMITTED THROUGH THE TETHER AND IS PASSED THROUGH A BUCK CONVERTER THAT STEPS DOWN THE VOLTAGE TO 12V. THE 12V POWERS MANY COMPONENTS, SUCH AS THE ESCS AND SOLENOIDS. TO POWER THE RASPBERRY PI, THE 12V IS PASSED THROUGH ANOTHER BUCK CONVERTER THAT OUTPUTS 5V. THE 48V-12V BUCK CONVERTER IS A VALEFORD 600W STEP-DOWN TRANSFORMER, AND THE 12V-5V IS A TOBSUN 50W BUCK CONVERTER. SCYLLA ALSO UTILIZES A SERVO DRIVER TO CONTROL THE ESCS' PWM SIGNALS THROUGH I2C; A FAST AND RELIABLE WAY TO CONNECT MULTIPLE SENSORS TO THE RASPBERRY PI. THERE IS ALSO A PCA9685 SERVO DRIVER TO CONTROL ALL EIGHT THRUSTERS USING THE RASPBERRY PI, SINCE THERE AREN'T ENOUGH PINS. THE RASPBERRY PI ALSO COMMUNICATES THROUGH AN ETHERNET CONNECTION IN THE TETHER, UTILIZING A ROUTER TO ENABLE SSH ACCESS, AND ESTABLISHES UDP SOCKET CONNECTIONS FOR DATA TRANSMISSION.

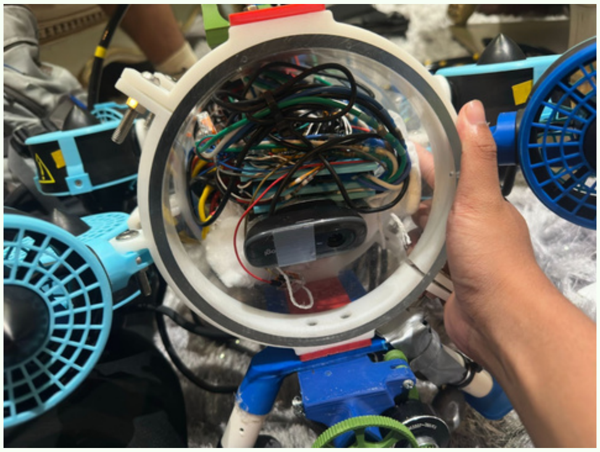

FIGURE 2. INTERNAL WIRING BY VOLODYMYR SURIN

DESIGN PROCESS

PREVIOUSLY, CRUSH DEPTH'S PERCY USED THE EAGLE SUBSEA PCB PROVIDED BY BLUE ROBOTICS. DUE TO THE TEAM'S DECISION TO SWITCH FROM AN ARDUINO MEGA TO A RASPBERRY PI, THE TEAM HAD TO DESIGN THE CIRCUIT DESIGN FROM THE GROUND UP. THE TEAM USED WAGO CONNECTORS TO PROTOTYPE HOW THE ROV WOULD BE POWERED BY A 12V SOURCE. ONCE FUNCTIONAL, SCYLLA'S INTERNALS WERE CLEANED UP BY 3D PRINTING PARTS TO HELP MANAGE THE CABLES.

THRUSTERS

SCYLLA USES EIGHT BLUE ROBOTICS BASIC ESCS TO CONTROL THE T200 THRUSTERS. EACH OF THESE IS CONNECTED TO ONE OF THE PCA9685'S SIGNAL PORTS. THE SIGNAL RANGES FROM A PULSE WIDTH OF 1100MS TO 1900MS AT A FREQUENCY OF 50HZ. TO PREVENT POWER-RELATED PERFORMANCE THROTTLING AND TO ENABLE OVERDRAW PROTECTION, THE THRUSTERS ARE PROGRAMMED TO OPERATE AT 50% OF THEIR MAXIMUM CAPACITY.

SENSORS

SCYLLA USES A GYROSCOPE WIRED USING I2C. TO INTERFACE WITH THE GYROSCOPE, THE TEAM USED THE MPU6050 LIBRARY DEVELOPED BY ALEX MOUS. AT FIRST, THE TEAM TRIED TO DEVELOP THEIR OWN WAY TO INTERFACE WITH THE GYROSCOPE, BUT DUE TO THE DIFFICULTY, THE TEAM DECIDED TO USE MOUS'S LIBRARY. THE MPU6050 ALSO ALLOWS FOR THE ROV TO READ ACCELERATION. SCYLLA WILL ALSO HAVE AN UNDERWATER 12V FLASHLIGHT FOR THE COLLABORATIVE TASK. THIS WILL BE CONTROLLED BY A RELAY INSIDE THE ROV.

TETHER

SCYLLA CONNECTS TO A DUAL-LAYERED TETHER CABLE. THE INNER LAYER HOUSES 4 PAIRS OF TWISTED WIRES THAT ENABLE ETHERNET CONNECTIVITY VIA AN RJ-45 JACK. THE OUTER LAYER CONTAINS TWO WIRES (GREEN AND YELLOW) CONNECTED TO A NEGATIVE TERMINAL, AND ANOTHER TWO WIRES (RED AND ORANGE) CONNECTED TO A POSITIVE TERMINAL (SEE FIGURE 3).

CLAWS

SCYLLA'S CLAW IS CONTROLLED USING FIVE QX-MOTOR QM3507 BRUSHLESS MOTORS, EACH CONNECTED TO A BLHELI_S LANRC ESC. THE ESCS OPERATE USING SIGNAL RANGES OF 1000MS TO 2000MS AT 50HZ, WITH THE DEAD ZONE AT 1500MS. EACH ONE WAS SET TO OPERATE IN BIDIRECTIONAL MOTION, ALLOWING THE MOTORS TO MOVE CLOCKWISE AND COUNTERCLOCKWISE. TWO MOTORS CONTROL THE VERTICAL MOTION OF THE CLAW, AND ONE CONTROLS THE HORIZONTAL ANGLE. 12V IS SENT TO THE ESCS, WHERE ONE OPERATES ROTATION, AND THE OTHER OPERATES CONTRACTION. THE SECOND CLAW CONSISTS OF A SOLENOID THAT IS ACTIVATED USING A RELAY THAT OUTPUTS 12V.

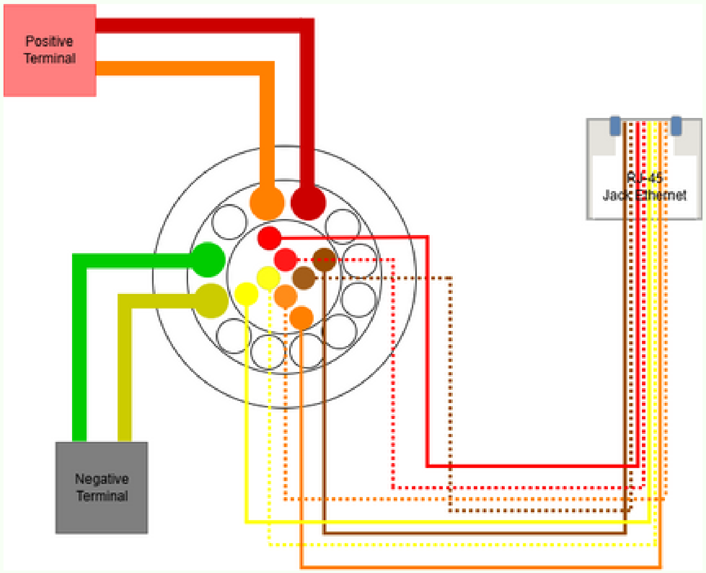

FIGURE 3: TETHER WIRING DIAGRAM BY DONALD LI

SOFTWARE DESIGN RATIONALE

CRUSH DEPTH DESIGNED SCYLLA'S SOFTWARE STACK TO BE SIMPLE, LIGHTWEIGHT, AND EFFICIENT. THIS YEAR, THE COMPANY AIMED TO IMPROVE ITS 2024 DESIGN, PERCY, BY SWITCHING OUT THE ARDUINO MEGA WITH A RASPBERRY PI. ALTHOUGH AN ARDUINO IS FUNCTIONAL, A RASPBERRY PI OFFERS THE PROCESSING POWER NECESSARY TO DO THE LEVEL OF QUICK COMPUTATION NEEDED FOR THE AUTO-LEVELING SYSTEM (ALS) AND CONTROLS. THIS CHANGE ALSO ALLOWED THE COMPANY TO USE DIFFERENT PROGRAMMING LANGUAGES, SUCH AS C++ AND PYTHON, FOR DIFFERENT LEVELS OF ABSTRACTION IN THE CODE BASE. THE RASPBERRY PI ALSO RUNS A HEADLESS UBUNTU SERVER DUE TO THE LACK OF BLOATWARE. TO COMMUNICATE WITH SCYLLA, THE UI TRANSMITS TO THE ROV OVER A USER DATAGRAM PROTOCOL (UDP) SOCKET FOR FAST DATA TRANSFER FROM THE PILOT'S CONTROLLER. THE TECH STACK ALSO UTILIZES GOOGLE'S PROTOCOL BUFFERS (PROTOBUFS) TO SERIALIZE AND COMPRESS DATA FOR EASE OF USE. ON THE EMBEDDED SIDE, SCYLLA USES THE LGPIOD LIBRARY TO INTERFACE WITH THE GPIO PINS AND I2C TO COMMUNICATE WITH THE DIFFERENT SENSORS AND BOARDS ON THE ROV. CRUSH DEPTH ALSO UTILIZED GITHUB TO COLLABORATE, SPLITTING THE PROJECT INTO THREE DIFFERENT REPOSITORIES WHERE THEY DOCUMENTED USAGE OF THEIR CODE IN THEIR RESPECTIVE READMES.

DESIGN PROCESS

THE TEAM LOOKED AT DIFFERENT OPTIONS FOR PILOTING THE ROV, SUCH AS USING LOGITECH FLIGHT STICKS OR EVEN DEVELOPING OUR OWN CUSTOM CONTROLLER FOR THE ROV. THE TEAM FACED SOME PROBLEMS EARLY ON WITH DEAD ZONES ON THE FLIGHT STICKS, MAKING THE LOGITECH NOT IDEAL FOR PILOTING THE ROV. ADDITIONALLY, WE MADE THE DECISION TO REBUILD THE CODE BASE FROM SCRATCH AND FOCUS MORE ON THE ROV RATHER THAN DEVELOPING A CUSTOM CONTROLLER SOLUTION. CRUSH DEPTH ALSO PROGRAMMED A WAY TO CONTROL THE ROV USING A KINEMATIC MODEL OF THE THRUSTER CONFIGURATION. THIS GREATLY IMPROVED THE PILOT'S ABILITY TO ADJUST THE THRUSTERS IN CASE A THRUSTER BECAME DAMAGED FOR ANY REASON. ORIGINALLY, SCYLLA'S MESSAGING PROTOCOL WAS MESSAGE QUEUING TELEMETRY TRANSPORT (MQTT), BUT DUE TO HIGH LATENCY, THE TEAM SWITCHED TO USING UDP SOCKETS INSTEAD.

CONTROL STATION

THE CONTROL STATION CONSISTS OF A LAPTOP WITH 2 CONTROLLERS. THE CONTROLLERS ARE GENERIC XBOX CONTROLLERS SINCE THEY WERE EASY FOR THE PILOTS TO GET ACCUSTOMED TO. ON THE SURFACE, THERE IS ALSO A ROUTER THAT ENABLES A CONNECTION FROM THE GUI TO THE RASPBERRY PI.

FIGURE 4: SURFACE-SIDE CONTROL STATION BY JULIAN LAXAMANA

CONTROLS

TO CONTROL THE ROV, THE COMPANY DEVELOPED A KINEMATIC MODEL OF THE ROV. EACH THRUSTER PROVIDES A FORCE ON THE ROV IN THE DIRECTION NORMAL TO THE FACE OF THE THRUSTER. IN THE COMPANY'S MODEL, THE FORCE GENERATED BY THE THRUSTER IS DIRECTLY PROPORTIONAL TO THE PULSE WIDTH. AS SHOWN IN FIGURE 4, THE RELATIONSHIP BETWEEN THE THRUST GENERATED AND THE PULSE WIDTH CAN BE MODELED LINEARLY (SEE FIGURE 5).

FIGURE 5: PULSE WIDTH VS THRUST BY JULIAN LAXAMANA

THUS, THRUST (T) CAN BE REPRESENTED AS A 3-DIMENSIONAL VECTOR EQUAL TO THE NORMAL VECTOR (N) MULTIPLIED BY A COEFFICIENT (M) REPRESENTING THE PULSE WIDTH GENERATED BY THE ESC. THE TEAM USED A SYSTEM OF EQUATIONS THAT REPRESENT HOW THE THRUSTERS MOVE THE ROV IN 3D-SPACE. THE MOORE-PENROSE PSEUDO-INVERSE CAN BE FOUND USING THE EIGEN LIBRARY, WHICH CAN THEN BE USED TO FIGURE OUT WHICH THRUSTERS NEED TO BE POWERED TO FIND SURGE, SWAY, HEAVE, ROLL, PITCH, AND YAW. ON THE SURFACE SIDE, THE TEAM USES A LAPTOP RUNNING THE CUSTOM GUI THAT SENDS THE CONTROLLER DATA TO SCYLLA, WHERE IT DOES THE AFOREMENTIONED CALCULATIONS TO FIND WHICH THRUSTERS NEED TO BE POWERED FOR THE DESIRED MOVEMENTS. A UDP SOCKET IS OPENED TO ALLOW QUICK COMMUNICATION BETWEEN THE GUI AND SCYLLA FOR NEAR-INSTANT FEEDBACK.

CAMERAS

SCYLLA HAS THREE DIFFERENT CAMERAS LOCATED ON THE FRONT, BOTTOM, AND TOP. AT FIRST, THE TEAM STREAMED THE LIVE DATA OF THE CAMERAS USING A WEB SERVER DEVELOPED USING THE FLASK API. DURING TESTING, THE CAMERA FEED HAD NOTICEABLE LATENCY, WHICH CAUSED MANY ISSUES FOR THE PILOT. TO FIX THIS, THE TEAM USED ANOTHER UDP SOCKET AND COMPRESSED THE IMAGE DATA FOR LESS LATENCY ON THE VIDEO FEED. THE THREE VIDEO FEEDS ARE DISPLAYED SIMULTANEOUSLY ON THE GUI.

AUTO LEVELING SYSTEM

MAINTAINING THE ROV AT A STILL POSITION AND DESIRED ANGLE IS NECESSARY TO COMPLETE MANY OF THE TASKS EFFICIENTLY. TO ASSIST IN THIS, THE ROV USES A CONTROL LOOP TO MAKE IT EASIER FOR THE PILOT TO HANDLE THE ROV ACCURATELY, SUCH AS MAINTAINING A CERTAIN PITCH OR ROLL. IN THE CONTROL LOOP, THE USER INPUT IS ENTERED INTO THE PROPORTIONAL INTEGRAL DERIVATIVE (PID) CONTROL, WHICH CALCULATES THE AMOUNT OF ROLL/PITCH THE ROV SHOULD HAVE TO COUNTERACT THE ERROR. EACH PORTION OF THE CONTROLLER HAS A CONSTANT ATTACHED TO IT: KP, KD, AND KI FOR THE PROPORTIONAL, INTEGRAL, AND DERIVATIVE CONSTANTS, RESPECTIVELY. THE CONTROL SCALES THE CONSTANTS BASED ON HOW MUCH THE ROV NEEDS TO BE CORRECTED. FOR MAXIMUM ADAPTABILITY, THE PILOT CAN CHANGE THESE CONSTANTS WITHIN THE UI. ORIGINALLY, THE PID CONTROL LOOP WAS GOING TO BE CREATED IN MATLAB AND SIMULINK, BUT DUE TO THE UNNECESSARY COMPLEXITY, THE TEAM DECIDED IT WAS BEST TO USE C++.

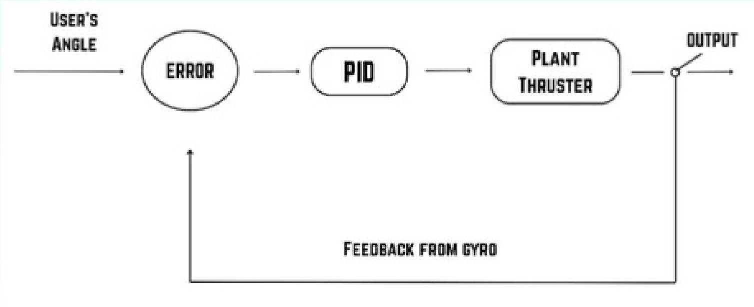

FIGURE 6: PID CONTROL LOOP BY JAZMIN JOY

GRAPHICAL USER INTERFACE (GUI)

THE MAIN LAYOUT OF THE CRUSH DEPTH GUI IS HEAVILY INSPIRED BY THE GUI DEVELOPED BY THE AVALON COMPANY IN THE 2020 MATE ROV COMPETITION. THE LAYOUT OF THE GUI WAS CREATED WITH THE QT CREATOR APPLICATION, A DRAG-AND-DROP PROGRAM THAT IS COMPATIBLE WITH PYSIDE6. COMPANY MEMBERS ARE ELIGIBLE FOR FREE EDUCATIONAL LICENSES THROUGH CLOVIS COMMUNITY COLLEGE (CCC), MAKING THIS THE MOST EFFICIENT OPTION FOR OUR COMPANY IN TERMS OF COST, EASE OF USE,

AND CAPABILITIES. TO CONNECT THE FEATURES OF THE GUI TO EXECUTABLE CODE, THE COMPANY THEN MOVED TO PYTHON AND PYSIDE6 TO INTEGRATE CUSTOM FUNCTIONS. THE MAIN CONTROL PANEL DISPLAYS ALL THREE CAMERA FEEDS FROM SCYLLA SIMULTANEOUSLY (SEE FIGURE 7). THE CAMERAS ABOARD SCYLLA ARE CONNECTED TO A RASPBERRY PI, WHICH ORIGINALLY STREAMED THE CAPTURES TO A WEBSITE USING THE FLASK WEB FRAMEWORK. DURING TESTING, THIS APPROACH CAUSED SEVERE LATENCY, AND SO THE COMPANY IMPLEMENTED MULTITHREADING AND USED ANOTHER UDP SOCKET, COMPRESSING THE IMAGE DATA AND USING OPENCV TO READ THE CAPTURES AND DISPLAY THEM IN A QLABEL AS A PIXEL MAP.

THE DATA PANEL OF THE GUI IS USED TO COMPLETE TASK 3. THE FLOAT TEAM DECIDED TO TRANSMIT THEIR SENSOR DATA TO THE SURFACE SIDE AS A JAVASCRIPT OBJECT NOTATION (JSON) FILE VIA THE LONG-RANGE (LORA) MODULE. THE JSON FILE IS LOADED WITH THE PYTHON JSON PACKAGE AND CONVERTED TO A PD.DATAFRAME WITH THE PANDAS LIBRARY. FOLLOWING THIS, THE DATA IS THEN DISPLAYED AS A TABLE AND GRAPH USING THE MATPLOTLIB LIBRARY.

THE MAPPING PANEL OF THE GUI IS USED TO DIGITALLY MODEL THE MOVEMENT OF INVASIVE CARP FOR TASK 1.3. THIS SECTION OF THE GUI TAKES A CSV FILE, INTERPRETS IT WITH PANDAS, AND USES OPENCV TO CREATE A CUSTOM IMAGE BY OVERLAYING PNGS ONTO THE PROVIDED MAP THE CSV FILE IS CREATED USING MS EXCEL'S "DATA FROM PICTURE" FEATURE, SINCE THE DATA SUPPLIED DURING THE COMPETITION IS ONLY ON A PHYSICAL DOCUMENT. WHEN PROCESSING IDENTICAL IMAGES, THE EXCEL OPTICAL CHARACTER RECOGNITION (OCR) PROVED TO BE SIGNIFICANTLY MORE ACCURATE THAN POPULAR PYTHON OCRS, SUCH AS PYTHON-TESSERACT. MEMBERS HAVE FREE, EDUCATIONAL LICENSES TO MICROSOFT APPLICATIONS PROVIDED BY CCC.

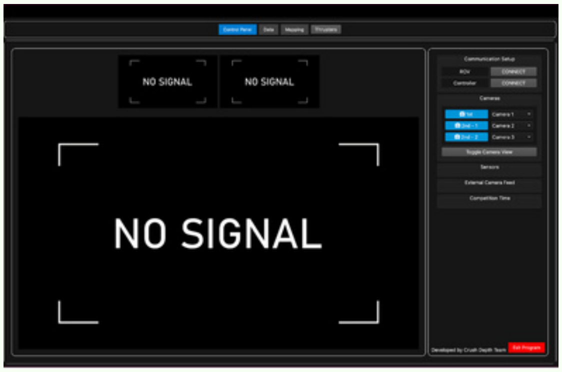

FIGURE 7: CONTROL PANEL BY JOREL ABRANTES

PHOTOSPHERE

AFTER EXPLORING SEVERAL OPTIONS FOR TASK 1.1, CRUSH DEPTH CHOSE TO USE AUTOPANO GIGA TO CREATE THE PHOTOSPHERE. THIS APPLICATION WAS PAID FOR DURING ITS ORIGINAL RELEASE, BUT FORTUNATELY, THE DEVELOPERS RELEASED A FREE LICENSE IN 2023. THE GREATEST BENEFIT TO AUTOPANO GIGA IS THAT THE AUTODETECTION KEEPS THE SAME LEVEL OF ACCURACY WHEN PHOTOS ARE ADDED IN BATCHES, MEANING THAT THE COMPANY MEMBER CREATING THE PHOTOSPHERE CAN ADD ALL THE CAMERA CAPTURES AT ONCE AND LET IT AUTOMATICALLY PROCESS WHILE COMPLETING ANOTHER TASK. TO VIEW THE PHOTOSPHERE, THE COMPANY HAS CHOSEN FSPVIEWER, ANOTHER FREE APPLICATION. THE DRAG-AND-DROP INTERFACE MAKES THE SOFTWARE EASY TO USE. ADDITIONALLY, COMPARED TO SIMILAR APPLICATIONS THAT WERE TESTED, FSPVIEWER HAD THE MOST EFFECTIVE AUTODETECTION OF CONTROL POINTS CONNECTING THE TOP AND BOTTOM EDGES, AS WELL AS THE LEFT AND RIGHT EDGES. THIS WAS A KEY DECIDING FACTOR FOR SELECTING THIS APPLICATION, AS OTHER APPLICATIONS WOULD ONLY ALLOW A PANORAMIC VIEW OF THE 360° IMAGE IF THEY COULD NOT MATCH THE EDGES OF THE PHOTOSPHERE TO EACH OTHER, SO THE CAPTURES FROM THE ROV CAMERAS HAD TO BE RETAKEN AND REPROCESSED (SEE FIGURE 8).

FIGURE 8: FSPVIEWER (LEFT) VS. SPHERICAL VIEWER (RIGHT) BY ELLA SIADTO

TETHER COUNTER

AS PART OF THE TETHER MANAGEMENT SYSTEM, CRUSH DEPTH HAS CHOSEN TO CONSTRUCT A TETHER COUNTER. USING A ROTARY ENCODER WIRED TO AN ARDUINO, THE COMPANY CAN DIGITALLY DISPLAY THE LENGTH OF THE TETHER RELEASED INTO THE WATER. FOR THIS ASSEMBLY, SEVERAL PARTS WERE 3-D PRINTED, INCLUDING A WHEEL MOUNT BY HASANAIN SHUJA ON GRABCAD, THE CAP FOR THE ROTARY ENCODER, AND THE ROLLING PIPES. THE WHEEL MOUNT ALLOWS US TO INSERT AND REMOVE THE TETHER FROM THE COUNTER BOX WHILE IT IS STILL ATTACHED TO THE ROV AND POWER SUPPLY. THE ROTARY ENCODER THAT WAS PURCHASED HAD A D-SHAFT, WHICH MADE IT DIFFICULT TO KEEP THE WHEEL CENTERED WHEN ATTACHED. TO SOLVE THIS ISSUE, A CAP WAS MODELED TO FIT OVER THE D-SHAFT AND PROVIDE AN INTERFERENCE FIT INTO THE WHEEL, ENSURING THAT THE ROTARY ENCODER WOULD SPIN WITH THE WHEEL. FINALLY, ROLLING PIPES ARE ATTACHED BEARINGS AND AN AXLE TO PREVENT FRICTION FROM BUILDING UP AND DAMAGING THE TETHER. AS IT WAS THE FIRST TIME THE COMPANY PUT TOGETHER A TETHER COUNTER, THE DESIGN WAS KEPT SIMPLE AND PRACTICAL.

MECHANICAL DESIGN RATIONALE

DESIGN EVOLUTION/DESIGN PROCESS

IN ITS SECOND YEAR, CRUSH DEPTH GREW ITS TEAM AND ADOPTED A DIVIDE- AND-CONQUER APPROACH. EACH TEAM BEGAN WITH RESEARCH AND DOCUMENTATION THAT CONTRIBUTED IN ESTABLISHING A SOLID REFERENCE FOR THE FUNDAMENTAL CONCEPTS ASSOCIATED WITH SCYLLA. FROM THESE INSIGHTS, VARIOUS DESIGN OPTIONS WERE EVALUATED TO DETERMINE THE MOST EFFECTIVE SOLUTIONS. THE QUALITY CONTROL DEPARTMENT CONDUCTED RIGOROUS FLUID SIMULATIONS AND TESTS THAT SUPPORTED MANUFACTURING TECHNIQUES DURING THE JOURNEY. EACH TEST LED TO IMPROVEMENTS ON THE FRAME, MANIPULATORS, AND CABLE MANAGEMENT.

THROUGH ITERATIVE TESTING, THE THRUSTER CONFIGURATION, MANIPULATOR DESIGN, AND CONTROL CODE WERE OPTIMIZED TO ACHIEVE EASY MANEUVERABILITY. THESE TESTS ALLOWED SCYLLA TO ACQUIRE CRUCIAL CHARACTERISTICS IN FUNCTIONALITY THAT INCLUDED PRECISE PITCH CONTROL, AND FAST RESPONSE TIME—FEATURES CONSIDERED IDEAL FOR EFFICIENT UNDERWATER OPERATION. THE THRUSTER LAYOUT WAS RECONFIGURED TO ENHANCE UNDERWATER MANEUVERABILITY, PRESERVING THE CORE STRUCTURAL DESIGN FOR RELIABILITY. VARIOUS MANIPULATOR DESIGNS WERE EXPLORED, INCLUDING FIXED, ARTICULATED, AND 360-DEGREE ROTATING MODELS, WITH SOME OF THESE CONCEPTS INCORPORATED TOGETHER INTO THE FINAL DESIGN TO OPTIMIZE FUNCTIONALITY FOR SPECIFIC TASKS IN DYNAMIC UNDERWATER ENVIRONMENTS. THESE ITERATIVE IMPROVEMENTS ULTIMATELY RESULTED IN A MORE RESPONSIVE, CAPABLE, AND TASK-ORIENTED ROV DESIGN THAT CAN BE PILOTED EASILY.

SOLIDWORKS SERVED AS THE MAIN CAD MODELING SOFTWARE FOR THE ENTIRETY OF SCYLLA'S DESIGN PROCESS. WITH THE USAGE OF ASSEMBLIES AND RESPECTIVE SUBASSEMBLIES, CRUSH DEPTH'S TEAMS OBTAINED THE ABILITY TO CREATE THEORETICAL MODELS THAT AIDED WITH VISUALIZATION OF EACH ITERATED COMPONENT. THIS AIDED IN REDUCING MANUFACTURING TIME AND WASTE. FIGURE #.1 FLOW SIMULATION OF THE INITIAL DESIGN REVEALED SIGNIFICANT DRAG COMING FROM FLOW SEPARATION AND TURBULENCE AROUND THE HANDLE CAVITIES. FIGURE #9 THE NEW CONFIGURATION INTRODUCED MINOR INCREASES IN SURFACE AREA AND FLOW DISRUPTION; THE SIMULATIONS SHOWED THAT THE RESULTING DRAG INCREASE WAS NEGLIGIBLE. ADDITIONALLY, THE INTRODUCTION OF FRONT-MOUNTED MANIPULATORS DID NOT SUBSTANTIALLY AFFECT THE OVERALL DRAG.

THE ADDITIONAL TETHER STRAIN RELIEF ACTS LIKE A DORSAL FIN, WHICH CONTRIBUTED TO IMPROVED DIRECTIONAL STABILITY BY DAMPENING YAW OSCILLATIONS. HARMONIOUSLY, PRECISE LATERAL THRUSTER PLACEMENT GREATLY IMPROVED BODY ROLL WHILST GIVING GREATER CONTROL IN FORWARD AND REVERSE TRANSLATION. SOLIDWORKS PARTS AND ASSEMBLY FILES WERE CONVERTED TO STL FILES TO MEET THE MANUFACTURING NEEDS FOR VARIOUS 3D PRINTING SOFTWARES. THE MAIN ONES USED BY CRUSH DEPTH WOULD BE BAMBULAB, DREMEL, AND ANKERMAKER FOR 3D PRINTING. THE MANUFACTURING PROCESS FOLLOWED A PRIORITIZED LIST BASED ON EACH COMPONENT'S IMPORTANCE TO MEETING THE ROV'S REQUIREMENTS AND THE IMMEDIACY OF ITS NEED. THE FRAME WAS ADDRESSED FIRST, AS IT FORMED THE STRUCTURAL FOUNDATION, FOLLOWED BY THE MANIPULATOR SYSTEM AND OTHER ESSENTIAL SUBSYSTEMS. VARIOUS 3D PRINTING FILAMENTS SUCH AS ABS, PETG, AND PLA WERE UTILIZED DURING THE MANUFACTURING PROCESS. THESE 3D PRINTING FILAMENTS WERE EACH CHOSEN BASED ON THEIR MATERIAL PROPERTIES, AVAILABILITY, AND SUITABILITY FOR SPECIFIC COMPONENTS. PLA WAS OFTEN USED FOR RAPID PROTOTYPING DUE TO ITS EASE OF PRINTING AND LOW COST, WHILE . PETG AND ABS WERE SELECTED FOR PARTS REQUIRING HIGHER DURABILITY. ADDITIONALLY, DIFFERENT INFILL PERCENTAGES AND PRINT PATTERNS WERE TESTED TO BALANCE STRENGTH, WEIGHT, AND MATERIAL EFFICIENCY.

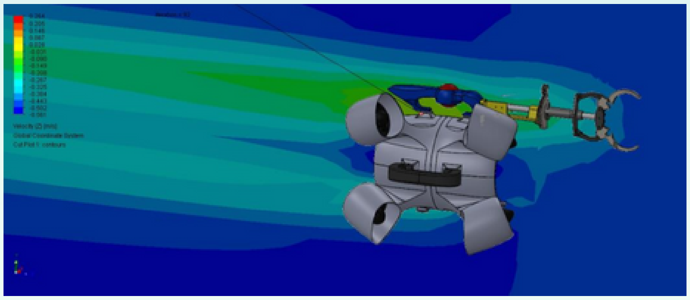

FIGURE 9: FLOW SIMULATION BY ESTEBAN VALENCIA GARCIA

FRAME

DURING THE BEGINNING STAGES OF THE FRAME DESIGN, THE COMPANY AIMED TO UTILIZE AN EIGHT-THRUSTER CONFIGURATION COMPARED TO PERCY'S SIX-THRUSTER CONFIGURATION. ONE OF THE MAIN REASONS FOR THE INCREASE IN THE THRUSTERS WAS TO HAVE PITCH CONTROL THAT PERCY DID NOT HAVE THE PREVIOUS YEAR. THE DESIGN MODEL IS CONFIGURED TO HAVE FOUR THRUSTERS ON EACH SIDE, WITH FOUR OUT OF THE EIGHT THRUSTERS AT 45-DEGREE ANGLE. THE FIRST ITERATION FOLLOWED A DESIGN WITH A CARBON FIBER CHASSIS TO MAKE IT LIGHTWEIGHT WHILE IMPROVING STRUCTURAL INTEGRITY. DUE TO BUDGET AND TIME CONSTRAINTS FOR TESTING AND MANUFACTURING OF THE FRAME, THE COMPANY DECIDED TO GO WITH A DESIGN SIMILAR TO PERCY'S FRAME. FOUR RINGS WERE UTILIZED TO CREATE AN EXOSKELETON DESIGN; EACH RING REQUIRED TWO HALF RINGS TO CREATE A CIRCULAR SHAPE AROUND THE ACRYLIC TUBE. THESE RINGS WERE UTILIZED TO ATTACH THRUSTERS AS WELL AS MOUNTING PLATES FOR MANIPULATORS, STRAIN RELIEF, AND OTHER TASK-ORIENTED TOOLS.

EACH OF THE ROV'S STRUCTURE RINGS ARE COMPOSED OF SEMICIRCLES DESIGNED AND MANUFACTURED TO PROVIDE SUPPORT ON THE BASIS OF A USER-FRIENDLY CONFIGURATION.

APART FROM THE TABS IMPLEMENTED FOR FASTENING THE HALF RINGS TOGETHER, EACH RING HALF IS DESIGNED WITH COUNTERBORE SCREW HOLES AND THRUSTER MOUNTS WITH ANGLE LOCKING GROOVES. THIS SPECIFIC DESIGN NOT ONLY PERMITS HARMONIOUS INTERACTION WITH OTHER COMPONENTS OF THE ROV, BUT ALSO PROVIDES FAST MANUFACTURING THROUGH THE USAGE OF 3D PRINTERS. THROUGHOUT THE DESIGN AND MANUFACTURE OF VARIOUS ITERATIONS OF THE ROV'S STRUCTURE RINGS, THE COMPANY WAS ABLE TO REPEATEDLY IMPROVE THE HALF RINGS FOR THE DESIRED APPLICATIONS. THE FOUR-RING STRUCTURE DESIGN ALSO TAKES INTO CONSIDERATION THE ABILITY TO ACCESS EITHER END OF THE ACRYLIC HOUSING FOR BOTH MAINTENANCE AND OPTIMAL VISION FOR THE ROV'S PILOTS.

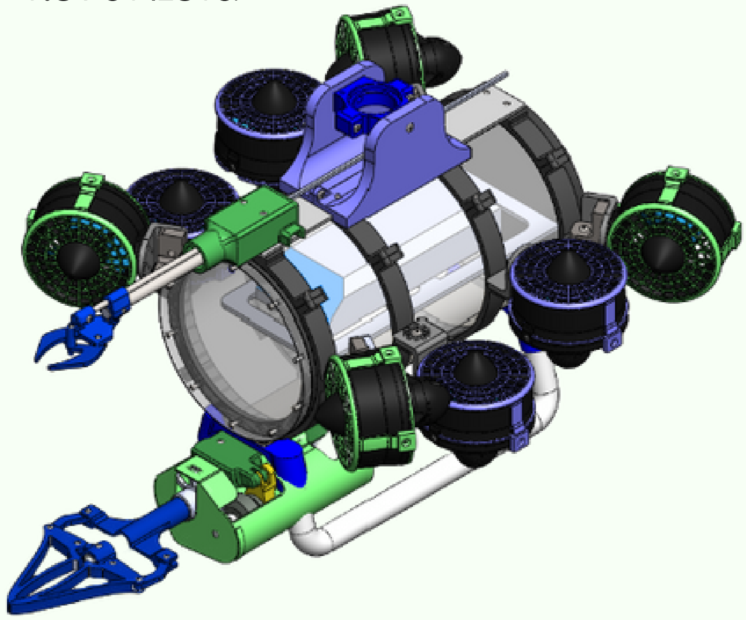

FIGURE 10: ROV ASSEMBLY (SCYLLA) BY GEVORG KAREYAN

UPON THE COMPLETION OF VARIOUS UNDERWATER PILOTING TESTS, THE THRUSTER CONFIGURATION WAS ALTERED TO PROVIDE EFFICIENT MOVEMENT WITHIN SIX DEGREES OF FREEDOM. THE NEW CONFIGURATION FEATURES FOUR CENTRALLY MOUNTED THRUSTERS PLACED ON EACH SIDE OF THE ROV. THIS NEW CONFIGURATION ALLOWED THE ROV TO INHABIT HEAVE TRANSLATION, PITCH, AND ROLL ROTATION. MEANWHILE, THE REMAINING FOUR THRUSTERS WERE MOUNTED ON EACH CORNER OF THE ROV'S ACRYLIC HOUSING, ANGLED 45 DEGREES FORWARD, GRANTING SURGE TRANSLATION, SWAY TRANSLATION, AND YAW ROTATION. UPON THE IMPLEMENTATION OF THIS ALTERATION, SCYLLA WAS ABLE TO ACHIEVE THE DESIRED PITCH CONTROL ALONGSIDE THE PREVIOUSLY ESTABLISHED FIVE DEGREES OF FREEDOM.

SCYLLA IS EQUIPPED WITH A TOTAL OF THREE CAMERAS STRATEGICALLY POSITIONED FOR THE OPTIMAL FIELDS OF VIEW. PILOTS HAVE THE ABILITY TO TOGGLE FROM THE ROV'S FRONT, DEPTH, AND TOP MANIPULATOR FACING CAMERAS.

BUOYANCY/BALLAST

DURING SCYLLA'S SUBMERGED TESTING, A NOTICEABLE POSITIVE FRONT-BIASED BUOYANCY WOULD CAUSE THE ROV TO REMAIN FACING TOWARDS THE SURFACE WITH AN UPWARD PITCH AT ALL TIMES. BUOYANCY WAS AN IMMEDIATE CHALLENGE AS THE COLLECTION BETWEEN THE ROV'S HOUSING VOLUME AND THE 3D PRINTED COMPONENTS' VOLUME, FORCED THE ROV TO THE SURFACE. WITH THE USAGE OF THEORETICAL CALCULATIONS AND EXPERIMENTAL BALLAST TO CONTROL THE OVERALL BUOYANCY, SCYLLA ACHIEVED A NEUTRAL BUOYANCY AT DEPTHS OF 3 METERS. NOT ONLY DID THE NEUTRAL BUOYANCY AT DEPTHS FROM THE SURFACE ENSURE EASE WHILE DIVING, HEAVY THRUSTER INVOLVEMENT WAS REDUCED WHILE FACILITATING PRECISE DEPTH CONTROL. DEPTH STABILITY WAS IMPROVED WHILE PERFORMING TASKS AS THE PILOTS WOULD ONLY HAVE TO FOCUS ON MINIMAL ROV POSITION CORRECTION AND CLAW ORIENTATION. EACH NEWLY REDESIGNED AND IMPLEMENTED COMPONENT WOULD DISTURB THE BUOYANCY BALANCE CAUSING RAPIDLY DESCENDING OR ASCENDING WHILE IN OPERATION. TO ADJUST TO THE CONTINUOUS BUOYANCY CHANGES, FISHING WEIGHTS WERE PLACED AND REMOVED FOR RAPID ADJUSTMENTS UNTIL AN OBSERVABLE EQUILIBRIUM BETWEEN BUOYANCY AND BALLAST WAS ACHIEVED.

ELECTRONIC HOUSING

IN CONSIDERATION OF UPCYCLING PREVIOUSLY USED COMPONENTS AND MINIMIZING THE COMPANY'S EXPENSES, PERCY'S ACRYLIC HOUSING SERVED AS THE ROV'S HUB FOR ALL OF THE ELECTRONIC COMPONENTS AND WIRING. PREVIOUSLY ACQUIRED FROM BLUEROBOTICS, THE 152 MM OD WATERTIGHT ENCLOSURE PERMITS THE COMPANY TO PROTECT, MAINTAIN AND FURTHER CONFIGURE THE ROV'S ELECTRONICS. THE HOUSING FEATURES A CLEAR ACRYLIC HOUSING FOR INTERNAL VISIBILITY, AS WELL AS AN ACRYLIC END CAP FOR THE ROV'S FORWARD-FACING CAMERA. ADDITIONALLY, AN ALUMINUM END CAP FOR BLUEROBOTICS WETLINK CABLE PENETRATORS INSTALLATION WAS USED. THE HOUSING'S END CAPS AND CABLE PENETRATORS CONTAIN O-RINGS AND CABLE SEALS COMPOSED OF NITRILE RUBBER THAT ENSURE WATERTIGHT FASTENING. DURING THE INITIAL WATER TESTING, VARIOUS LUBRICATION MATERIALS WERE USED FOR THE HOUSING O-RINGS. THESE VARIED FROM MARINE GREASE TO SILICON GREASE IN AN ATTEMPT TO ACHIEVE PROPER O-RING MAINTENANCE AND WATER SEALING OF THE END CAPS. IT WAS CONCLUDED THAT SILICON GREASE NOT ONLY PROVIDED PROPER WATER SEALING, BUT ALSO IMPROVED THE LONGEVITY AND PERFORMANCE OF THE RUBBER O-RINGS. INSIDE THE HOUSING REMAINS AN ELECTRONIC COMPONENT MOUNTING PLATE THAT ALLOWS COMPONENT ORGANIZATION AND CABLE MANAGEMENT THAT PREVENTS UNNECESSARY FORCES FROM INFLUENCING THE HOUSING END CAPS.

TETHER

THE DESIGN FOR THE ROV'S STRAIN RELIEF IS BASED AROUND A COMMERCIAL OFF-THE-SHELF (COTS) THREADED STAINLESS STEEL MESH STRAIN RELIEF. THE MESH STRAIN RELIEF IS CONNECTED TO THE TETHER HOLDER BLOCK BY A JOINT, WHICH IS INTENTIONALLY PLACED ON THE ROV'S TOP SIDE MOUNTING PLATE. THIS PERMITS THE TETHER TO REMAIN ORIENTED TOWARDS THE SURFACE WHILE PREVENTING DISRUPTION ON THE ROV'S CENTER OF GRAVITY AND UNNECESSARY TETHER MANIPULATION DURING OPERATION.(FIGURE 10).THE TETHER STRAIN RELIEF TAKES ON A THREE-PIECE DESIGN, WHICH INCLUDES THE HOLDER BLOCK, MESH STRAIN RELIEF, AND JOINT. THE STRAIN RELIEF'S JOINT COMPONENT PROVIDES A THREADING POINT TO SECURE THE MESH STRAIN RELIEF ONTO THE PIVOTING ASSEMBLY. THE PIVOTING MOTION IS MADE POSSIBLE WITH TWO FASTENERS THAT SECURE THE JOINT ONTO THE TETHER HOLDER BLOCK. DURING THE MANUFACTURING PROCESS, THE TETHER HOLDER BLOCK WAS SECTIONED INTO TWO SYMMETRICAL PARTS. NOT ONLY DOES THIS TYPE OF SECTIONING PROMOTE FASTER MANUFACTURING TIME, BUT ALSO ALLOWS STRONGER 3D PRINTING AS THE PIECES ARE PRINTED PERPENDICULAR TO THEIR APPLICATION TO ELIMINATE STRESS FRACTURES.

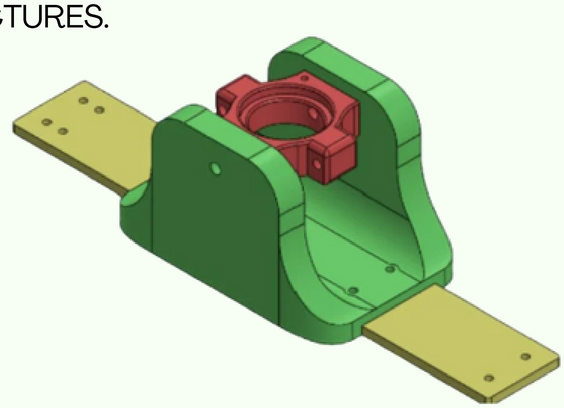

FIGURE 11:TETHER STRAIN RELIEF BY RANA EYIT

CLAWS:

INITIALLY, SCYLLA FEATURED A SINGLE STATIONARY CLAW MODELED AFTER ONE OF PERCY'S PRIMARY MANIPULATORS. THE REVISED DESIGN NOW UTILIZES TWO BRUSHLESS MOTORS PAIRED WITH A FOUR-GEAR ASSEMBLY, PROMOTING ROTATIONAL EFFICIENCY AND SUITABLE TORQUE FOR NECESSARY OPERATIONS. THE GEAR ARRANGEMENT IS DESIGNED TO PERMIT THE OPENING/CLOSING OF THE CLAW PRONGS AND 360 DEGREES OF ROTATION. CHOSEN FOR THEIR HIGH EFFICIENCY, LONGER LIFESPAN, TORQUE CONTROL, AND COMPACT DESIGN, BRUSHLESS MOTORS ARE USED AS THE PRIME SOURCE OF MOVEMENT FOR THE PRIMARY CLAW. WHILE TESTING, THE HIGH NOMINAL RPM OF THE BRUSHLESS MOTORS OPPOSED PRECISE MOVEMENTS WHILE PERFORMING TASKS. AS A SOLUTION TO THE HIGH RPM RATE, THE CLAW GEARS ARE SUBJECTED TO A 6:1 GEARING RATIO, PROVIDING THE CLAW WITH A LOWER RPM SPEED WHILE PROMOTING A HIGHER TORQUE FOR TASK COMPLETION.

THE SIMPLISTIC SOLENOID DRIVEN SECONDARY CLAW GIVES PILOTS THE ABILITY TO MAINTAIN A HOLD ON OBJECTS WHILE THE PRIMARY CLAW FURTHER INTERACTS WITH THE POSSESSED OBJECTS. A SOLENOID MOTOR WAS CHOSEN FOR ITS QUICK RESPONSE TIME, RELIABILITY AND EFFICIENCY TO COMPLETE NECESSARY TASKS BY CONVERTING LINEAR MOVEMENT INTO ROTATIONAL MOTION. THIS MOTOR CONTRIBUTED IN THE FUNCTIONALITY OF ALLOWING THE CLAW TO OPEN AND CLOSE. WHILE KNOWN FOR THEIR HEAT INCREASE DURING OPERATION, THE APPLICATION OF A SOLENOID MOTOR IN UNDERWATER TASKS, PROVIDES THE SOLENOID MOTOR WITH ENVIRONMENTAL HEAT CONTROL

SUPPORT LEG MECHANISM:

KEEPING ROV MAINTENANCE AND CLAW PROTECTION IN MIND, SCYLLA IS EQUIPPED WITH BOTTOM MOUNTED SUPPORT LEGS. THE SIMPLICITY OF THE DESIGN ALLOWS SCYLLA TO STAND AT AN ELEVATED HEIGHT OFF OF THE GROUND. THIS ALLOWS EASE IN CONDUCTING SURFACE SIDE MAINTENANCE AND PRE-DIVE PREPARATIONS. THE SUPPORT LEG'S 60 DEGREE ANGLE RELATIVE TO THE GROUND WAS CHOSEN TO PROVIDE CLEARANCE FOR THE PRIMARY CLAW AND FOR ROV STATIC LOAD SUPPORT. THE LEG SUPPORTS WERE NOT CONNECTED TO IMPROVE MANUFACTURING TIME AND REDUCE MATERIAL WASTE.

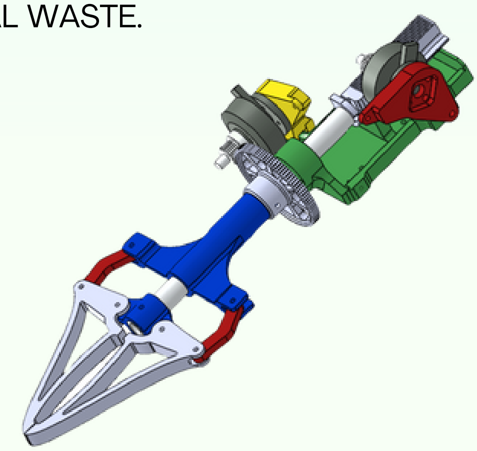

FIGURE 12: PRIMARY CLAW BY GEVORG KAREYAN

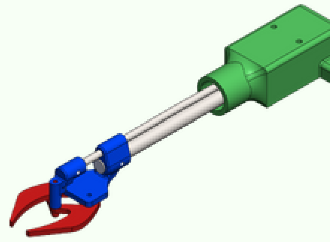

FIGURE 13: SECONDARY CLAW BY GEVORG KAREYAN

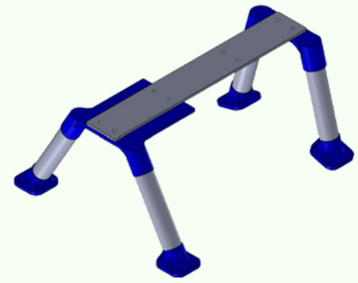

FIGURE 14: SUPPORT LEGS BY KATHERINE HERNANDEZ

PH PROBE AND WATER SAMPLE:

THE INITIAL PH MEASUREMENT AND WATER COLLECTION DESIGN INVOLVED A SINGLE, INTEGRATED SYSTEM MOUNTED BENEATH THE ROV. THIS SYSTEM WAS INTENDED TO DRAW SOLUTION FROM THE 5-GALLON BUCKET VIA A HOSE INTO A 100 ML SYRINGE, WHERE THE PH PROBE WOULD BE POSITIONED INTERNALLY TO ALLOW FOR DIRECT IN-LINE TESTING. HOWEVER, AFTER REVIEWING THE MISSION FLY-THROUGH VIDEO, THE TEAM DECIDED TO TREAT THE PH AND WATER SAMPLE TASKS AS DISTINCT OPERATIONS, PROMPTING A SHIFT TO SEPARATE SYSTEMS FOR GREATER FLEXIBILITY AND TASK ALIGNMENT.

THE CURRENT DESIGN STRATEGY UTILIZES BOTH MANIPULATORS TO GRASP A SYRINGE AND DRAW IN A WATER SAMPLE SECURELY. A PRE-CALIBRATED PH PROBE WILL BE POSITIONED WITHIN THE MANIPULATOR'S GRASP TO OBTAIN AN IN-SITU PH MEASUREMENT. THE MANIPULATOR WILL THEN INSERT THE PROBE DIRECTLY INTO THE SOLUTION, ENABLING REAL-TIME MONITORING OF PH LEVELS DURING SAMPLE COLLECTION.

FIGURE 15: GAOHOU PH PROBE BY ARMAAN DHAH

THRUSTER SHROUDING:

CONSIDERING MAXIMUM FLOW CAPACITY OF THE T200 THRUSTERS, SCYLLA'S THRUSTER SHROUDS WERE DESIGNED WITH A CONCENTRIC RING PATTERN INSPIRED BY THE SAFETY GRILLES COMMONLY FOUND ON HOUSEHOLD FANS. THE SPACING OF THESE RINGS WAS CAREFULLY CHOSEN TO PREVENT FINGERS OR OTHER BODY PARTS FROM REACHING THE INTERIOR OF THE THRUSTER WHILE REMAINING IP-20 COMPLIANT. TO MINIMIZE ADDITIONAL HARDWARE, THE TEAM MOUNTED BOTH SIDES OF THE SHROUD USING THREE PRE-EXISTING SCREWS ON EACH OF THE BLUEROBOTICS T200 THRUSTERS.

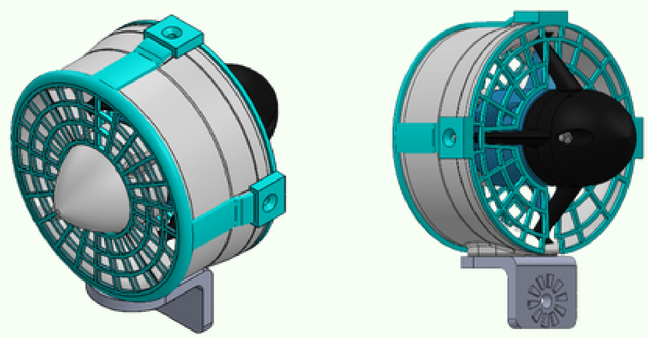

FIGURE 16: THRUSTER SHROUDS BY KATHERINE HERNANDEZ

LOGISTICS

COMPANY ORGANIZATION

CRUSH DEPTH IS A COMMUNITY COLLEGE ENGINEERING TEAM WITH OVER 30 MEMBERS, OPERATING UNDER A STRUCTURED AND COLLABORATIVE LEADERSHIP MODEL THAT FOSTERS INNOVATION, ACCOUNTABILITY, AND TEAM COHESION. THE CHIEF EXECUTIVE OFFICER (CEO) PROVIDES OVERALL DIRECTION AND ENSURES ALIGNMENT WITH THE TEAM'S MISSION, WHILE THE CHIEF OPERATING OFFICER (COO) MANAGES DAILY OPERATIONS AND COORDINATES BETWEEN DEPARTMENTS. SUPPORTING THEM ARE SEVERAL C-LEVEL OFFICERS: THE CHIEF TECHNOLOGY OFFICER (CTO) LEADS TECHNICAL DEVELOPMENT, INCLUDING PROGRAMMING AND ELECTRICAL TASKS, AND OVERSEES THE ROV, FLOAT, AND SURFACE SIDE LEADS. THE CHIEF LOGISTICS OFFICER (CLO) MANAGES EQUIPMENT, SCHEDULING, TRANSPORTATION, BUDGETING, AND SPONSORSHIP COMMUNICATION. THE CHIEF MARKETING OFFICER (CMO) HANDLES BRANDING, VISUAL CONTENT, AND PUBLIC OUTREACH. THE CHIEF COMPLIANCE OFFICER (CCO) ENSURES RULE, SAFETY, AND DOCUMENTATION COMPLIANCE, SUPPORTED BY THE CHIEF QUALITY OFFICER (CQO), WHO UPHOLDS THE QUALITY OF DELIVERABLES. THE CHIEF DESIGN OFFICER (CDO) LEADS THE DEVELOPMENT OF PHYSICAL DESIGNS, WORKING WITH THE ROV AND FLOAT DESIGN LEADS. DEPARTMENT LEADS MENTOR MEMBERS, MANAGE WORKFLOWS, AND REPORT TO THEIR RESPECTIVE OFFICERS, WHO COLLABORATE WITH THE COO AND CEO TO MAINTAIN ALIGNMENT AND TRANSPARENCY. THIS ORGANIZATIONAL MODEL ENABLES EFFICIENT COMMUNICATION, CLEAR DELEGATION, AND A COLLABORATIVE ENVIRONMENT WHERE INNOVATION THRIVES.

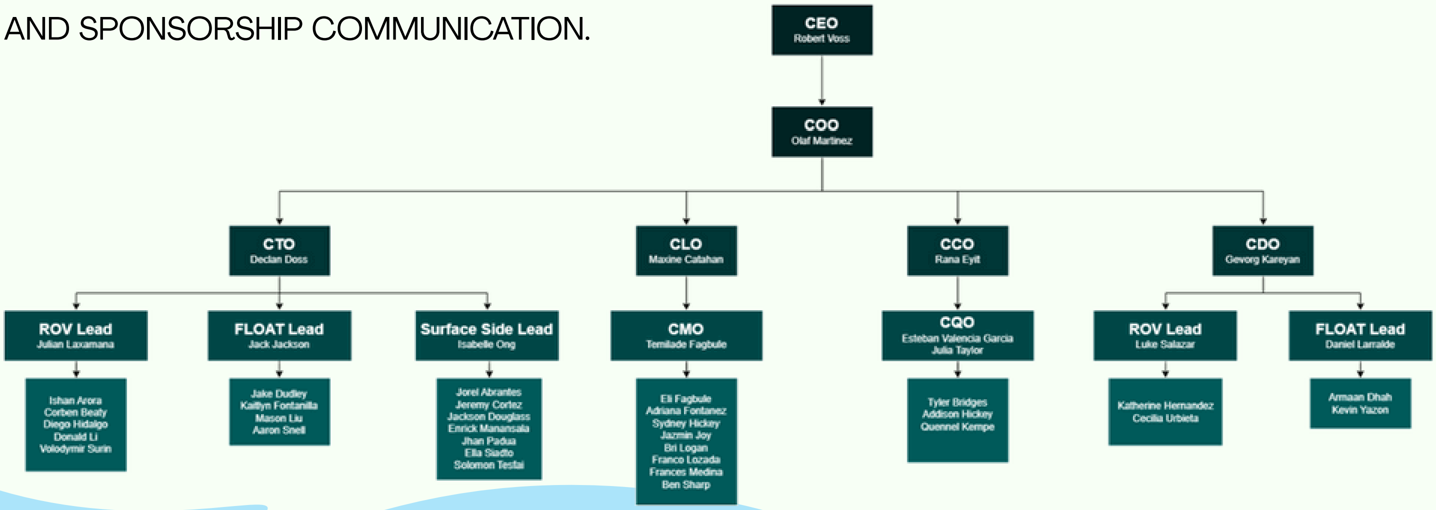

FIGURE 17. ORGANIZATIONAL CHART BY MAXINE CATAHAN

COLLABORATIVE WORKSPACE

THE COMPANY RELIES ON A VARIETY OF DIGITAL PLATFORMS TO STREAMLINE COMMUNICATION, DOCUMENTATION, TIME MANAGEMENT, AND COLLABORATION ACROSS THE TEAM. THESE TOOLS INCLUDE GOOGLE DRIVE, CANVAS, DISCORD, CLOCKIFY, MICROSOFT WORD, AND CANVA, EACH SERVING A UNIQUE PURPOSE TO SUPPORT EFFICIENT REMOTE AND IN-PERSON WORK. GOOGLE DRIVE IS USED TO STORE MEETING MINUTES, 3D DESIGNS, AND ANY DOCUMENTATION THAT THE COMPANY MIGHT NEED IN THE FUTURE, ENSURING THAT ALL CRITICAL INFORMATION IS EASILY ACCESSIBLE AND WELL-ORGANIZED. DISCORD IS EMPLOYED TO MAINTAIN CONSTANT COMMUNICATION AND COLLABORATION AMONG TEAM MEMBERS, ENABLING THEM TO SHARE UPDATES AND RESOURCES SEAMLESSLY. CLOCKIFY, A TIME-TRACKING TOOL, IS USED BY ALL MEMBERS TO LOG THE HOURS THEY DEDICATE TO SPECIFIC TASKS AND PROJECTS, HELPING THE TEAM MONITOR CONTRIBUTIONS, MANAGE WORKLOADS, AND MAINTAIN ACCOUNTABILITY. MICROSOFT WORD IS COMMONLY USED FOR WRITING AND ORGANIZING OFFICIAL DOCUMENTATION, INCLUDING PROPOSALS, REPORTS, AND TECHNICAL MANUALS. ADDITIONALLY, CANVA IS UTILIZED BY THE MARKETING TEAM OF THE COMPANY TO CREATE PROMOTIONAL MATERIALS, SOCIAL MEDIA GRAPHICS, AND OTHER VISUAL CONTENT.

BY LEVERAGING THESE DIGITAL TOOLS, THE TEAM ENSURES THAT ALL MEMBERS HAVE ACCESS TO NECESSARY RESOURCES AND CAN CONTRIBUTE TO PROJECTS IN REAL TIME, PROMOTING FLEXIBILITY, TRANSPARENCY, AND PRODUCTIVITY.

OUTREACH

THE TEAM ENGAGED IN MULTIPLE OUTREACH EFFORTS THROUGHOUT THE SEASON TO PROMOTE STEM AWARENESS AND SHARE THEIR WORK WITH THE BROADER COMMUNITY. THESE INCLUDED SHOWCASING THE ROV AT BOTH COLLEGE-HOSTED AND COMMUNITY EVENTS, ALLOWING STUDENTS, FACULTY, AND MEMBERS OF THE CLOVIS AND FRESNO COMMUNITIES TO GAIN INSIGHT INTO THE ENGINEERING, DESIGN, AND PROBLEM-SOLVING INVOLVED IN THE MATE ROV COMPETITION. THROUGH THESE EVENTS, THE TEAM NOT ONLY FOSTERED INTEREST IN UNDERWATER ROBOTICS AND TECHNICAL EDUCATION, BUT ALSO BUILT MEANINGFUL CONNECTIONS WITH STUDENTS, EDUCATORS, PROFESSIONALS, AND LOCAL ORGANIZATIONS. THESE INTERACTIONS PROVIDED OPPORTUNITIES FOR MENTORSHIP, COLLABORATION, AND FUTURE SUPPORT. OVERALL, THE OUTREACH EFFORTS STRENGTHENED COMMUNITY TIES, HIGHLIGHTED THE VALUE OF HANDS-ON STEM EXPERIENCES, AND SUPPORTED THE TEAM'S MISSION TO INSPIRE AND CONNECT WITH THE NEXT GENERATION OF INNOVATORS.

SAFETY

SAFETY PHILOSOPHY

CRUSH DEPTH HAS ALWAYS MADE IT A TOP PRIORITY TO MAINTAIN THE SAFETY AND INTEGRITY OF ITS PRACTICES. THIS YEAR OUR COMPLIANCE DIVISION CREATED MANY CHECKLISTS FOR USE DURING ASSEMBLY TESTING AND OPERATIONS. THESE INCLUDE CHECKLISTS FOR ROV AND FLOAT TESTING, FOLLOWING MATE ROV GUIDELINES FOR SAFTEY PROTOCOLS. THESE CHECKLISTS HAVE LED TO POSITIVE RESULTS IN EFFICIENCY AND LESS INCIDENTS OVERALL.

ROV OPERATIONAL SAFETY

CRUSH DEPTH DEDICATED NUMEROUS HOURS TO ENSURING PERCY MET AND EXCEEDED ALL SAFETY GUIDELINES OUTLINED IN THE 2025 COMPETITION MANUAL. ON TOP OF THIS, EMPLOYEES FOLLOW AN EXTENSIVE SAFETY PROTOCOL CHECKLIST BEFORE ATTEMPTING TO OPERATE THE ROV. DURING OPERATION, THE FOLLOWING SAFETY RULES ARE IMPLEMENTED:

EMPLOYEES ENSURE THAT ALL ITEMS ARE ATTACHED TO THE ROV AND NO CABLES ARE EXPOSED.

OPERATIONAL SAFETY

SOME EXAMPLES OF OUR COMMITMENT TO KEEP OUR MEMBERS PROTECTED WHILE DEALING WITH ELECTRONICS, CHEMICALS AND SHARP TOOLS ARE REQUIRING SAFETY GLASSES WHEN USING POWER TOOLS, ALWAYS WEARING CLOSED-TOED SHOES TO MEETINGS WITH EQUIPMENT OUT, AND THE USE OF CHEMICALS TO BE IN A WELL-VENTILATED AREA WITH SAFETY GLOVES ON. ANY MISTAKES OR INCIDENTS ARE OT BBE REPORTED TO LEADERSHIP TO SOLVE THIS ISSUE IN THE FUTURE.

FIGURE 18: SAFETY REGULATIONS BY LUKE SALAZAR

NON-ROV DEVICE: VERTICAL PROFILING FLOAT

THE FLOAT'S OBJECTIVE IS TO AUTONOMOUSLY DESCEND IN A POOL OF WATER TO A DEPTH OF 2.5 METERS, COLLECT DATA, RISE TO THE SURFACE, AND COMMUNICATE WITH OUR BASE STATION. THE DEVICE MUST COMPLETE THIS SERIES OF TASKS TWICE TO RECEIVE A MAXIMUM OF 70 POINTS IT COMPLETES THIS TASK BY USING A SINGLE LARGE PISTON BUOYANCY ENGINE DRIVEN BY A CREALITY 42-34 STEPPER MOTOR.

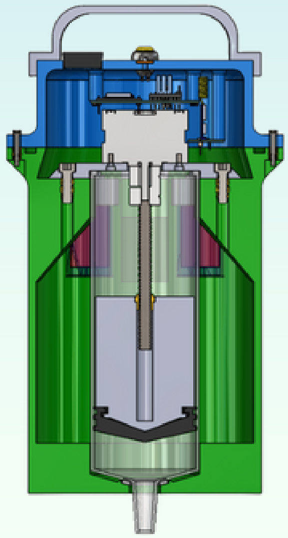

FIGURE 19: FLOAT SECTION VIEW BY LUKE SALAZAR

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CONCLUSION

CHALLENGES

ONE OF THE GREATEST CHALLENGES CRUSH DEPTH FACED THIS YEAR WAS THE INFLUX IN COMPANY SIZE. ALTHOUGH THERE WERE MORE MEMBERS TO AID IN THE PROCESS OF DESIGN, PRODUCTION, AND TESTING, THE COMPANY HAD TO UNDERGO MAJOR IMPROVEMENTS IN MANAGEMENT TO BE SUCCESSFUL THIS YEAR. MORE TEAM LEADS WERE INSTALLED AND SUB-TEAMS REGULARLY MET IN ADDITION TO FULL TEAM MEETINGS.

DURING TESTING FOR THE COMPANY PRODUCT DEMONSTRATION, PILOTS HAD DIFFICULTY MAINTAINING ELEVATION WHILE KEEPING SCYLLA STILL. THE MAIN REASON FOR THIS WAS DUE TO THE ORIGINAL THRUSTER CONFIGURATION. IN ORDER TO COMPLETE THE PRODUCT DEMONSTRATION IN REASONABLE TIME, THE COMPANY HAD TO REDESIGN SCYLLA'S EXOSKELETON AND MANUFACTURE IT WITHIN THREE DAYS.

FUTURE IMPROVEMENTS

CRUSH DEPTH IS FOCUSING ON IMPROVING THE CLAWS, ERGONOMICS, AND SAFETY OF OUR PRODUCT. WE PLAN TO INCREASE THE FIXED CLAW'S RANGE OF MOTION, OPENING, AND CLOSURE SPEED. AN IMPROVED STAND FOR THE ROV, AS WELL AS HANDLES TO EASE ITS TRANSPORT IS PLANNED. ADDITIONALLY, THE ABILITY OF TEAM MEMBERS TO OPERATE ON IT WITH THE PROPER HANDLES WOULD BE IMRPOVED. INTERNAL VOLT AND AMMETER TO MEASURE POWER DRAW, AS WELL AS INSURING COMPONENTS DO NOT OVERHEAT IN THE ROV CASING IS ONE OF OUR NEXT STEPS. INSTALLING A CAMERA RIG TO MOVE THE CLAW CAMERA, WHICH WILL IMPROVE THE PILOTS' ABILITY TO TACKLE MISSIONS. CREATING A MODE IN WHICH THE ROV CAN OPERATE IN A "NOSE DOWN" ORIENTATION WILL BE USEFUL FOR TASKS REQUIRING CLOSE PROXIMITY TO THE BOTTOM OF THE POOL. FINALLY, CREATING A NEW AXIS OF ROTATION ABOUT THE CENTER OF THE FIXED CLAW WILL ENABLE QUICK AND SIMPLE ALTERATIONS TO THE ROV'S POSITION, SPEEDING UP COMPLETION OF OUR MISSIONS.

ACKNOWLEDGEMENTS

CRUSH DEPTH WOULD LIKE TO EXTEND OUR DEEPEST GRATITUDE TO THE INDIVIDUALS AND ORGANIZATIONS WHO HAVE GENEROUSLY LENDED SUPPORT THROUGHOUT THIS TEAM'S ROV JOURNEY:

MATE ROV - PROVIDED US WITH FUNDS & TRAVEL EXPENSES

MARINE TECHNOLOGY SOCIETY - PROVIDED US WITH FUNDS

MID-STATE GRAPHICS - PROVIDED OUR T-SHIRTS

THE PRINTING ELVES - PROVIDED OUR FILAMENTS

PODER - FUNDED $6,000 TO OUR ORGANIZATION

CCC ASSOCIATED STUDENT GOVERNMENT - GAVE US FUNDS & BUDGETS

CLOVIS COMMUNITY COLLEGE - ACCESS TO 3D PRINTERS & FILAMENT

WOODWARD PARK PI DAY RUN - PROVIDED US WITH FUNDS

FRESNO CITY SOCIETY OF WOMEN ENGINEERS - PROVIDED US WITH FUNDS

MR. KHAIRA & MR. BOHAN - OFFERED THEIR TIME, GUIDANCE, AND UNWAVERING SUPPORT

APPENDIX

GANTT CHART

PROJECT TITLE	MATE ROV						COMPANY	CRUSH DEPTH	
PROJECT DETAILS							DELIVERABLES	COST/HOURS	
STATUS	PRIORITY	START DATE	END DATE	DURATION (HRS)	TASK NAME	ASSIGNEE	% DONE	ESTIMATED HOURS	ACTUAL HOURS
DESIGN							**99%**	**912**	**1,087**
Complete	High	2/14/25	4/15/25	61	Float	FLOAT Team	100%	487	532
Complete	High	2/20/25	3/25/25	35	Frame	Design Team	100%	35	49.6
Complete	High	2/24/25	3/25/25	29	Outer rings	Katherine Hernandez, Rana Eyit	100%	53	63
Complete	High	3/14/25	3/30/25	16	Thrusters Configuration	Gevorg Kareyan, Olaf Martinez	100%	20	27
Complete	High	3/14/25	3/30/25	16	Shrouds	Luke Salazar	100%	16	45
Complete	Medium	3/14/25	4/5/25	21	Rigging	Gevorg Kareyan	100%	20	29.4
Complete	High	3/20/25	4/15/25	25	Claws	Design Team	100%	256	297
Complete	High	3/25/25	4/15/25	21	pH Probe	Julia Taylor	95%	25	44
PROGRAMMING / ELECTRICAL							**100%**	**1,046**	**1,373**
Complete	High	2/14/25	3/25/25	41	Electrical system	Julian Laxamana, Donald Li, Gevorg Kareyan, Olaf Martinez	100%	452	512
Complete	High	2/14/25	3/25/25	41	Motor Program	Julian Laxamana, Donald Li	100%	61	87
Complete	High	3/2/25	4/1/25	29	ALS system	Jack Jackson, Julian Laxamana	100%	41	72
Complete	High	3/31/25	5/1/25	31	GUI	Surface Side Team	100%	142	153
Complete	High	4/1/25	5/5/25	34	Float Electrical	FLOAT Team	100%	150	247
Complete	High	4/1/25	5/5/25	34	Float Program	FLOAT Team	100%	200	302
MANUFACTURING							**100%**	**342**	**525**
Complete	High	2/26/25	4/15/25	49	Electronics Assembly	Design/Electrical Team	100%	72	106
Complete	High	3/2/25	4/16/25	44	Manipulators	Luke Salazar, Gevorg Kareyan, Rana Eyit, Olaf Martinez	100%	72	72
Complete	High	3/30/25	4/20/25	20	Thruster mounts	Luke Salazar, Gevorg Kareyan, Rana Eyit, Olaf Martinez	100%	55	55
Complete	High	4/1/25	5/2/25	31	Float	Luke Salazar	100%	73	222
Complete	High	4/15/25	5/6/25	21	Water testing	Quality Control/Design/Electrical Team	100%	70	70
QUALITY CONTROL							**100%**	**73**	**87**
Complete	High	1/15/25	2/18/25	33	Shop / product demo checkists	Addison Hickey, Tyler Bridges	100%	15	16
Complete	High	2/28/25	3/15/25	15	Testing procedures	Tyler Bridges	100%	12	12
Complete	High	3/16/25	4/1/25	15	Initial data collection	Julia Taylor	100%	18	18
Complete	High	3/16/25	4/1/25	15	Initial data reports	Quality Control Team	100%	5	8.2
Complete	High	4/18/25	4/30/25	12	Final data collection	Quality Control Team	100%	7	6.9
Complete	High	4/20/25	5/1/25	11	FLOAT regulatory checklist	Julia Taylor	100%	5	8.7
Complete	High	4/20/25	5/1/25	11	Job site safety checklist	Quality Control Team	100%	6	9.5
Complete	High	4/21/25	5/5/25	14	Final data reports	Quality Control Team	100%	5	7.2
LOGISTICS / MARKETING							**96%**	**379**	**464**
Complete	Medium	1/10/25	3/2/25	52	Create social media accounts	Marketing & Logistics Team	100%	35	41
In Progress	Medium	1/10/25	5/5/25	115	Collecting funds (fundraising, grants..etc)	Maxine Catahan, Temi Fagbule & Logistics Team	100%	75	78
Complete	High	1/31/25	3/20/25	50	Parts budget	Logistics Team	100%	65	66
Complete	High	2/2/25	3/20/25	48	Travel budget & plan	Robert Voss, Rana Eyit, Maxine Catahan	100%	70	92.7
Complete	Medium	3/15/25	5/2/25	47	Uniforms	Temi Fagbule	100%	19	21
Complete	High	4/5/25	5/21/25	46	Technical Documentation	All Teams	100%	70	81
In Progress	High	4/15/25	6/1/25	46	Marketing Display	Marketing Team	75%	45	84

TABLE 1. GANTT CHART BY MAXINE CATAHAN & RANA EYIT

BUDGET & ACCOUNTING

Expense Details				
Description	**Type**	**Quantity**	**Cost per Unit**	**Total Cost**
Hotel (6 rooms * 6 nights)	Accommodation	36	$89.00	$3,204.00
Airfare (round trip from Sacramento - Detroit)	Transportation	12	$539.00	$6,468.00
Van (wheelchair accessible; 6 passengers)	Transportation	1	$763.00	$763.00
Van rental	Transportation	1	$1,925.00	$1,925.00
Meal Stipend	Food/Dining	60	$50.00	$3,000.00
Gas for both vehicles	Transportation	86	$3.30	$283.80
Car Travel	Transportation	1101	$0.70	$770.70

Table 2. Travel Expense Breakdown by Robert Voss, Maxine Catahan & Rana Eyit

Task	Priority	Category	Status	Start date	End date	Financials	Amount	Deliverable	Notes
College Funding	Completed	Funding	Completed	2/28/2025	2/28/2025	Funding	$1,000.00	Gift Funding from CCC	Done
College Funding	Completed	Funding	Completed	2/28/2025	2/28/2025	Funding	$100.00	Gift Funding from ASG	Done
College Funding	High	Funding	Completed	2/28/2025	2/28/2025	Funding	$1,000.00	from ASG	Not yet sure
Curry Pizza Company	Completed	Fundrasing	Completed	2/1/2025	2/6/2025	Fundraising	$218.99	Fundraised thru CPC	Done
Panda Express	Completed	Fundrasing	Completed	12/13/2024	12/13/2024	Fundraising	$38.00	Fundraised thru Panda Express	Done
In n Out	Low	Fundrasing	In progress	2/28/2025	4/11/2025	Fundraising	$50.00	Fundraised thru In n Out	In Progress, 7 left
Pi Day STEM Booths	Completed	Fundraising	Completed	3/21/2025	3/21/2025	Donation	$600.00	Donated after Competition	N/A
FCC	Medium	Fundraising	Completed	3/21/2025	3/21/2025	Donation	$321.00	FCC donation	Thru check
See's Candy	Completed	Fundraising	Completed	3/7/2025	4/4/2025	Fundraising	$159.70	Fundraised thru See's Candy	Check pending
Mountain Mike's Pizza	Completed	Fundraising	Completed	4/3/2025	4/3/2025	Fundraising	$150.73	Fundraised thru Mountain Mikes	Check pickup
Deli Delicious	Medium	Fundraising	In progress	5/9/2025	5/9/2025	Fundraising		Fundraised thru Deli Delicious	Notes
Dave & Busters	Medium	Fundraising	Completed	2/26/2025	5/6/2025	Fundraising	$35.94	Fundraised thru Dave&Busters	Check pending
Chipotle	Medium	Fundraising	Cancelled	4/26/2025	4/26/2025	Fundraising	$0.00	Did not reach fundraising goal to earn enough profit	Did not reach $
Go-FundMe	Medium	Fundraising	In progress	4/21/2025	6/13/2025	Donation	$1,025.00	Donations recieved from anyone	Online
Basket Auction	Completed	Fundraising	Completed	5/7/2025	5/7/2025	Fundraising	$684.00	Funds recieved thru basket auction	Funds collected
Spring Extravaganza raffle	Completed	Fundraising	Completed	5/7/2025	5/7/2025	Fundraising	$123.00	Raffle ticket $5 each	Funds collected
Total so Far		Category		2/28/2025	2/28/2025		$5,506.36	Deliverable	Goal: $8k

Table 3. Collected Funds Summary

# Order No.	Item	Status	Submission Date	Approval Date (Officers)	Approval Date (Club)	Cost
1	Taiss/AB 2 Phase I	Delivered CEO A	1/3/2025	1/3/2025	1/1/2025	$18.99
2	BIGTREETECH TM(	Delivered Team	3/6/2025	3/6/2025	1/1/2025	$26.99
3	RYLR896 Lora Mod	Delivered CEO A	3/6/2025	3/6/2025	1/1/2025	$31.80
4	ESP32 DEVKIT	Delivered	3/7/2025	3/7/2025	1/1/2025	$15.98
5	Fuse 0314.750MXF	Delivered	3/7/2025	3/7/2025	1/1/2025	$17.51
6	GL.iNet GL-SFT120	Delivered	3/7/2025	3/7/2025	1/1/2025	$37.34
7	500ml Large Syring	Delivered	3/7/2025	3/7/2025	1/1/2025	$21.64
8	Digital Caliper Mea	Delivered	3/7/2025	3/7/2025	1/1/2025	$25.99
9	Safety Glasses Cry:	Delivered	3/7/2025	3/7/2025	1/1/2025	$45.90
10	ABS / Black (40101	Delivered	3/7/2025	3/7/2025	1/1/2025	$19.25
11	Amazon Basics 3ft	Delivered	3/7/2025	3/7/2025	1/1/2025	$13.50
12	2-Pack Spa and Po	Delivered	3/7/2025	3/7/2025	1/1/2025	$11.87
13	Amazon Basics 5-F	Delivered	3/7/2025	3/7/2025	1/1/2025	$11.29
14	6ft Micro USB Cabl	Delivered	3/7/2025	3/7/2025	1/1/2025	$11.75
15	HiLetgo PCA9685 '	Delivered	3/7/2025	3/7/2025	1/1/2025	$9.62
16	PLA Basic - Black (	Delivered	3/7/2025	3/7/2025	1/1/2025	$16.25
17	ABS / Silver (40102	Delivered	3/7/2025	3/7/2025	1/1/2025	$32.50
18	15Pcs GIKO N95 Re	Delivered	3/7/2025	3/7/2025	1/1/2025	$38.66
19	Teyleten Robot GY-	Delivered	3/7/2025	3/7/2025	1/1/2025	$16.25
20	RYLR896 Lora Mod	Delivered	3/7/2025	3/7/2025	1/1/2025	$15.90

Table 4. Materi