Desert WAVE (Women inAutonomous Vehicle Engineering)

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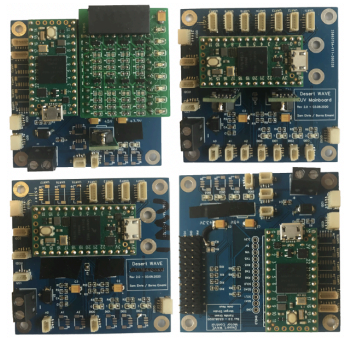
Abstract - Desert WAVE (Women in Autonomous Vehicle Engineering) is preparing for the 2025 RoboSub Competition with the return of its two autonomous underwater vehicles (AUVs), *Dragon* and *Baby Dragon*. Both AUVs have undergone significant upgrades through iterative testing and design refinements, enabling them to perform tasks that were previously beyond their capabilities in past competitions.

Design Strategy

Dragon

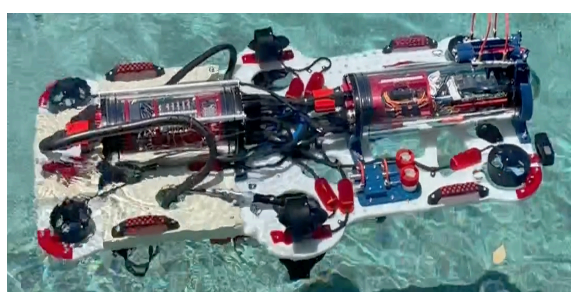


Electrical Boards - Dragon features four custom student-designed boards. The AUV Main Board handles system-wide communication. The Pneumatics Board controls solenoids and manipulators, while the Thruster Board manages all ten thrusters. The Sensor Integration Board gathers data from sensors including the fiber optic gyro (FOG), doppler velocity log (DVL), depth sensor, and Subsonus hydrophone array. *(Student-made boards are depicted on the right)*

Fiber Optic Gyroscope - The FOG[1] detects orientation by sending two laser beams in opposite directions through a coiled fiber optic cable and measuring time differences caused by movement. Integrated with the DVL and depth sensor, it enables Dragon to navigate missions with high precision.

Subsonus - The Subsonus[2] system detects acoustic pings to determine both the direction and distance to a sound source using its hydrophone array. This data enables precise navigation toward the transmitter. This year, it was tested using previous data and additional water trials to refine accuracy.

Doppler Velocity Log - The DVL[3] measures velocity relative to the seafloor by emitting four acoustic pings and analyzing the Doppler shift in their return. It calculates displacement over time to track movement from the starting point. Proven accurate in past competitions, the DVL will continue to provide reliable velocity and displacement data this season. See fig. 1 in Appendix A for accuracy details.

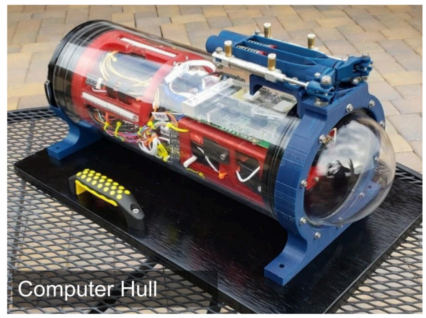


Chassis - Dragon's modular chassis includes separate hulls for the computer, thruster controllers, batteries, and pneumatics. This design enhances reliability by isolating components—e.g., dual battery hulls limit damage from leaks and reduce electrical noise from thrusters affecting sensitive systems. Initial buoyancy tests were conducted using a wooden chassis. Based on the results, high-density polyethylene (HDPE) was chosen for the final frame due to its near-neutral buoyancy and ease of machining *(see above image)*. The modular hulls simplified system integration and enabled parallel manufacturing. The long, narrow shape—modeled after a submarine—improves hydrodynamics, reducing drag and increasing speed in the surge direction.

Thruster Hull - The thruster hull houses all propulsion electronics, including the fuse panel, speed controllers, LEDs, fans, and contactor and is powered by a 16.8 V Blue Robotics 4-cell LiPo battery[4]. Dragon uses six T-100 (5.2 lbf) and four T-200 (11.2 lbf) thrusters[5], providing full control with redundancy. Inspired by the team's first AUV, *Phoenix*, this configuration emphasizes speed in the surge direction, enabling Dragon to reach 1.3 m/s and complete more mission runs to maximize time bonuses.

Pneumatics Hull - Powered by the AUV Main Board, the pneumatics system uses CO_2 cartridges and solenoid valves to control manipulators. It can support up to eight solenoids, with six currently used for the torpedo launcher, claw, and marker dropper. A student-designed shield activates the solenoids based on commands from the Main Board.

Computer Hull - The computer hull houses the NVIDIA Jetson Orin Nano[6], FOG, two student-designed boards (AUV Main and Sensor Integration), and two cameras—front-facing and downward-facing. It also includes a WiFi antenna for surface communication and cooling fans to prevent overheating. Designed for easy access, the hull can be quickly removed for code development (see image on right). For more details regarding the software architecture, see Table 1 in Appendix A.


Computer Hull

Battery Hulls - Dragon uses separate battery hulls to independently power the computer and thruster systems. This setup ensures efficient power distribution and prevents voltage drops that could cause the computer to brown out when thrusters draw high current.

<u>Baby Dragon</u>

Originally a tethered teleoperated ROV, Baby Dragon was converted to an autonomous AUV for RoboSub. The 50-foot tether was replaced with a removable USB tether for in-water code uploads and data collection. A battery was installed inside the hull, and both a kill switch and mission switch—matching Dragon's—were added for diver access and safety. These changes enabled the integration of a depth sensor for depth control, an IMU[7] for straight-line navigation, and a modem for inter-vehicle communication with Dragon. Future improvements for Baby Dragon include adding manipulators to allow it to complete more tasks.

Acoustic Modem for Inter Vehicle Communication - Both AUVs use WaterLinked M16 acoustic modems[8] for communication. These devices transmit and receive acoustic signals that represent ASCII characters. For example, sending "DW" results in signals for ASCII codes 68 and 87. This enables effective underwater data exchange between the vehicles.

Software

<u>Dragon</u>

Waypoints - Dragon navigates using preset X and Y coordinates (waypoints) representing landmark locations such as the start gate. These waypoints form a 2D map that enables fast, coarse navigation across the course using Dragon's 10 thrusters. While this gets Dragon within about one foot of each task, fine adjustments are made using machine learning–based visual servoing.

Waypoints are generated using an a priori map that the team creates using a laser tape measure, annotated images, and known facility geometry. Reliable dead reckoning is achieved using a sensor suite that includes the FOG and DVL to track orientation and distance traveled.

Vision - To improve performance over last season, the team integrated even more computer vision into Dragon's navigation system. Upon reaching a waypoint, Dragon uses vision to align precisely with tasks such as launching torpedoes or targeting bins.

The system detects visual cues—like the shark image—and identifies key features, converting them into coordinates for fine-tuned movement. This allows Dragon to iteratively approach the target, moving 80% closer with each step without overshooting. Two Waveshare IMX219-160 cameras[9], front and bottom-facing, provide full visual coverage for navigation and task execution.

<u>Baby Dragon</u>

Baby Dragon navigates using an inertial measurement unit (IMU) and pressure sensor while communicating with Dragon. It runs Arduino-based code on a Teensy[10] microcontroller. Once the magnetic mission switch is activated, Baby Dragon's position is set, and depth is maintained using a control loop that keeps pressure readings within a tested range.

A second control loop adjusts for uneven thruster power by monitoring yaw from the IMU and modulating motor speeds to maintain a straight path. Both loops calculate error in depth and heading, apply proportionality constants, and adjust motor speeds accordingly.

Competition Strategy

The team's competition strategy focuses on improving reliability, accuracy, and task coverage. After completing 5 of 6 tasks last year, the goals for this season is to add underwater object manipulation, increase torpedo task accuracy from 33% to 80%, and enhance the strategic use of both AUVs.

Dragon is now equipped with a claw to attempt the previously incomplete Ocean Cleanup task, and its depth control loops have been refined to improve accuracy for tagging. Baby Dragon got an upgrade of components with an addition of a depth sensor and an IMU to expand its capabilities. Overall, the approach emphasizes rapid maneuvering between tasks to maximize time for visual target acquisition and allow multiple mission attempts if errors occur.

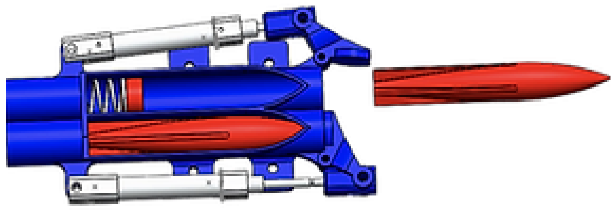
Navigation - For the 2025 RoboSub competition, Dragon will continue using dead reckoning with an a priori map for course navigation and machine learning–based visual servoing for terminal navigation. This approach is faster than computationally intensive methods like SLAM. Last year, waypoint navigation significantly reduced course time, enabling Dragon to complete three full runs and average five tasks per run in the finals.

Rough Seas - Before the coin flip, Dragon is aligned at a fixed poolside location using two standoffs and set to 0 degrees, establishing a consistent origin. After the coin toss determines its starting orientation, the mission switch is activated, and Dragon uses the FOG to realign to its intended heading.

Enter the Pacific - After realignment, Dragon uses waypoints to determine which side of the gate to enter—currently favoring the shark side with a 95% success rate. It then completes the tasks associated with that side for the rest of the run. To save time, Dragon skips the style points, which are handled by Baby Dragon. Once Dragon begins its run, Baby Dragon enters, flips twice for style points, then descends to the pool floor. Upon receiving a signal from Dragon, it changes state and surfaces, confirming communication.

Channels - To navigate the channel task, the team will use waypoint navigation with three setpoints: one at the entrance, middle, and exit. This approach is faster and more efficient than relying on vision-based navigation.

Tagging - Dragon's machine learning–based vision system detects the red circle near the shark and aligns the AUV. Once locked on, it triggers the pneumatics system to open the torpedo tube and launch the spring-powered torpedo. (*See CAD rendering to the right*)



Bins - Last season, Desert WAVE completed the bins task with 80% accuracy. Using machine learning, Dragon identifies the bin image, stops, and takes a photo to calculate coordinates. It then moves 80% closer to the target. This process repeats up to five times for precise alignment before deploying the marker *(image on the right)*. The same method is used for torpedo targeting to prevent overshooting and reduce alignment oscillation. Since shadows created by Dragon's frame can affect its ability to see the bins, the current position of the sun is considered when deciding which angle Dragon should approach the bins to ensure that its shadow is not cast over them.

Octagon - At the target coordinates, Dragon rises to locate the shark, then surfaces in the octagon facing it while holding red-colored trash for six seconds. It then descends, deposits the trash in the matching bin, and spins to indicate the number of collected items. To complete the pinger task, Dragon uses the Subsonus system to detect and follow the correct pinger sequence for bonus points.

Inter-Vehicle Communication (IVC) - At the 2024 RoboSub Competition, Dragon and Baby Dragon successfully used acoustic modems to communicate. After Dragon completed the buoy task, Baby Dragon entered the gate, performed pitch rolls, and waited for Dragon's "DW" signal to surface—replying with ":)" before returning to the gate. Baby Dragon currently surfaces after each task, but expanded IVC features are planned for 2025.

Testing Strategy

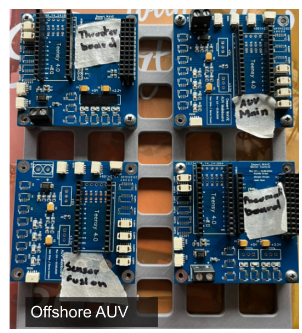
<u>Dragon</u>

Claw - The initial 3D-printed prototype proved ineffective, leading the team to evaluate two pneumatic alternatives: a 3-finger and 4-finger flexible claw. Using a pairwise matrix assessing weight, grip, water resistance, and cost, the iFarming claws outperformed the prototype. While both handled test objects, the 3-finger claw[11] was more reliable, especially with misaligned items.

Subsonus Software Simulation for Pinger Detection - A new algorithm was developed to enable the Subsonus to detect pingers in noisy, reflective environments. The code tracks pinger positions relative to Dragon and processes ANPackets over a set interval, filtering out signals outside defined angle ranges. Each pinger has a counter assigned to it and Dragon navigates toward the one with the highest signal count within range.

To simulate AUV movement and dynamic pinger detection, a simulator was developed where mouse movements represent Dragon's position and field of view (see Fig. 2 in Appendix A). Testing of this algorithm also included a "bucket test" with actual hardware where a pinger was placed under Dragon to verify azimuth readings, confirmed via output messages to the Operator Interface (OI). A virtual simulation was also used, where sample ANPacket values were input and the system identified the active pinger and completed the simulated mission.

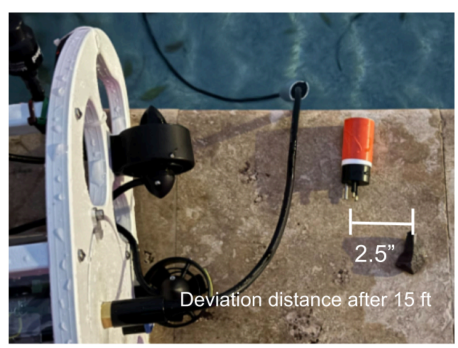
Stuttering Issue - During the 2024 RoboSub Competition, Dragon experienced a stuttering issue when disconnected from the tether. While running a simple mission, the status LEDs displayed rainbow colors instead of blue, indicating a process interruption. The issue stemmed from the AUV attempting to send telemetry packets to the Operator Interface without a tethered connection. When tethered, communication was stable; without it, the packets could not transmit, causing system delays. The team resolved the issue by updating the software to ignore addresses that don't request packets within a 2 second window. After the fix, mission tests ran smoothly and the LEDs confirmed proper operation.


Offshore AUV

Offshore AUV - Programming Dragon requires extended hours at the team's work area or transporting the full vehicle and equipment off-site. To simplify this, the team built the Offshore AUV—a bench-top replica of Dragon's computer hardware. It enables efficient code development and testing without needing to access and transport the full AUV.

<u>Baby Dragon</u>

IMU and Depth Sensor - After Baby Dragon's first competition, it became clear that reliable sensing was needed—specifically a working depth sensor and IMU. Although a depth sensor was installed, the lack of a data tether prevented testing. After the competition, a tether was added, allowing for pool calibration and the successful testing of a depth-hold algorithm.



Deviation distance after 15 ft

The IMU was tested to support heading control, with thruster output adjusted based on yaw readings. Initial dry tests confirmed responsiveness, followed by in-water trials where Baby Dragon maintained a straight path over 15 feet with only a 2.5-inch deviation. With both systems functioning independently, they were successfully integrated for combined operation.

Conclusion & Next Steps

The team's goal for this year was to strengthen task execution and to be able to complete all tasks successfully for the competition. To do this, the team was able to implement a claw that is able to pick up and score the trash at the octagon task. For software, the team was able to add more IVC code to showcase the collaboration between Dragon and Baby Dragon, with Baby Dragon completing Enter the Pacific after Dragon had already done so. After recent tests, the team is satisfied in having completed the goals that were set at the beginning of the season. The team's remaining time before the competition will be spent tuning vision and acoustic algorithms.

Acknowledgements

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Appendices

Appendix A: DVL accuracy

Table 1 - Positional Accuracy Testing with DVL

Distance (*m*) Measured by DVL	Test 1 Distance (*m*) Measured by Distance Meter	Test 2 Distance (*m*) Measured by Distance Meter
4.00	4.164	4.950
5.00	5.339	5.952
6.00	6.315	6.952
7.00	7.364	7.957

Appendix B

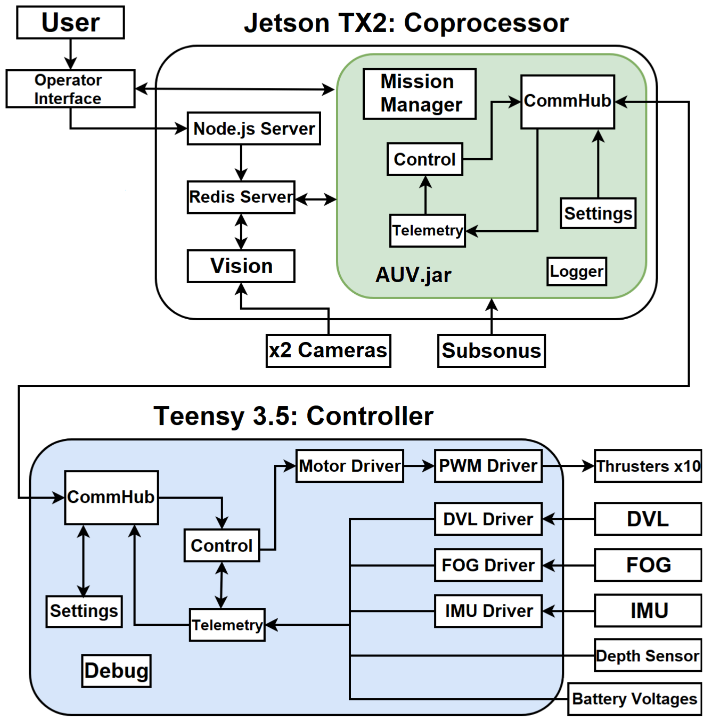

Figure 1 Software architecture

Figure 2: Subsonus Simulation: Dragon's view directly on top of the pinger from the Subsonus

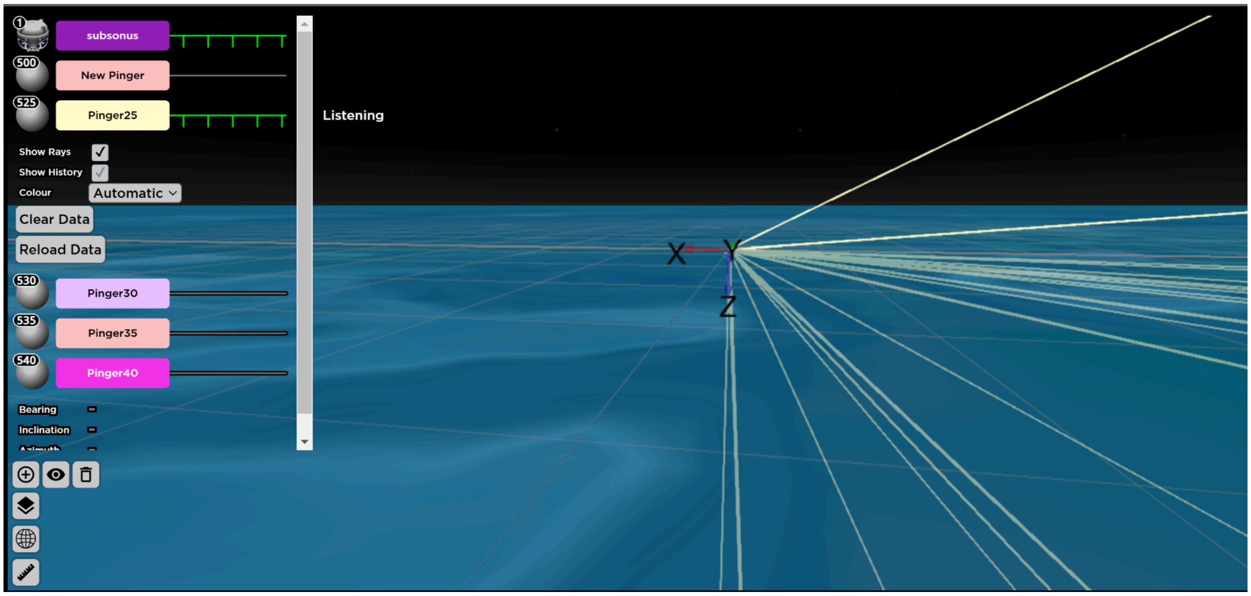

Figure 3: Subsonus Simulation: Neoprene coving half of Subsonus

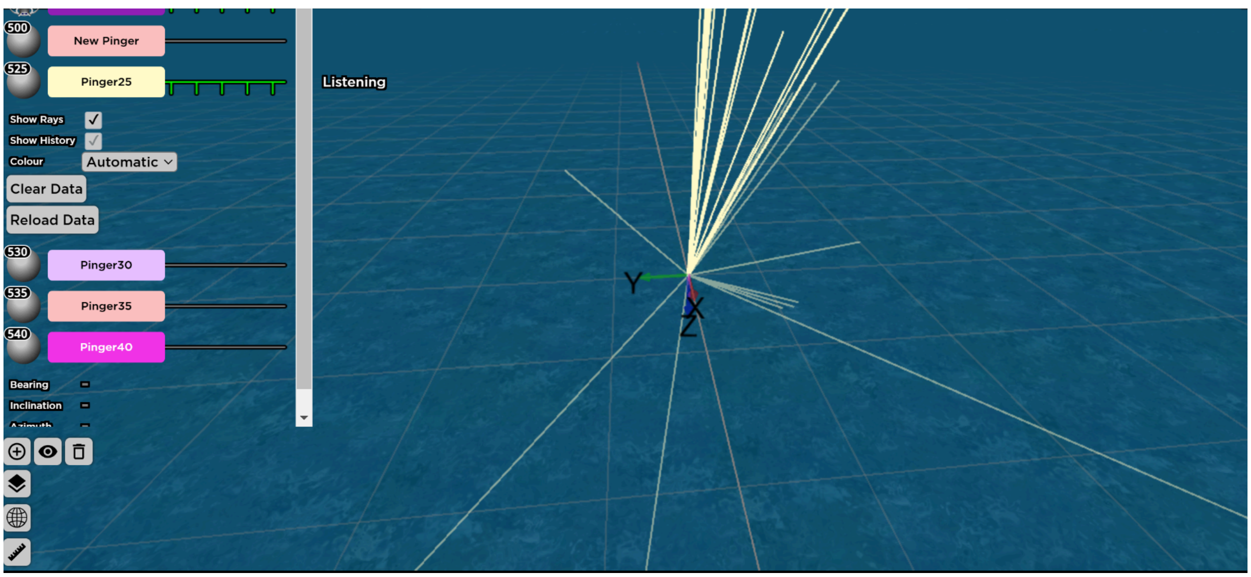

Figure 4: Subsonus Simulation: Average view of what subsonus saw from pinger around pool

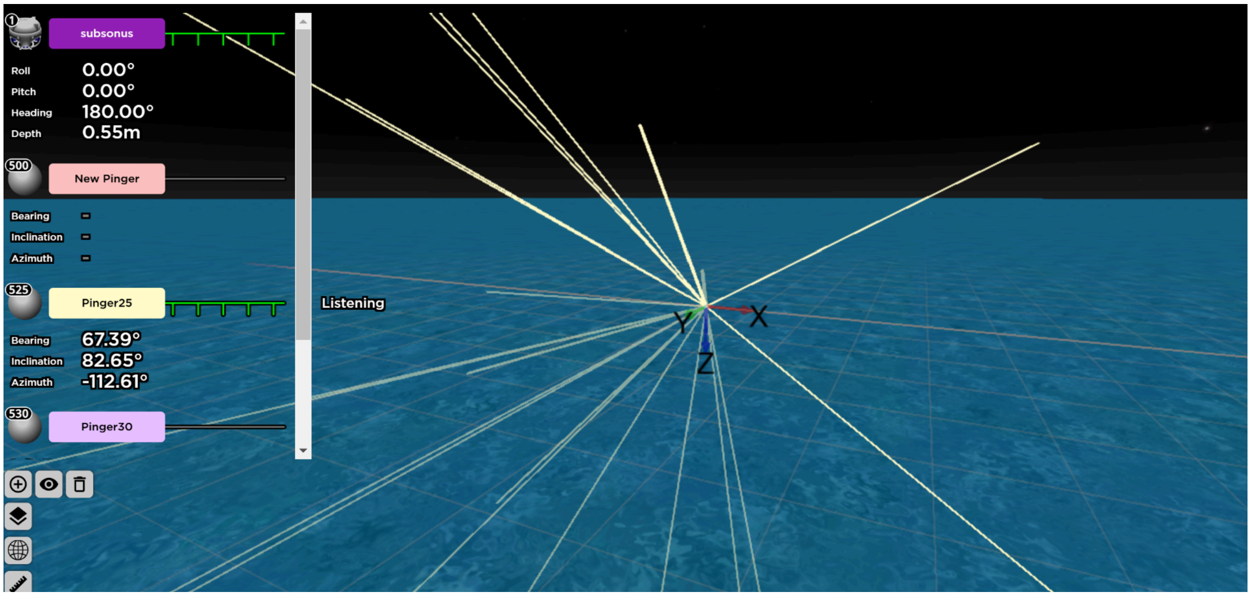

Figure 5: Still lots of reflections after adjusting echo time