System Technical Requirements V.5

Requirement Number	Hierarchy			Description		
	System	Subsystem	Component	Type	Requirement	Verification
1.0.0	Drone Flight Time			Performance	Shall fly for at least 30 minutes with magnetometer payload during normal autopilot flight. May fly for one hour as a reach goal.	Simulation - Test flights in simulations will model battery levels and estimate total obtainable flight time Physical Testing - The drone will be flown and have its flight time measured, as well as winds speeds and other factors.
1.1.0		Power Usage		Performance	Component power should be optimized in part selection, design, and usage	Design - Power budget will be created to assist in the design of the drone to select parts. Simulation - Current draw will be monitored in flight simulation to ensure power budget was accurate Physical Testing - Battery voltage will be monitored during flight to estimate power usage
1.1.1			Hardware	Functional	Shall consume power within the power budget 11.4kW	Simulation - Test power usage within simulator Physical Testing - Power draw measured using multimeter
1.1.2			Battery	Functional	Battery shall be capable of supplying all components listed in subsystem 1.1.1 for the amount of time listed in 1.0.0	Design - Power budget shall decide battery size Simulation - Battery levels will be monitored during simulated flights Physical Testing - The drone will have its flight time and battery levels measured
1.2.0		Drone Effective Weight		Functional	The drone shall have an effective weight of between 0 and 5 N. This requirement must be balanced with 1.1.0, since the effective weight will affect power usage.	Design - Use solidworks to determine mass of drone, and use offset of estimated bouyancy of lift bag at STP to determine effective weight Testing - Weigh the drone after full construction and inflation to determine effective weight
1.2.1			Drone Body	Functional	The weight of the drone body and components shall be less then 15 N. The payload weighs 9.8N. The estimated lifting force of the bag specified in 2.2.0 is 19.6N. Weight should be minimized to assist on requirement 1.1.0, since effective mass is not affected.	Design - Weight budget will be used to estimate the weight of the final drone Physical Testing - The drone body will be weighed on its own.
1.2.2			Lift Bag	Functional	The drone shall have a lift bag capable of counteracting drone mass, resulting in effective weight of < 5N. Currently specified at 4.07 cubic meter nominal volume, but might change based on requirements 1.1.0 and 2.1.0	Design - The drone mass and required lift force will be calculated and adjusted to meet requirements Physical Testing - Will test effective weight
1.3.0		Control System Optimization		Performace	System design may implement a throttle control in autopilot to remain in optimal efficiency range of motors where possible, but shall not conflict with 1.2.0	Design - See if this is a possible solution when motor choices and force analysis are finalized. Will use travel speed, not wind speed for optimization Simulation - Test flight to see if there is a worthwhile difference Physical Testing - Monitor throttle outputs during autopilot flight and battery voltage to estimate efficiency range of motors
2.0.0	Minimal Drone Speed			Performance	Drone shall be able to fly at least 5mph in winds up to 15mph	Design - All forces will be calculated, including drag, to estimate proper motor size Simulation - Flight Simulations will test flight speed under different conditions Physical Testing - The drone will use its GPS to measure the flight speed of the drone
3.0.0	RC Control			Performance	RC Control: Drone shall respond to user commands with pitch and roll angles within ± 0.1 radians and a height of 1 ± 0.15m.	Simulation - Flight simulation will model responses to user input Physical Testing - Motor angles will be tracked and used to confirm accuracy of RC response, and flight response in air will also be monitored
3.1.0		System Response		Performance	The drone shall respond to user input in < 0.5 seconds	Physical Testing - Time response time. Easiest test is from floating position to a hard acceleration.
3.1.1			RC Controller	Functional	A controller should be chosen that is capable of providing all neccesary commands (Foward, turn, ascend, descend and others if deemed necessary) as well as relaying information to the user as specified in requirement 3.2.0	Physical Testing - The drone responds to the user's inputs, including forward, turn, ascend, and descend
3.1.2			Software	Functional	The software shall be fast enough to respond quickly to all user commands and error handling.	Simulation - Software speed will be measured in simulation tests. Physical Testing - Responses will be measured for different situations in both normal flight and lab conditions (since we want to model a crash not actually crash)
3.1.3			Autonomous Functions	Functional/Performace	Some autonomous functions should be called while in the RC control state to assist the user, such as terrain tracking 4.2.0 and auto landing 4.5.0	Simulation - Responses in simulation will be tested, with simulated terrain, simulated landing and other needed functions Physical Testing - Using and switching between autonomous and RC FUNCTIONS will be tested for safety and reliability.
3.2.0		Data Feedback		Functional	The drone shall be able to send feedback to the user so the user can respond	Design - The software will be designed to send back drone data Physical Testing - Data will be monitored; this also assists with confirming other system requirements
3.2.1			Camera	Functional	The drone shall send camera feedback to assist in user controlled flight	Physical Testing - The camera feed will be monitored and any cutouts or issues will be recorded
3.2.2			Crash Detection	Functional	The drone shall alert the user if it is determined to have crashed	Simulation - Crashes will be simulated and output will be monitored Physical Testing - A crash will be simulated in a lab setting to test drone response
3.2.3			Low Battery	Functional	The drone shall alert the user when the battery runs low, and autoland specified in requirement 4.5.0 if critically low. Specific values to be determined.	Simulation - Voltage levels will be simulated and fed to the system and response of the simulation will be recorded Physical Testing - The drone will be flown until it has a low battery, then pushed until it autolands. Tested away from users in case of crash
3.3.0		Switch from Autonomous Control to RC		Performance	The drone should be able to switch from autonomous control to remote control but may need to move into a safe position first, and have preset settings, to prevent a crash. Component level will be determined as we find potential problems	Design - Can switch control modes from remote controller Physical Testing - The drone will be switched to RC control from autonomous in both safe and unsafe conditions to measure effectiveness Simulation - Switching between RC and autonomous in the simulation will be tested
3.4.0		Closed-Loop RC		Functional	The system should be able to maintain pitch and roll angles within 0.1 radians of zero and a height of 1+-0.15 m	
4.0.0	Autonomous Control			Performance/Environmental	Autonomous Control: Drone shall maintain stable pitch/roll/height and follow a path.	Design - A feedback control system will be used to ensure the drone succesfully flies on its own Simulation - Paths and environments will be generated to test autonomous responses Physical Testing - Plan a path and test the drones ability to follow it accurately using GPS data and monitor height with ultrasonics
4.1.0		Path Following		Performance/Environmental	The drone shall be able to follow a path specified by the user in up to 15mph wind with a positional accuracy of 5m	Simulation - Drone position will be kept track of in a simulated environment with wind Physical Testing - GPS data will be used to confirm drone position compared to the preplanned path.
4.1.1			GPS Sensor	Functional	The sensor shall be accurate to within 5m of its location with sampling of at least 3Hz	Design - Check sensor data sheet for rated values Physical Testing - Test GPS location data compared with actual sensor position

4.2.0		Terrain Tracking		Performance/Environmental	The drone shall maintain a constant height above the ground, approximately 1m, and adjust height as needed. < 15% overshoot	Simulation - A terrain will be generated and the drone's height will be monitored, as well as its altitude Physical Testing - The drone will be given a preplanned path over flat and rough terrain and its flight while ultrasonic data will be used to confirm actual height
4.2.1			Ultrasonic Sensors	Functional	The sensors shall be able to monitor area in front of the drone in order to maintain constant height of 1 m. Physical location and sensor sensitivity affects effectiveness	Simulation - The field of view and ability of the sensors to update the system in time will be simulated Physical Testing - The range of the sensors, distance, and angle will be confirmed and adjusted for
4.2.2			Barometric Sensor	Functional	The sensor shall be able to monitor altitudes above 4m for drone altitude awareness.	Physical Testing - Measurements in real-time will be confirmed and adjusted for
4.3.0		Error Handling		Performance/Environmental	The drone should be able to detect flight errors and compensate accordingly, specified in component section	Simulation - Errors will be simulated and responses recorded Physical Testing - Errors will be performed in a lab setting and responses will be recorded
4.3.1			IMU Sensor	Functional	The IMU should be able to detect crashes and abnormal situations and feed the data back into the system	Simulation - Sensor reading will be simulated and fed into error handling functions to test functionality Physical Test - The data will be tested in flight and in a laboratory setting to ensure proper system response
4.3.2			Error Detection	Functional	Follows same requirements as 3.2.2 and 3.2.3	Same tests as in 3.2.2 and 3.2.3
4.3.3			Popped balloon	Functional	The drone should be able to detect a popped balloon with a pressure sensor and by calculating the force needed to stay afloat. Will make emergency landing if popped	Simulation - The bouyancy of the drone will be quickly changed in a simulated flight and the drone response recorded Physical Test - The drone response will be tested with a sudden change in drone mass (attaching a weight) and pressure sensor manipulated to simulate deflation, and result will be recored. Test done in lab setting
4.4.0		Data Feedback		Functional	The drone shall send required data back to the user, as well as any errors specified in requirement 4.3.0	Simulation - Data will be fed to the simulator during simulated flights Physical Testing - Data will be tracked during flight and laboratory tests
4.5.0		Autolanding		Performance/Environmental	The drone should be able to safely land without damage to itself, the environment, or users.	Simulation - Simulated landing on several types of surfaces and wind conditions Physical Testing - The drone will be be autolanded throughout tests
4.6.0		Calculate New Path		Performance	If there is a system failure as specified in 4.3.0 that requires landing, the drone shall take the nearest path to a landing zone in <5s	Simulation - Partial system failure will be tested and the drone's ability to make it to a landing zone will be tested Physical Testing - TBD Need to plan safe way to test
4.7.0		Switch from RC to Autonomous Control		Performance	The drone should be able to switch from remote control to autonomous control but may need to move into a safe position first, and have preset settings to prevent a crash. Specifics will be determined as we find potential problems	Design - Can switch modes from remote controller Physical Testing - The drone will be switched to autonomous control from remote control in both safe and unsafe conditions to measure effectiveness Simulation - Switching between RC and autonomous in the simulation will be tested
4.8.0		State Estimation		Functional	The drone should be able to determine its pitch, yaw, roll, and NED states, as well as their derivatives to use in the autonomous functionality and error detection systems	Design- Returns pitch, yaw, row, and state of microprocessor. Physical Testing - Drone must stabalize itself after a while.
5.0.0	Cost			Functional	The drone shall cost less than $10,000. Reach-The drone may cost less than $6,000	Bill of materials will be recorded and manufactuing costs will be estimated
6.0.0	Magnetometer Interference			Performance	The magnetometer interference shall be less than 10 nT	Physical Testing - The magnetometer will record magnetic field with the drone on and off and the difference will be compared
6.1.0		Motor Generated Interference		Functional	The interference from the motors will be calculated and shall be less than requirement 6.0.0	Design -The magnetic contributions from motor locations will be added and summed together to estimate net interference
6.1.1			Outputted Interference	Functional	The interference should be calculated for each motor, and balanced with 6.1.2	Design - Magnetic Fields will be calculated for each motor Physical Testing - Will use a magnetometer to record actual magnetic fields with the motor on
6.1.2			Physical Location	Functional	The physical location of motors on the drone shall be decided with magnetic field outputs of motors in 6.1.1 in order to meet 6.0.0	Design - The positions will be calculated based off motor outputs in 6.1.1 Physical Testing - The total field will be measured at the point of the magnetometer
7.0.0	Drone Safety			Performance/Functional/Safety	The drone, its usage, and build should be safe to all individuals involved	Test for each factor will be designed, tests listed in subsystems
7.1.0		Collision Considerations		Performance	The drone should be designed to cause minimal damage to the user and environment in the event of a crash	Physical Testing - Since this is a safety test, we will need to find a safe way to test this. Specific test TBD
7.1.1			Body Design	Functional/Safety	The body of the drone should have no protruding or sharp componets that can hurt the user	Physical Testing - Since this is a safety test, we will need to find a safe way to test this. Specific test TBD
7.1.2			Propellers	Functional/Safety	The propellers should be safe if the user comes in close contact. May be enforced with propeller guards, propeller material, and other methods that will be determined.	Physical Testing - Since this is a safety test, we will need to find a safe way to test this. Specific test TBD
7.2.0		Electrical Safeguards		Functional/Safety	The drone should have features to protect the drone and user from electrical malfunctions	Physical Testing - Since this is a safety test, we will need to find a safe way to test this. Specific test TBD
7.2.1			Protected Electronics	Functional/Safety	The electronics and wires should be protected and securely mounted to prevent shorts, dropping components, etc	Physical Testing - Since this is a safety test, we will need to find a safe way to test this. Specific test TBD
7.2.2			(Fuses, Other safeguards?)	Functional/Safety	Some electrical components may be implemented to protect electronics	Physical Testing - Since this is a safety test, we will need to find a safe way to test this. Specific test TBD
7.3.0		Helium		Safety	A method of handling shall be adopted or developed by the team to ensure the helium and helium tank are handled safely.	A procedure will be written up in team documentation and followed by all people handling helium
8.0.0	Helium Leakage			Environmental/Functional	The lift bag shall maintain 90% of its buoyancy over a one week period	The drone will be weighed on a scale, then weighed again a week later. Helium loss will be calculated at the end of the week.
8.1.0		Detect Helium Leakage		Enviromental/Functional	Pressure sensor shall send out an error message when pressure sensor is decreasing during flight	Physical Testing - Will test a slowly leaking balloon with the pressure sensor mounted. Can be tested with normal air
8.1.1			Pressure Sensor	Environmental/Functional	Sensor should detect volume drop of helium balloon	In software, check if error message is being received
9.0.0	Leagal Compliance			Legal/Functional	The drone and team shall abide by all applicable laws for drone flight.	

9.1.0		FAA Compliance		Legal/Functional	The drone and team shall abide by all applicable laws for drone flight	Get confirmation from someone who knows drone laws (TBD) so we abide by all rules
9.1.1			Follow FAA part 107 (flying small drones < 30kg)	Legal/Functional	Drone shall be less than 30kg when in flight outdoors.	Get confirmation from someone who knows drone laws (TBD) so we abide by all rules
9.1.2			Statutory provision (PL 115-254, Section 350)	Legal/Functional	Drone shall follow PL 115-254, Section 350. 'Use of Unmanned Aircraft Systems at Institutions of Higher Education.'	Get confirmation from someone who knows drone laws (TBD) so we abide by all rules
9.1.3			Registered Drone with FAA	Legal/Functional	We shall create an FAADroneZone account with email and password and register the drone through the account.	Receive Registration confirmation
10.0.0	Noise Level			Performance	The drone should be quieter than 65dB	Physical Testing - Measure noise level of drone from 5 ft away
11.0.0	Manufacturability			Functional	The drone should be able to be manufactured with equipment within our access, further decomposed in subsystem requirements	Can be manufactured
11.1.0		3D Printing		Functional	All 3d printed components should fit within dimensions of the Lulbot Taz4 or Lulzbot Mini printer beds	Can be printed
11.2.0		Soldering		Functional	All components must be able to be soldered with Soldering Iron and team member skill level	
11.3.0		Envelope		Funtional	The envelope must be able to be cut with standard scissors and sewed with sewing machine Dylan owns, for dimensions to be within 5% of design when inflated.	
11.4.0		PCB		Functional	The PCB design must fit within manufacturing manufacturing abilities of OSHAPark	

*All edits within a section, add at the bottom of that section, since interpendencies refer to specific numbers. If a new system requirements, add to the bottom of list

1/13/2021	V.1	Created
1/28/2020	V.2	Cleaned up shall statements to make requirements more clear. Finalized for submission.
2/4/2021	V.3	Completed reformatted and new requirements added, and broken down. In part due to new things we have learned and to better align with instructor requirements in the request for a resubmission. Due to scale of changes, the original file is in original tab for records
2/8/2021	V.4	Updated shall should and may statements to make more concrete and finalize for submission. 30min Flight time shall, and 60 moved to may, but it is highly preferable.
6/7/2021	V.5	Updated techincail requirmets to their final state, some where move around, and varification methods