DFMEA for Autonomous Boat

Severity of Failure (1-10)

1- Failure would not have any effect on the operator or process
2- Failure not clear to the operator but have minor effect on the process
3- Failure would create a minor nuisance to the operator but can be used without performance loss
4- Failure would require process modification but there would be a minor performance loss
5- Failure would cause performance loss sufficient to make user complain
6- Failure would cause high level of user dissatisfaction
7- Failure would cause subsystem failure
8- Failure would make the automatic control mechanisms inoperable
9- Failure would make the manual control methods inoperable
10- Failure would cause operator injury

Probability of Failure Occurring (1-10)

1 = No possible way of failure occurring
2 = Designed with mechanism to prevent this failure method
3 = Failure mechanism method may fail
4 = Unlikely
5 = Failure is rate but it may occur based on specific scenario
6 = Failure may occasionally occur
7 = Failure rate uncertain
8 = Failure is likely
9 = Failure is inevitable
10 = No basis for design in history

Ability to Detect (1-10)

1 = Failure will not occur
2 = Failure mode has been predicted and strong detection capability added
3 = Failure is rare and slow to occur with significant signals in place
4 = Failure is unlikely but is slow to occur and signals in place
5 = Failure occurs occasionally but is slow to occur and signals in place
6 = Failure occurs occasionally but occurs at a moderate rate with signals in place
7 = Failure occurs often but occurs at a moderate rate with signals in place
8 = Failure mode gives slight opportunity to detect failure is occuring
9 = Failure mode can't be predicted by operator's senses
10 = Failure mode hasn't been predicted: surprise

Item #	Subsystem / Component Description	Component Function	Potential Failure Mode	Potential Effect of Failure 1- Failure would not have any effect on the operator or process 2- Failure not clear to the operator but have minor effect on the process 3- Failure would create a minor nuisance to the operator but can be used with out performance loss 4- Failure would require process modification but there would be a minor performance loss 5- Failure would cause performance loss sufficient to make user complain 6- Failure would cause high level of user dissatisfaction 7- Failure would cause subsystem failure 8- Failure would make the automatic control mechanisms inoperable 9- Failure would make the manual control methods inoperable 10- Failure would cause operator injury	Severity	Potential Cause of Failure / 1 = No possible way of failure occuring 2 = Designed with mechanism to prevent this failure method 3 = Failure mechanism method may fail 4 = Unlikely 5 = Failure is rate but is may occur based on specific scenario 6 = Failure may occasionally occur 7 = Failure rate uncertain 8 = Failure is likely 9 = Failure is inevitable 10 = No basis for design in history	Occurrence:	Control Method (Ability to detect & mitigate, or limit exposure) 1 = Failure will not occur 2= Failure mode has been predicted and strong detection capability added 3 = Failure is rare and slow to occur with significant signals in place 4= Failure is unlikely but is slow to occur and signals in place 5 = Failure occurs occasionally but is slow to occur and signals in place 6=Failure occurs occasionally but occurs at a moderate rate with signals in place 7=Failure occurs often but occurs at a moderate rate with signals in place 8 = Failure mode gives slight opportunity to detect failure is occuring 9= Failure mode can't be predicted by operator's senses 10 = Failure mode hasn't been predicted: surprise	Detection	Risk assesment = RPN = Sev x Occur x Detect	Recommended Action **Cutoff = 160**	Action Results (New RPN)
1	Sail Stepper motor	Attaches to the winch and drives the sail system	Motor speed will not be adaquate to rotate the saill fast enough for realtime autonomy	Sail will not react fast enough to changes in wind direction and will capsize.	10	Gearbox casuing a decrease in output motor speed.	8	Visually see the sail moving very slow and boat not sailing correctly	6	480	Select a new motor	80
2	Stepper motor stand	A 90 degree stand that elevates the stepper motor off of the surface by attaching to the face of the motor	Deformation in the part, or mechanical failure in the weld joint that attaches the stand to the surface.	Misalign the motor, therefore misaligning the axis of rotation between the motor and winch.	7	High toques and moments caused by high tension forces in the rope.	3	Sailor notices deformation and unsymetric rotation of the motor shaft and winch, and disengages from autonomous mode.	2	42	none	
3	Motor stand mounting screws	Attached the stepper motor to the motor stand using four M4 - 0.75 x 15 mm socket head screws	Fail due to shear from moments experienced by motor when rope is in high tension	Eliminate the connection between the motor and motor mount, ultimatley damaging the connection between the motor and winch	7	Moments experienced by the motor when working against high tension forces in the rope	3	Sailor will observed misalignment between the motor and motor stand	4	84	none	
4	Motor and Winch coupler	Connects the shaft of the motor to the idle shaft of the winch	Deformation from excess shearing when a torque is applied	Can fail due to shear force.	7	Excess force applied to the winch from the rope that applies a large torque on the coupler.	5	Sailor observed deformation in the coupler and disengages autonomous mode.	3	105	none	
5	Winch	Holds the spool of	Failure in the weld	Wont have the opposing force needed	6	Moments experienced at the	1	Sailor will notice the deformation	1	6	none	
6	Rear and Front Pulley	Guide rope from the	Failure in the	Cause and obstruction in the rotation	6	High tension forces in the rope,	4	Sailor will see tangled rope and	3	72	none	
7	Rear and Front Pulley Pin	Holds the rotor that allows the rope to move though pulley	Deform or fail in bending	prevent the rotor in the pulley from rotating freely which will obstruct the motoion of the rope	7	High tension forces in the rope due to tangling of the rope	2	Sailor will see the tangled rope and attempt to untangle it before damages occur.	6	84	none	
8	Rope Connectors (for	Used to attach	The rope will slip and	Will cuase the sail angle to be	6	High tension forces in the rope	3	Sailor will observe it slipping	4	72	none	
9	Control software	Control the winding and releasing of rope	Can miscalculate the length of travel of the clip which will potentially cause the clip to conflict with	Jam up the sail system or potential break pulleys if excess force is applied	4	Conversion between the PWM signals and stepper pulse signals have some uncertainty	6	Sailor will observe the clip conflicting with pulleys. Will disengage from autonomous mode if system is jammed.	5	120	implement signal filter from pixhawk to arduino	85
10	Front surface plate	Is the mounting plate for components at the front of the boat	Permanent deformation.	Can misalign the pully system and the connection between the motor and winch	6	Moments from the winch, motor, and right angle mounting plate when rope is in high tension can cause the plate to bend and deform.	5	Sailor will observe the surface plate deforming	2	60	none	
11a	Rudder Mounting	Serve as foundation	Rudder slides off	Rudder control system will completely	6	Clips holding plate to boat fail	5	Extra clips are being applied and	4	120	Add extra	65
11b			Surface Plate above	Bars connecting upper surface to	8	Welds connecting rod to	3	Visual observation of cracks at	4	96	none	

12	Upper surface plate (Rudder)	Serves as the track that will restrict the moving cart to 1-D motion	Track will fail due to bending	Failure in the track will prevent the cart from moving .	8	Forces exterted on the rudder that translate to the tiller that is connected to the upper plate	6	Sailor will visually see deformation	5	240	calculate the bending stress in surface plate	80
13	Support Bars	Serve as connection of	Bar no longer able to	Rudder control system would fall and	8	1)Failure from too much	3	Visual observation of tilting of	3	72	none	
14	Side Walls - Upper	Serve as guiding rails	No longer able to	Cart no longer functioning as intended	0	1)Deformation of slots from	4	Visual observation of slots and	3	0	none	
15	Mounted Bearing	Hold shafts and hubs	Loses position	Shafts and hubs become lose	7	1) screws fail due to shear	1	Visual observation over time of	1	7	none	
16a	Belt Hub	Transmits force to belt	Teeth no longer	Not able to transmit force therefore	5	Deformation and fatigue of	3	Visual check	3	45	none	
16b			Hub out of position	Not able to transmit force therefore	7	Excessive force from	5	Visual check	3	105	none	
17a	Belt	Transmits force from one hub to another	Loses shape	Not able to transmit force therefore the rudder isn't controlled	6	1)Force above UTS	4	Visual check	2	48	none	
17b			Cracks	Rudder control system not	6	1) Repeated load causing	8	Visual check	2	96	none	
18a	Shafts	Rotate in order to	Deformation of shaft	Force isn't transmitted and rudder is	5	1)Repeated loading	1	Visual check	1	5	none	
18b			Crack in shaft	Rudder control functions but operator	3	Excess stress	1	Visual check	3	9	none	
19	Cart Adhesive	Connect Cart to rudder control belt	No longer able to attach cart to belt	Rudder is no longer controlled	8	1)Force on adhesive beyond capability 2)Excess water 3)Excesss sun	6	Visual check	8	384	Calculate the shear force at the belt to cart connection	32
20	Wheel Bearings	Keep cart moving	No longer moving	Cart is not moving so rudder is held in	2	1)Deformation from excess	4	visual check	3	24	none	
21a	Clip Attachment	Hold the tiller in place	Doesn't open when	Operator is not able to take over of	5	1)Failure of clip opening	4	visual check	3	60	none	
21b		Hold the tiller in place	Breaks and drops the	Autonomous control of the rudder is	6	1)Excess force on the clip	6	visual check	3	108	none	