FAILURE MODE	FAILURE DETERMINATION/ ROOT CAUSE	FAILURE EFFECTS ON PERSONNEL (BEFORE MITIGATION)	FAILURE EFFECTS ON SYSTEM (BEFORE MITIGATION)
In what ways can/did the item fail to meet the design goal(s) and deliverable(s)? What could/did go wrong?	How can/did the failure occur? Describe in terms of what can be corrected or controlled. Try to identify the causes that directly impact the failure.	What is the effect on the personnel for each failure mode?	What is the effect on the robot for each failure mode?
Unpredictable Movement	Motor controller failure	Robot uncontrollable	Damage to the robot or surrounding equpiment.
Unpredictable Movement	Communication failure	Robot uncontrollable	Damage to the robot or surrounding equpiment.
Unpredicted Program Changes	Faulty Progamming	Personnel injury due to collision, course changes	Damage to the robot or surrounding equpiment.
Short in Battery Charging System	Improper Wiring	Personnel Shock (115VAC/22.8VDC)	Electrical damage
Battery catches on fire	Faulty battery	Personnel Injury	Damage to the robot or surrounding equpiment.
Battery catches on fire	Overheating	Personnel Injury	Damage to the robot or surrounding equpiment.
Battery catches on fire	Punctured/Damaged	Personnel Injury	Damage to the robot or surrounding equpiment.
Battery catches on fire	Overcharge damage	Personnel Injury	Damage to the robot or surrounding equpiment.
Gearbox mounting bolts coming loose	Did not use loctite	Personnel injury	Robot Slowed/ Flied botls
Battery Disconnected	wire end not installed correctly and shorted	Robot Stopped	Robot Stopped
Tread slips off	Not stabilized-no through bolt and slid around	Robot stopped	Robot stopped. motors burned out. Tooth track pully damaged

Insufficient Voltage/Current	Something causing brown outs during intake Possible bad battery, but it passed initial voltage test	Robot Slowed	Robot Slowed
Arm fell down in autonomous	Code Error	Personnel Injury	Arm didn't lift/lower/ overeach/ expand/ activate before code deploy
Wheels stop turning	Motor failure	Robot Stopped	Robot Stopped
Wheels stop turning	Power Loss	Robot Stopped	Robot Stopped
Wheels stop turning	Battery terminal breaks	Robot Stopped	Robot Stopped
Wheels stop turning	Broken belt	Robot Stopped	Robot Stopped
Wheels stop turning	Wiring	Robot Stopped	Robot Stopped
Wheels stop turning	Broken axle	Robot Stopped	Robot Stopped
Wheels stop turning	Bearing failure	Robot Stopped	Robot Stopped
Wheels stop turning	Bearing falls	Robot Stopped	Robot Stopped
Wheels stop turning	Jam in spokes	Robot Stopped	Robot Stopped
Power loss	Battery unplugs	Robot Stopped	Robot Stopped
Power loss	wire shorting	Robot Stopped	Robot Stopped
Power loss	dead battery	Robot Stopped	Robot Stopped
Robot falls	Axels bend	Robot Stopped	Robot Stopped
Flexing frame	Collision	Robot Slowed	Robot Slowed
Flexing frame	Loose Hardware	Robot Slowed	Robot Slowed
Flexing frame	Broken Beams	Robot Slowed	Robot Slowed
Flexing frame	Belt tensioner	Robot Slowed	Robot Slowed
Flexing frame	overtightened strip bolts	Robot Slowed	Robot Slowed
Catch points	2 gears landed on top of bot	Lost Points	Lost Points
Catch points	drove on gear	Lost Points	Lost Points
Stripped gearbox	stripped	Lost Points	Lost Points
Intake design fail	working	Lost Points	Lost Points
motor failure	borke electrical connection	Can't Pick up/hold/expell cubes	Can't Pick up/hold/expell cubes
motor failure	power loss, chain	Can't Pick up/hold/expell cubes	Can't Pick up/hold/expell cubes
Not picking up or ejecting cube	flywheel(s) have debris and not catching	Can't Pick up/hold/expell cubes	Can't Pick up/hold/expell cubes
Not picking up or ejecting cube	pneumatic air loss/leak or communication failure	Intake Head/Side didn't open/close	Intake Head/Side didn't open/close
Not picking up or ejecting cube	communication failure	open/close	open/close
Lift mechanism	communication, gear box	Arm didn't lift/lower	Arm didn't lift/lower
C-Support arms	sync/programming	Arm didn't lift/lower	Arm didn't lift/lower
elevator slides are off track	Robot hit or tipped while extended	Arm will not extend	Arm will not extend
pinched or twisted	extended	Arm will not extend	Arm will not extend
Elevator falls off C support	in collision/use	Robot Stopped	Robot Stopped

Camera	rate	Robot Slowed	Robot Slowed
gearboxes	ratchet not turned back	Can't climb	Can't climb
gearboxes	put gear on wrong peg	Can't climb	Can't climb
climbed too slow	and out of spec for motor	Robot Slowed	Robot Slowed
Browning Out	Brown Out	Robot Stopped	Robot Stopped
1/8" clearance-not 1/4"	1/8" clearance-not 1/4"	Robot Slowed	Robot Slowed
Gear Ratio-Too high	Gear Ratio-Too high	Robot Slowed	Robot Slowed
Robot slips	malleable/bent	Can't climb	Can't climb
1 shot/chance only	Actions not repeatable	Lost Points	Lost Points
Can't climb	incorrectly/flipped	Lost Points	Lost Points
Tires go flat	Pneumatic Tires go flat	Robot Slowed	Robot Slowed
rope broke	rope broke	Can't climb	Can't climb
Robot Fell	Didn't change rope	Can't climb	Can't climb
Low Power	Didn't change battery	Robot Slowed	Robot Slowed
breaker broke	impact	Robot Stopped	Robot Stopped
Set Up too long	Set Up too long	No failure	No failure
voltage	voltage	Robot Stopped	Robot Stopped
loose wires	loose wires	Robot Stopped	Robot Stopped
Cumbersome/slow	Body too long to maneuver	Robot Slowed	Robot Slowed
Body too tall-Tippy	Body too tall-Tippy	Robot Slowed	Robot Slowed
25 Chain fell off	25 Chain fell off	Robot Stopped	Robot Stopped
Rubber on wheels fell off	Rubber on wheels fell off	Robot Slowed	Robot Slowed
35 Chain fell off	35 Chain fell off	Robot Stopped	Robot Stopped
Couldn't Catapult	and slid around	Lost Points	Lost Points
Weld broke	Weld broke	Robot Stopped	Robot Stopped
Belt on wheel broke	Belt on wheel broke	Robot Stopped	Robot Stopped
Wheel assembly bolt broke	Wheel assembly bolt broke	Robot Stopped	Robot Stopped
bolt too small	bolt too small	Robot Slowed	Robot Slowed
Catapult won't work	removed for match	Lost Points	Lost Points
Tension too high	Tension too high	Lost Points	Lost Points
over time	over time	No failure	No failure
Too large	Outside frame too large	Out of Spec	Out of Spec
Wrong color wiring used/OOS	Wrong color wiring used/OOS	Robot Slowed	Robot Slowed
instead of braided	instead of braided	Robot Slowed	Robot Slowed
wiring disconnected	on impact	Robot Stopped	Robot Stopped
amperage	amperage	Robot Slowed	Robot Slowed
Didn't shoot	Didn't shoot	Lost Points	Lost Points
floor	Design-didn't pick up off floor	Lost Points	Lost Points
lifted	lifted	Robot Stopped	Robot Stopped
Can't climb	to velcro	Lost Points	Lost Points
Can't climb	planetary Gear	Lost Points	Lost Points
Climbed too slowly	Incorrect gear ratio used	Lost Points	Lost Points
Battery	on high impact	Robot Stopped	Robot Stopped
Gear Stuck on robot	Gear Stuck on robot	Lost Points	Lost Points

Robot Fell	slid	Can't climb	Can't climb
Wheels tighted/loosen	rotation-bolts rub on bumpers	Robot Slowed	Robot Slowed
Can't find parts	Not organized	Slowed PIT	Slowed PIT
Bent frame	match	Didn’t drive straight.	Didn’t drive straight.
Belt Slipping	loosening	Robot Stopped	Robot Stopped
Belt Slipping	(1/4" bolts were used instead	Robot Stopped	Robot Stopped
Not picking up or ejecting cube	Collar came off	Can't Pick up/hold/expell cubes	Can't Pick up/hold/expell cubes
Intake	Wheel fell off	Can't Pick up/hold/expell cubes	Can't Pick up/hold/expell cubes
Head won't open/close	tubing so popped off	Can't Pick up/hold/expell cubes	Can't Pick up/hold/expell cubes
Arm Lifted Slowly	place, Gem Key no longer	Arm didn't lift/lower	Arm didn't lift/lower
335 Feedback Cable	disconnected when arm	Robot not responding	Robot not responding
Robot Too Big	when arm is up and are OOS	Out of Spec	Out of Spec
Anderson Connector	attached incorrectly	Can't Pick up/hold/expell cubes	Can't Pick up/hold/expell cubes
Computer	loaded after test work	Robot Stopped	Robot Stopped
tensioner was bent/bolt was coming out	1/2" bolts were used instead of 1/4"	Robot Slowed	Robot Slowed
Loose Bolts	tighten down	Robot Slowed	Robot Slowed
Gem key failure	sides - keys destroyed under	Arm didn't lift/lower	Arm didn't lift/lower
Arm will not extend	armchain fell off internally	Lost Points	Lost Points
Gem key failure	Right Arm motor question hot	Arm didn't lift/lower	Arm didn't lift/lower
further to be perfect	incorrectly	Lost Points	Lost Points
stages coming apart	attached incorrectly	Arm didn't lift/lower	Arm didn't lift/lower
Intake Head won't open/close	surges coming apart	Can't Pick up/hold/expell cubes	Can't Pick up/hold/expell cubes
Didn't go far enough	Exception handling-	Lost Points	Lost Points
Loosen nut didnt retighten	on nut	Arm didn't lift/lower	Arm didn't lift/lower
strategy miscommunication	to scale	Lost Points	Lost Points
electrical wasnt done correctly	roborio	Robot not responding	Robot not responding
Arm Fell Back	matching; Reset Baseline for	Robot Stopped	Robot Stopped
Communication	communication wires, boom	Robot Stopped	Robot Stopped
Intake Head won't open/close	coiled hose causing issue	Can't Pick up/hold/expell cubes	Can't Pick up/hold/expell cubes
pulled out	installation, connected now	Robot Stopped	Robot Stopped
Air piston shaft- intake bent	intake bent	Can't Pick up/hold/expell cubes	Can't Pick up/hold/expell cubes
Arm dropped on autonomous	out gem backlash	Arm didn't lift/lower	Arm didn't lift/lower
Ran autonomous by itself	which carried into teleop	Didn’t drive straight.	Didn’t drive straight.
Intake didn’t compress cube	cylinder	Can't Pick up/hold/expell cubes	Can't Pick up/hold/expell cubes
Didn't go far enough	on calculation	Lost Points	Lost Points
Overloaded away switch	without focusing on ours	Lost Points	Lost Points
Talon	durring the match the talons	Robot not responding	Robot not responding
Power cut	exposed power switch was hit by robot & powered down	Robot Stopped	Robot Stopped
Camera was trying to connect the entire match	Cord wasn’t plugged in all the way, driver station console		
Can't see cubes to intake in	wasn’t open	Lost Points	Lost Points
No control over the arm	condition causes reliability	Arm didn't lift/lower	Arm didn't lift/lower
cubes in vault and switch	Potential Gem key switch	Arm didn't lift/lower	Arm didn't lift/lower
position	gearbox(es) stuck, hubs	Arm didn't lift/lower	Arm didn't lift/lower

not letting turned	navx.	Robot not turning	Robot not turning
See	overlapped	Robot not responding	Robot not responding
Intake Motor Collar	No Failure - preventive FMEA	No failure	No failure
Loose wheel	motion and movement on	Robot Slowed	Robot Slowed
Browning Out	accurate	Robot Slowed	Robot Slowed
Hesitant to Turn	tread thin - all weight on	Robot Slowed	Robot Slowed
Not Communicating	Not a genuine controller	Robot not responding	Robot not responding
Autonomous didn't run	loaded-launched cube in wrong	Lost Points	Lost Points
responses did not work	much bandwidth/PCM Wire	Robot Slowed	Robot Slowed
responses did not work	Camera Cable not	Robot Slowed	Robot Slowed
Browning Out	accurate	Robot Slowed	Robot Slowed
Frame bent-rivets broke	known failure point on high	No failure	No failure
open/close	to fall off of Left Motor	Can't Pick up/hold/expell cubes	Can't Pick up/hold/expell cubes
Intake didn’t compress cube	pneumatic cylinders	Can't Pick up/hold/expell cubes	Can't Pick up/hold/expell cubes
Intake wheel fell off	Grease on shaft	Can't Pick up/hold/expell cubes	Can't Pick up/hold/expell cubes
Reboot every 10 sec	POE injector jack was loose	Robot not responding	Robot not responding
Dropped Cubes	than they recharge. Not	Lost Points	Lost Points
Belts slipping	tear	No failure	No failure
Can't pick up Cubes	on impact	Can't Pick up/hold/expell cubes	Can't Pick up/hold/expell cubes
Camera USB came lose	tight		
Can't rotate arm	measured chain length	Chain seized	Chain seized
Can't pick up Cubes	strong, causeing the chain to	chain seized	chain seized
autonomous did not end	which caused the auto to go	Penalty points	Penalty points
controllers werent being recognized by driver station	unknown - csas have never seen problem before	No connection	No connection
Miswired	EM-CIS-Electric Module Gen 2	Can-wires disconnecting	Can-wires disconnecting
Miswired		Mis-Wriring Motor into Talons	Mis-Wriring Motor into Talons
Miswired		POs-Neg Controls	POs-Neg Controls
	Develop - Module		
	Bad components used - parts already tested		
	Wires identified and traceable		
	Potential Heat on Talons		
	Discinnection - repeated		
	Anderson connectors wear		
	Transport		
	ESD Arcing		
	Talon spacing		
	Anderson Connectors to talons. Anderson not installed correctly		
	Wiring traceability -		
	Vision capable		
	Platform from aluminum to carbon fiber		

Subsystem self Test Required in Programming

(3) 90Degree power ethernet (POE) required for RoboRio, 1 for camera, positive locking for computer

Protective top and side shields to be added

OCCURRENCE (BEFORE MITIGATION)	SEVERITY	OCCURRENCE (AFTER MITIGATION)	MITIGATION
How likely is this cause or failure to occur? 1-Very Low 2-Low 3-Moderate 4-High 5-Very Likely	How severe is the failure? 1-Very Low Severity 2- Low 3-Moderate Severity 4- High 5-Very High Severity	How likely is this cause or failure to occur? 1-Very Low 2-Low 3-Moderate 4-High 5-Very Likely	What are the existing measures or short term actions taken that will (1) prevent the cause of the failure or reduce its rate of occurence, (2) detect the cause and lead to corrective actions, or (3) detect the failure?
4	5	1	(1) Implement program to stop motor controllers if one is not working/communicating (1) Determine correct voltage inputs (3) Implement system monitoring for motor controller operation
4	5	1	Install fail-safe modes
4	5	1	Install fail-safe modes
3	5	1	(1) Ensure Robot is removed from charging station/Deenergized while performing maintenance or operating
1	5	1	(1) Test battery meets safety standards and use BMS (Battery Management System). Use hard shell battery.
1	5	2	(1) Ensure enough ventiliation around battery (2) Install temperature monitor (3) Install cooling system if needed
1	5	2	(1) Create enclosure for battery to prevent damage (2) inspect for damages when received and before installing
1	5	1	(1) Function that prevent over-charging the battery, ensure battery is never fully drained before recharging.
2	4	1	Tightened up and monitor
4	5	1	Check shorted fuses/ Rewire
5	3	2	(1) Installation of durable treads. Addition of a design to keep tracks in place

2	2	1	Check battery voltage before use/
1	1		Power off. Disconnect. Reset
2	5		none
4	5		none
1	5		
1	5		none
5	5		Ziptie connecters
1	5		none
2	4		none
2	3		Bearing block
1	3		none
4	5		3D wire protector. Ice pick
4	3		data-logger
3	3		
5	5		none
5	3		none
5	3		locktight
1	5		none
2	3		none
3	3		none
4	3		
5	5		
3	4		
4	5		
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3	2	Reset
4	4	
5	5	
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3	4	
4	4	bolts
4	4	
4	4	
3	4	
1	5	train
3	4	different one.
3	4	different one.
1	1	Cut new tubes, trained
4	5	closed? loop and use new
4	3	hyperextend
1	5	Corrected
4	4	trained
1	5	retrained
1	4	Used correct bolts, trained
4	3	tightend axle bolts
2	4	replaced gem keys
4	3	Removed Extension
4	4	replaced gem keys
3	2	recalibrated
4	3	Rebuilt
4	4	tightened them
2	2	program
4	2	Changed arm, discussed error
4	3	Discussed with driver
4	2	Checklist
4	4	on robot
4	3	components - redesigned
3	3	Changed hoses to rigid hoses
4	4	Verified connection
4	4	Replaced parts, driver practice
1	3	Instructed to npt use hard stop
1	5	Disabled Autonomous
2	4	bent bolt, discussed with drive
2	2	Fixed calculation
1	1	to show off capabilities for
1	5	subsystems
2	5	powered robot back on checked systems
1	3	Plugged in, added to checklist
1	4	Reprogrammed
4	4	Fixed Gems
5	5	Fixed Gems

3	5	corrected code
1	4	Move to manual mode
1	4	Collar
4	2	A carbonized collar was applied
4	4	Rotation - Test Battery Now
3	4	File outsiddde wheels to match
5	4	switched controllers
4	1	Selection mode added
4	2	Quarentined Hall sensor
4	4	complete checklist and be
4	4	rotation
3	1	added inspection to checklist
3	3	like
5	4	Pnumatic hose cut and refitted
2	3	off and reattached
3	5	Rerouted POE cable and
2	3	and ziptied so bunjees do not
3	2	sides and back belt on right -
3	4	Replace cylinder with new one
3	1	taped down cord
5	3	replaced chain
5	3	code, added an additional
3	4	disable second cube auto
1	5	computers in case the controllers or laptop were

All wires must be labeled
Placement is a concern.
Mounting is a potential

ESD Bag and transport box
Ground panel
Training

add color coding or number

conductor?

Potential EMP?

FAILURE EFFECTS ON PERSONNEL (AFTER MITIGATION)	FAILURE EFFECTS ON SYSTEM (AFTER MITIGATION)
What is the effect on the robot for each failure mode?	What is the effect on the robot for each failure mode?
None	System shutdown
None	System shutdown
None	System shutdown
Personnel Shock (22.8VDC)	Electrical Damage
Personnel Injury	Damage to the robot or surrounding equpiment.
Personnel Injury	System shutdown
Personnel Injury	System shutdown
Personnel Injury	System shutdown
Personnel Injury	System shutdown
None	System shutdown
Personnel Injury	System shutdown

None	System shutdown