Component	Cause	Outcome	Occurrence	Danger	Severity	Risk	risk mitigation action	Mitigated Occurrence	Mitigated Risk	risk mitigation: analysis	risk mitigation: test plan
Shielding	Meteorite or other space debris striking spacecraft	tank breach/battery hit	5	spacecraft explodes	4	20	MMOD Shielding	1	4	Probabalistic debris flux and MMOD shielding design calculations	ballistic MMOD testing
Propulsion	spacecraft runs out of fuel during mission	unable to continue mission	3	put HST into non-ideal orbit, become space junk	4	12	carry enough fuel for mission (plan for +20% margin)	1	4	Fuel budget for all orbital manuvers	test engine to confirm correct thrust and Isp
Propulsion	leak in fuel and/or oxidizer tanks	unable to continue mission (eventually)	3	put HST into non-ideal orbit, become space junk	3	9	choose robust tank material, pressurize only to a safe margin under rated capacity	2	6	material analysis, probabilistic failure analysis	test proof & burst pressure of tanks
Propulsion	leak in pressurant tank	unable to continue mission (eventually)	3	put HST into non-ideal orbit, become space junk	3	9	choose robust tank material, pressurize only to a safe margin under rated capacity use PMD as backup	2	6	material analysis, probabilistic failure analysis	test proof & burst pressure of tanks
propulsion	valve shut mechanical failure (freeze, etc.)	engine fail	3	stuck in parking orbit, unable to rendez-vous	4	12	redundant valves in parallel	2	8	engine block diagram, probabilistic failure analysis	test fires with broken valves
Propulsion	valve open mechanical failure (freeze, etc.)	engine fail on	3	thrust in incorrect direction, thrust at HST during rendez vous	5	15	redundant valves in series	2	10	engine block diagram, probabilistic failure analysis	test fires with broken valves
Propulsion	turbo machinary mechanical failure	engine fail	2	stuck in parking orbit, unable to rendez-vous	4	8	supplier testing	2	8	engine block diagram, probabilistic failure analysis	
Propulsion	new piping configuration	prop/ox leaking	3	Propellent ignites not in combustion chamber	5	15	test fire spacecraft	2	10	FEA force loading, CFD pipe pressure, thermal analysis	test burns of assembled spacecraft
Propulsion	atmospheric drag, magnetic field, uneven gravitational field, etc.	slow de-orbit	4	de-orbit	2	8	carry enough fuel to compensate	2	4	orbital mechanics simulation	
Propulsion	launch vehicle gives incorrect parking orbit	not in correct parking orbit	3	need to recover from incorrect orbital insertion.	2	6	carry extra propellant to overcome variation in parking orbit alitude	2	4	orbital mechanics simulation, examine launch vehicle failure history	
Power	Insufficient battery charge	Loss of power to bus	3	loss of comms and control	4	12	sufficient capacity and charging	1	4	power budget analysis	Battery lifecycle testing
Power	Meteorite or other space debris striking solar panel, ionizing radiation	solar panel degraded performance	5	loss of power from one solar panel (extreme), less power from solar panel (more likely)	1	5	redundant solar panels	5	5	power budget analysis	solar panel MMOD testing, solar panel flight heritage
Electronics	ionizing radiation	CPU single event upsets	4	CPU inaccurately controls spacecraft, collides with another spacecraft	5	20	3 CPU's	1	5	SEU probability analysis	disable CPU's or make some give faulty signals, and make sure correct output is still achieved.
Electronics	magnetic field	induces charge in chassis	1	spacecraft discharges onto CPU or HST	2	2	short duration of mission	1	2	spacecraft magnetic flux and charge calculation	Charge build up on previous spacecraft when in presence of B field
Electronics	comms mechanical failure (hit by MMOD, cable severed, etc.)	cannot communicate	3	unable to communicate with ground/HST	3	9	2 ways of communicating: low gain and high gain antenna	1	3	comms bandwidth simulation	ground based antenna testing, flight heritage
Electronics	LIDAR covered with debris, mechanical failure	LIDAR failure	2	unable to detect HST for docking	3	6	able to use other sensors to compinsate (cameras), kalman filter	1	3	rendezvous simulation	
Electronics	looking at sun, mechanical failure	startracker failure	2	unable to localize in orbit	3	6	use GPS to localize, kalman filter	1	3	rendezvous simulation	
Electronics	looking at sun, mechanical failure	camera failure	5	unable to detect HST for docking	3	15	use seconary camera, or LIDAR, kalman filter	1	3	rendezvous simulation	
Electronics	gps 'blackout', mechanical failure	GPS failure	2	unable to localize in orbit	3	6	use startracker to compensate, kalman filter	1	3	rendezvous simulation	
Electronics	SEU event on IMU curcuitry, mechanical failure	IMU failure	3	gives incorrect outputs	3	9	use startracker to compensate, multiple IMUs, kalman filter	1	3	GNC simulation	
Electronics	system reboot	loss of filter model propagation	2	loss of localization	3	6	re-localize using current sensor readings	1	3	GNC simulation	
Electronics	Over charging battery		5	battery catches fire, spacecraft loses power	4	20	EPS board to properly regulate charging	1	4	Circuit simulation, and maximum power discharge rate	Stress test circuit by adding more energy to system than battery capacity
Electronics	waste heat generation (solar panels, CPUs, radiation, etc.)	heats up spacecraft beyond operating conditions	4	hardware outside specs, electronics malfunctions	2	8	protective radiation layer, MLI, radiators to dissappate heat	1	2	heat analysis budget analysis based on prior spacecraft	TVac testing, run system on ground & fake heat inputs
Structure	spacecraft structural design / integrity not sufficient	spacecraft buckles during HST reboost	5	destroy HST	5	25	spacecraft built to withstand this force, with a safety factor.	1	5	structual FEA analysis / simplified beam-buckling analysis	failure and g-force load testing
Structure	Meteorite or other space debris striking spacecraft, space environment, solar wind, solar ionizing radiation, etc.	material degradation, structure compromised	5	chassis not as structural	3	15	chassis safety factor should be high enough to withstand slight degradation. MMOD shielding should help.	1	3	structual FEA with component degradation	ballistic MMOD testing/failure and g-force load testing with degridated structure

Subsystem	Failure	Cause	Sev	Effect	Sev	RPN	Mitigation	Occ	RPN	Analysis	Testing
Structure	Large Thrust deflects HST Solar Booms	Violate mission requirement	5	Mission Failure	5	25	Determine Maximum Allowable Thrust	1	5	Structural Analysis to determine deflection	
Structure	Thermal effects on structure	deformation of parts	5	causes spacecraft into new configuration	4	20	take into account when designing	2	8	thermal spacecaraft deformation analysis	heat up critical areas of the spacecraft and see if anything deforms
Soft Capture	Meteorite or other space debris striking spacecraft/capture motor malfunction	soft capture mechanism damaged	3	rendezvous failure	4	12	soft capture mechanism should be able to function while slightly damaged. redundant motors. Package motors inside Shielding	2	8	Probabalistic motor failure analysis model, dynamic interaction simulation	soft capture mechanism testing
Soft Capture	soft capture mechanism damaged from vehicle impact/capture motor malfunction	soft capture mechanism won't let go/destroyed	4	unable to de-orbit spacecraft, HST must expend extra energy to point. Mission Failure	3	12	mechanism testing, redundant failsafe motor and mechanical design. Package motors inside shielding	2	6	Probabalistic motor failure analysis model, dynamic interaction simulation	soft capture mechanism testing
Launch	Launch-Vehicle Separation	Impact Force	5	Spacecraft is damaged / structural failure	5	25	design structure for launch environment	1	5	yield strength calculations	Separation/Impact testing
Launch	launch environment	vibrational loading	5	structural failure	5	25	design structure for launch environment	1	5	stress calculations, modal analyses	vibration testing(Shake table)
Launch	launch environment	acceleration loading	5	structural failure	5	25	design structure for launch environment	1	5	stress calculations(von mises) using appropriate safety factor	vibration testing(8.5g axial, 3g lat), (shake table)
Launch	launch environment	pressure loading	5	structural failure	5	25	design structure for launch environment	1	5	stress calculations	failure and g-force load testing (acoustics)
GNC	Meteorite or other space debris striking spacecraft, uneven gravitational field, earths magnetic field	GNC perturbation, error in 'pointing' measurements	4	spacecraft no longer pointing in correct direction	3	12	account for perturbations in spacecraft control using reaction wheels or cold gas thrusters, kalman filter to take into account sensor noise	1	3	GNC simulation	
GNC	bearing seizes	rxn wheel stops functioning	3	spacecraft no longer pointing in correct direction	3	9	redundant reaction wheels, and ability to use monoprop for pointing	2	6	GNC simulation	
GNC	launch vehicle incorrect launches spacecraft	vehicle tumble	3	spacecraft unable to orient itself	3	9	reaction wheels and monopropellant must be able to detect overcome and compensate for a vehicle tumble.	2	6	GNC simulation	
GNC	attitude control causes reaction wheel spin build up	unable to point vehicle	3	incorrect docking, burns in incorrect direction	4	12	momentum dump using alternate moment source	1	4	GNC simulation	
GNC/Propellant	spacecraft (or spacecraft + HST) on track to hit another satellite	spacecraft must execute evasive manuvers	4	spacecraft collision, total destruction	5	20	carry enough fuel for evasive manuvers, and allow for manuvers in orbital manuvers, pre-plan hohmann transfer with HST attached	1	5	evasive manuver simulation (orbital mechanics)	
Rendezvous	High velocity approach from poor sensor data.	Soft capture mechanism experiences structural failure.	3	HST solar arrays excessively deflect and break off, structural damage makes HST inoperable.	5	15	Control rendezvous within impulse force bounds specified by HST. Use multiple sensors to acquire relative state vector.	2	10	rendezvous simulation	
Rendezvous	Poor sensor data/sensors have failures.	Fail to dock.	3	Poor alignment with soft capture mechanism, collision with HST.	4	12	Redundant sensor readings to estimate relative state vector to HST.	2	8	rendezvous simulation	
Rendezvous	Exhaust from de-coupling damages HST.	HST solar arrays experience degraded performance.	3	HST inoperable if exhaust hits the wrong part of HST	4	12	Soft capture mechanism detaches from hubble using a spring based system, use cold gas thrusters near HST.	1	4	dynamic interaction simulation	soft capture mechanism testing
Rendezvous	Sensors fail during final approach.	Poor estimate of HST relative position.	3	Collision with HST.	5	15	Abort rendezvous and wait for sensor reacquisition.	2	10	rendezvous simulation	
de-orbit	spacecraft de-orbit	de-orbits over land	5	sprays spacecraft parts over houses and causes danger to civilians	3	15	time de-orbit to land over ocean	1	3	orbital mechanics simulation	