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 altitude	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	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
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	

Subsystem	Cause	Failure Mode	S	Effect	O	RPN	Mitigation	O	RPN	Analysis	Testing
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	