Subsystems	SubSubSystem	SubSubSubSystem	Reference letter	Function & requirements	Responsible	open/closed
Payload	HSI	OPU (on board processing unit)	A	Payload control and data processing, this is the interface between HSI+BoB and the spacecraft bus	Joe	open
		Imager	B	High resolution hyperspectral imaging. Stores data in three dimensions (spatial x, spatial y, spectral)	Joe × Sivert	open
		BOB(break out board)	C	The interface between OPU and PC/EPS/Cameras	Magne	Lukket
	Software defined radio	RF front end	D	Receives and converts analog/digital signal to be processed by mother-board	Gara	open
		RF motherboard	E	Controls the front-end and processes the digital signal received from front-end	Gara	open
	RGB camera		F	Used for validating HSI images spatially and utilized for geo-referencing. Has larger FoV than HSI but lower spatial resolution.	Dennis	open
Communications	S-band radio		G	Recieving and sending HSI data (large amounts)	Roger	open
	UHF radio		H	Used for sending telemetry (housekeeping) and receiving mission plan updates, spacecraft SW updates and camera parameters. Always ON	Roger	open
ADCS	AC		I	Controlling the spacecrafts physical motions. Orients the spacecraft towards desired attitude and actuates reaction wheels to perform a slew maneuver. Estimates the orientation, position and velocity of spacecraft autonomously	Bjørn x Mariusz	open
	AD		J		Bjørn x Mariusz	open
Power			K	Providing electrical energy during operation from solar panels and stores in batteries which is managed at the Electrical Power System to distribute to other subsystems	Magne	open
Ground Station	NTNU		L	Daily monitoring. Operators identify, track and propagate based on TLEs. Sends commands and mission plan updates on request. Also receives HSI data through S-band. Will see the spacecraft about 6-7 times per day	Roger	open
	Svalbard		M	Receives HSI data through S-band. Will see the spacecraft 10-11 times per day	Roger	open
				Uplink of mission data (S-band)		
				Download of payload data (S-band)		

Mission requirements		Comments(feel free to edit or add)
1.MS-0-001	S/C shall successfully launch, deploy, detumble and initialize operations (LEOP and commissioning) in LEO within 3 weeks	Outside of the scope
2.MS-0-002	Shall observe Case 1 and Case 2 waters off the Norwegian of at least 70x70 km^2 area	Case 1: one type of water (far out to sea). Case 2: optically complex waters (close to the coast)
3.MS-0-004	Should image same target at least 3 passes per day	The satelitte orbits earth 15 times per day
4.MS-0-006	Should take at least 1 image with less than(at least?) 160 spectral bands in VIS-NIR with <10 nm spectral resolution	160 spectral bands, the challenge is software management
5.MS-0-008	HSI images should have at least 100 m spatial resolution	Optical performance
6.MS-0-010	S/C should perform cross-track slew maneuver at a angular velocity with magnitude of 0.01 deg stability over 60 s	Angle, magnetorquer and rotary wheel adjustment, important that it is precise enough!
7.MS-0-011	Shall downlink 1 hyperspectral images in L1A data format containing detectable optical signatures (Chl-a, CDOM etc.) to be processed on ground	Software problem
8.MS-0-012	Should downlink 1 operational hyperspectral images in less than 1 hr after successful onboard dimensionality reduction, classification and target detection with certainty of 10 % of positive optical signatures (Chl-a, CDOM etc.) to be ground truthed	Software problem
9.MS-0-013	Shall enable flexible mission planning & scheduling and subsystem updates through successfully integrated uplinked mission data, FPGA programming logic and codes	Satellite tray, UHF. Data package size. time requirements, confirm success or whether it created software problems
10.MS-0-016	Should be operational for at least 5 years with weekly mission updates during peak-season	Ground station, monitoring. current

- **What is FMECA, and what is the purpose?**

  FMECA — failure mode, effects and criticality analysis — is a tool for identifying potential problems, their causes, impact (effect) and criticality, and systematize this information in a standardized manner.

  The FMECA is usually created within a spreadsheet. In order to conduct a FMECA the analyst needs a deep understanding of the system to be analysed, but the tool itself is fairly simple to learn.

  The main purpose of a FMECA is to find out which components are the most critical, meaning which is the most likely to prevent the main functions and requirements. In addition, FMECA is a great tool to systematize and present a large amount of information about a system.

- **What is a failure mode?**

  A failure mode is the partial or full absence of a function.

  A failure mode occur when:

  - Preferred action is not happening, because of an unintentional error.
  - Preferred action is happening at the wrong time or with wrong duration, causing an unwanted effect.
  - There is an error related to the instruments. An instrument is for some reason giving incorrect data or reading.

When finding failure modes, one assume that all the other components in the system are working perfectly.

Example of a function: A smoke detector's function is to alert when there is smoke, and not alert when there isn't smoke.

Example of a failure mode: The smoke detector not alerting during a fire is a failure mode. The smoke detector alerting when there is no fire is another failure mode.

- **What is a failure effect?**

  The failure effect is the consequence of the failure mode. Which effect will the failure mode have on other units and the main function?
  Example of a failure effect: If the fire detector doesn't alert during a fire, the failure effect can be a burned down house.

- **What is a failure cause?**

  A failure cause is the circumstances during specification, design, manufacture, installation, use or maintenance that result in failure.
  Example of failure cause: Lack of batteries in the fire detector, or error in the speaker.

- **What is a RPN?**

  RPN stands for Risk Priority Number. Components with a high RPN should be paid special attention to. The RPN is calculated by this formula:

  RPN = Severity X Occurrence X Detection

  We have chosen to only use severity and occurrence to calculate the RPN:

  RPN = Severity X Occurrence

Severity number	Severity class	Severity description
1	Negligible	Operating conditions are such that personnel error, environment, design deficiencies, subsystem or component failure or procedural deficiencies will result in no effect on the systems function
2	Marginal	Failure may commonly cause minor effect on the systems function.
3	Considerable	Failure may in some cases cause functions to stop system from fulfilling mission success requirements
4	Critical	Failure causes serious absence of required functions. Most mission success requirements will not be met.
5	Catastrophic	System ceases to function, no mission success requirements can be met

Occurrence number	Occurrence class	Occurrence description
1	Improbable	So unlikely that occurrence is negligible
2	Remote	Occurrence possible but unlikely
3	Occasional	Likely to occur at some point in lifetime
4	Probable	Will occur several times in lifetime
5	Frequent	Likely to occur often

(A) Payload:HSI:Onboard processing Unit (System on Cip SoC) Sivert

Operational mode	Description of operational mode	Function	Failure mode nr.	Failure Mode	Failure detection	Failure cause	Failure effect on other units	Failure effect on main function	Occurence (1-5)	Severity (1-5)	RPN=O*S	Failure minimizing measures	Notes
Cleanup	Delete frames and prepare for new		A1	Does not delete the old image cube	Less memory left	Wrong OS path		Less space for more images	3	3	9	Test, monitor, housekeeping	It's important that we are able to take several images
						Hardware failure							
			A17	Deletes wrong area of memory	with multiple boot images, detect as falling back to boot 2	Bad programming, not setting the OS partitions of the memory as read-only		Main function temporarily unavailable	2	4	8	Redundant boot images	
					checksum changes							Mount as read only filesystem	
												Set up things in RAI	
Process image			A2	Modules run in the wrong order	Corrupted data	Bad scheduling on operator's side	modules receive corrupt data	wrongly processed data is downlinked	2	1	2	Double check command schedule prior to uplink	
					Error executing module	Erronous end-to-end testing	modules do not receive expected metadata					Test the end-to-en testing?	
						Erronous or limited descriptions of interfaces between modules						metadata module flags	
						Bad programming						Better programming standards, testing and verification procedures	
Intitilization	Same as Cleanup? But requires reboot of BoB, payload controller and HSI		A3	Datacube is corrupted in a malfunctioning module	data not passed to next module	A2		Main function temporarily unavailable. If the data is not passed to te next module, The satellite may transmit some error message, and the operators need to investigate the failure	2	3	6	have programs that verify data inbetween modules?	
					downlinked data observed to be corrupt	Undetected bug in module							
						Logic gates in FPGA flipped due to solar in-flux and cosmic rays							
			A4	Missing input metadata	error thrown by module	ADCS data not received	data processed in metadata agnostic way	simplified image processing	3	1	3	check input metadata	
						timing is not received						write code to work even without metadata	
						previous module does not send appropriate metadata							
			A5	Software crash	no response when controller is pinged	Untested software	nothing works	Main function temporarily not availably. Restart payload	3	3	9	Use the software a lot in different ways	
					Keep uptime in housekeeping telemetry	Heisen bugs						Watchdog (implemented in bus, but not in payload)	
						Erronous parameters							
						Cosmic rays flipping bits							
Geometry	*NOT sure if this is required*		A6	corrupted data received from other subsystems not handeld(skip)									
			A7	wrong / unexpected input meta data leads erronous processing(skip)									
			A18	OPU doesnt boot up	No response to csp ping from OPU	Error in software	Nothing regarding imaging works	imaging fails	1	5	5	secondary boot image	
						damage from space environment							
			A8	Image & analysis not transferred from OPU	empty data packages received at payload controller or ground	module in imaging pipeline does not transfer image	payload controller does not receive image	image is not downlinked	2	2	4	look at image after downlinking to ensure that it is present	
Thumbnail mode	*NOT sure if this is required*		A9										
			A10	Unexpected metadata cause crash (skip)	software crash	unex							
			A11	bit flip due to solar-influx causes erronous processing (skip)									
Lx Data processing mode	*NOT sure if this is required. Means that the processing board just processes the images/data but no images are taken*												
			A12	corrupted processed data, intended for downlink	Data fail reliability test	bad module in image processing pipeline	wrong data downlinked	data downlinked is wrong	3	1	3	Check downlinked data	
			A13	outdated calibration coefficients	data look suspicious	calibration coefficients not updated	image sent to payload controller is inaccurate	downlinked image is inaccurate	3	2	6	update calibration coefficients	
			A14	data not transferred to the payload controller	data is not received at pc	bad transfer	no image to downlink	no image downlinked	2	2	4	Check to see if image is downlinked	
												Adjust parameters accordingly	
			A15	does not store data	data is not stored by camera	bad transfer from HSI to OPU	no image to process	image not downlinked	1	2	2	alert groundstation if no image	
						or data not stored on HSI							
			A16	initialization goes wrong	camera does not take image	imager not initialized properly	no image to process	image not downlinked	1	1	1	alert groundstation if no image	

(B)Payload: HSI: imager

Operational mode	Description of operational mode	Function	Failure mode nr.	Failure Mode	Failure detection	Failure cause	Failure effect on other units	Failure effect on main function	Occurence (1-5)	Severity (1-5)	RPN=O*S	Failure minimizing measures	Notes
Record datacube	Camera on, camera initialized, record a datacube with a set sensor AOI, frame rate, exposure, spectral sampling rate	Record datacube	B1	No image	Erronous or unexpected Image cube	Software Malfunction	Ermous data can be sent to further processing modules	Unable to capture image cube	2	4	8	Test Software for all possible parameter configurations that are expected	
						Hardware Malfunction	Ermous data can be sent to further processing modules	Unable to capture image cube	3	4	12	Make sure that HW is designed for expected envimoment	See hardware FMECA
Example options:	Camera ON, Needs to initialize for x seconds,, Needs to initialize, medium AOI on sensor, High frame rate per second, low exposure (high data rate throughput). Camera settings need to be adjusted to this	Transfer datacube	B2	Offset/skewed image on sensor	Erronous or unexpected Image Cube	Hardware Malfunction	Ermous data can be sent to further processing modules	The entire image cube will not be useful for scientific purposes	4	2	8	Make sure that HW is designed for expected envimoment	See hardware FMECA
i. High Frame Rate	Camera ON, Needs to initialize for x seconds,, Needs to initialize, medium AOI on sensor, High frame rate per second, low exposure (high data rate throughput). Camera settings need to be adjusted to this		B3	Offset spectral bands	Thorugh analysis and calibration of sensor	degradation or mechanical movement of optical components	Ermous data can be sent to further processing modules	The data in the image cube is erronous	3	3	9	Make sure that HW is designed for expected envimoment, perform in-flight calibration	See hardware FMECA
			B4	Artifacts in image	Erronous or unexpected Image Cube	degradation or mechanical movement of optical components	Ermous data or data of poor quality can be sent to further processing modules	The data in the image cube is erronous	2	3	6	Make sure that HW is designed for expected envimoment, perform in-flight calibration	See hardware FMECA
			B5	Changing focus between orbits/imaging sessions	Erronous or unexpected Image Cube	degradation or mechanical movement of optical components	data of poor quality can be sent to further processing modules	The data in the image cube is of poor qualitty	2	3	6	Make sure that HW is designed for expected envimoment, perform in-flight calibration	See hardware FMECA
ii. High Image Resolution	Camera ON, Needs to initialize for x seconds, large AOI on sensor, medium frame rate per second, medium exposure (medium data rate throughput). Camera settings need to be adjusted to this		B6	Permanent lack of focus	Erronous or unexpected Image Cube	degradation or mechanical movement of optical components	data of poor quality can be sent to further processing modules	The data in the image cube is of poor qualitty	2	4	8	Make sure that HW is designed for expected envimoment, perform in-flight calibration	See hardware FMECA
			B7	Image of wrong area (pointing is offset)	Erronous or unexpected Image Cube	Worngly calibrated navigation subsystems	georefrencing and image registration will be of poor quality	Autnomous Assets can be sent to wrong destination	2	4	8	Perform in-flight calibration	
					Erronous or unexpected Image Cube	mechanical shift of system	georefrencing and image registration will be of poor quality	Autnomous Assets can be sent to wrong destination	2	3	6	Make sure that HW is designed for expected envimoment, perform in-flight calibration	see hardware fmeca
			B8	Noise in image	Erronous or unexpected Image Cube	Imaging Sensor degradation	data of poor quality can be sent to further processing modules	The data in the image cube is erronous	4	3	12	Make sure that HW is designed for expected envimoment, testing	see hardware fmeca
					Erronous or unexpected Image Cube	Optical degradation	data of poor quality can be sent to further processing modules	The data in the image cube is erronous	4	3	12	Make sure that HW is designed for expected envimoment, perform in-flight calibration	see hardware fmeca
					Erronous or unexpected Image Cube	Software Malfunction	data of poor quality can be sent to further processing modules	The data in the image cube is erronous	2	2	4	Do testing and verification of software	
iii. Low Bit Image	Camera ON, Needs to initialize for x seconds, small AOI on sensor, low frame rate per second, high exposure (low data rate throughput). Camera settings need to be adjusted to this		B9	Under/overexposed image	Erronous or unexpected Image Cube, underexposed	Too little light reaches the sensor	data of poor quality can be sent to further processing modules	The data in the image cube is of poor qualitty	3	4	12	Increase software gain	
												increase hardware gain	
					Erronous or unexpected Image Cube, overexposed	Too much light reaches the sensor	data of poor quality can be sent to further processing modules	The data in the image cube is of poor qualitty	2	2	4		
												Lower SW/HW gain	
												Increase framerate	
			B10	Image stuck in buffer	Erronous, unexpected or no Image Cube								
			B11	Only partial data cube transferred	Erronous or unexpected Image Cube								
iv. Subsampled	Camera ON, Needs to initialize for x seconds,, Needs to initialize, High AOI on sensor, High frame rate per second, low exposure (high data rate throughput).		B12	Timing metadata are not collected	Missing timing values	I/O pin does not read timing signal	Will hamper other processing steps	Not enough data to do timign accurally	2	4	8	Make sure that the connectors are designed to survive the space envirnoment	
						Software not read timing signal	Will hamper other processing steps		2	4	4	Do testing and verification of software	
			B13	Light does not reach sensor									
			B14	Data corrupted while being transmitted to BoB									
			B15	Unexpected camera shutdown									
			B16	Physical changes to camera prevent imaging									
			B17	camera initialization fails									
			B18	Outgassing causes lenses to be clogged									
Idle	Camera is off. But connected to the BoB and power (still alive)	Save power	B19	Camera will not turn back on									
		Camera is startable	B20	Camera is still drawing too much power									

(C)Paylod:HSI:Break Out Board	Magne												
Operational mode	Description of operational mode	Function	Failure mode nr.	Failure Mode	Failure detection	Failure cause	Failure effect on other units	Failure effect on main function	Occurence (1-5)	Severity (1-5)	RPN=O*S	Failure minimizing measures	Notes
Powered on	All systems on BOB receive power	Provides power to BOB systems	C1	OPU power transmission fails	No response from OUP	5V regulator fails	Cameras and OPU can't operate	No image acquistiion capability	2	5	10		
						Cables from EPS are damaged							
			C2	HSI power transmission fails	No response from HSI camera	EPS routing is damaged		No HSI image acquisition	2	4	8		
						Cables from EPS are damaged							
			C3	RGB power transmission fails	No response from RGB camera	5V regulator fails	ADCS validation and georeferencing can't get RGB data	No RGB image acquisition	2	3	6		
						Cables from EPS are damaged							
Image storage on SD-card	BoB stores data after OPU acquires images	Image data is transferred from OP to SD card on BoB	C4	Unable to store images on SD-card		data corrupted during transfer		Loss of one image	3	2	6	Verify image from non-volatile memory before clearing image from volatile memory.	
						does not store data		Unable to store any data, can only hold image in DDR memory	2	4	8	Have backup memory storage (PC buffering, eMMC)	The picozed has an embedded eMMC which could be repurposed to hold image data if SD card is damaged
						data store is corrupted		Loss of multiple current images	3	2	6	Use ECC when storing images	
CAN Communication	The OPU is able to communicate over the CAN-bus via BoB		C5	Cannot receive or transmit CSP data	No response from OPU	CAN transceiver damaged from overvoltage	Other units can't get any data or response from OPU	No HSI/RGB image acquisition	2	5	10	replacing transceiver with one with overvoltage protection	
						CAN transceiver damaged from cosmic rays			2	5	10	sourcing a space grade transceiver	
						Faulty circuit design			2	5	10	performing design reviews	
HSI Gigabit Ethernet	The OPU is able to communicate with the HSI Camera		C6	Cannot receive HSI data/metadata	No response from HSI camera	Ethernet connector mechanicalically damaged	Other units can't get HSI data	No HSI image acquisition	1	4	4	Creating and following assembly procedures	
						Ethernet cables mechanically damaged			2	4	8	Creating and following assembly procedures	
RGB USB Communication	The OPU is able to communicate with the RGB Camera		C7	Cannot receive RGB data/metadata, or transmit RGB commands	No response from RGB camera	USB connector mechanicalically damaged	ADCS validation and georeferencing can't get RGB data	No RGB image acquisition	1	3	3	Creating and following assembly procedures	
						USB cables mechanically damaged			2	3	6	Creating and following assembly procedures	

(F) Payload: RGB	Dennis													
Operational modes	Description of operational mode	Function	Failure mode nr.	Failure mode	Failure detection	Failure cause	Failure effect on other units	Failure effect on main function	Occurence (1-5)	Severity (1-5)	RPN=O*S	Failure minimizing measures	Notes
Off	Camera is disconnected from power and uses no energy.	Using no power	F1	Module uses power when it should not	If camera is connected to its own 5V power line, EPS can measure how much power the camera uses.	mechanical failure causing short circuit	more power use than desired, draining battery, and potentially hindering the main payload and other operational functions	if power use is too high for too long, can drain battery so that no more energy is left for normal operation	2	3	6	Prevention: Stringent shock and vibration tests on rgb camera related wiring. Mitigation: EPS disabling power to module	
		Being ready to be turned on	F2	Module does not turn on when operations expect	RGB camera service reports an error that camera is not connected	mechanical failure causing short circuit inside module that breaks the camera or mechanical failure that disconnects a vital circuit inside camera module or of the camera module	Verification of atitude is harder for humans to see	No failure effect on main function	2	2	4	Prevention: Stringent shock and vibration tests on rgb camera related wiring.	
Initializing	Process where power is connected to camera and RGB service opens the camera and applies parameters from config file. Takes about 15 seconds	Making camera ready for taking images and communicating with computer	F3	One step in initialization sequence fails	RGB camera service reports an error and cancels initialization	Cosmic/stellar ray or particles causing upset	RGB image delayed or missing	No failure effect on main function	3	2	6	Restart sequence	
Initialized / Opened / Standby	Camera initialized and ready to be confgured further and take pictures, waiting for capture command.	Ready to respond to commands	F4	Camera changing its state unexpectedly	The next command executed is failing	Upset, loose wiring?	RGB image delayed or missing	No failure effect on main function	2	2	4	Resending command or turning camera off and on again	
			F5	Command execution fails	The next command executed is failing		RGB image delayed or missing	No failure effect on main function	1	2	2	Restart initialization sequence	
Taking pictures	Camera is currently capturing an image: 1. Allocating memory 2. Waiting for HW or SW trigger 3. Exposing 4. Reading image from camera 5. saving image to SD card		F6	Noise in image	Visual inspetion of downlinked image	Too much space radiation hitting sensor during exposure, upsets changing camera gain settings	Verification of atitude is harder for humans to see	No failure effect on main function	4	1	4	Resetting camera parameters	
			F7	Underexposed image	Visual inspetion of downlinked image	Upset changing exposure, pixel clock or framerate settings	Verification of atitude is harder for humans to see	No failure effect on main function	2	1	2	Resetting camera parameters	
			F8	Overexposed image	Visual inspetion of downlinked image	Upset changing exposure, pixel clock or framerate settings	Verification of atitude is harder for humans to see	No failure effect on main function	2	1	2	Resetting camera parameters	
			F9	Unexpected camera shutdown	The next executed command is failing	Latchup or upset	RGB image delayed or missing	No failure effect on main function	2	2	4	Restarting camera	
			F10	Artifacts in image	Visual inspetion of downlinked image	Space radiation?	Verification of atitude is harder for humans to see	No failure effect on main function	2	2	4		
			F11	Changing focus between orbits/imaging sessions	Visual inspetion of downlinked images	Probably temperature variations causing change of optical system	Verification of atitude is harder for humans to see	No failure effect on main function	3	2	6		
			F12	Permanent lack of focus	Visual inspetion of downlinked images	Damage to optical system during launch or permanent damage from temperature variations, low pressure environment?	Verification of atitude is harder for humans to see	No failure effect on main function	2	3	6	Proper vibration and shock testing procedure	
			F13	Transfer Error	RGB Camera service reports an error	Unknown bu common error encountered during testing	RGB image delayed or missing	No failure effect on main function	3	1	3	Restarting camera	

(G)Payload: Comm S-band Radio

Operational mode	Description of operational mode	Function	Failure mode nr.	Failure Mode	Failure detection	Failure cause	Failure effect on	Failure effect on	Occurence (1-5)	Severity (1-5)	RPN=O*S	Failure minimizing n	Notes
S-band RX	Receiving data from ground. ALWAYS ON	Receive analog signal from ground	G1	Does not recieve data at all		Noisy signal, Wrong pointing of antenna,		Dont recives misson planning schedule	3	3	9	Testing	
		Convert signal from analog to digital data	G2	Receives corrupt data		Noisy signal		dont recives misson planning schedule	3	3	9	Have default mission planning onboard	
		Send digital data from radio to payload controller	G3	Does not send any data		Databus is saturated		Lose the mission planning	2	3	6		
		(Data corruption check)	G4	N/A							0		
		Acknowledge that packages are recived		Does not send an acknowledgement		Outside the communication window		Ground station wont be sure that we got tha last package	3	3	9	Send periodic acknowledgements	
											0		
											0		
											0		
											0		
S-band TX	Transmits data from payload controller to ground.	Transmit analog signal from satellite to ground	G5	Does not send data from satellite to ground		Bad pointing of the antenna		It will not downlink images, and housekeeping data	2	5	10	Switch to UHF radio	
		Convert data from digital to analog data	G6	Sends corrupt data		Corrupted encoder		Downlink corrupt images and housekeeping data	2	4	8		
		Receive digital data from payload controller	G7	doesnt recieve digital data from payload controller		Payload controller is busy with other tasks		It will not downlink images, and housekeeping data	2	4	8		
		Handshake with ground	G8	Resends old data without being asked to							0		
				No handshake		Bad pointing of antenna, strong interference		it will not downlink images and housekeeping data	2	5			
		Packet transmission control	Gx	cant resume transmitting the missing packets							0		
											0		
											0		
											0		
Safe Mode	Reboot and diagnostics; subsystem check-out. Initialize RX and TX	Reboots	G9	Does not reboot		frozen software		Cannot control S-band radio	1	4	4	switch to backup UHF radio	
			G10	Sends wrong telemetry		Sensors are not well calibrated		Does not have telemetry from satellite	2	3	6		
		Initialize RX	G11	Does not initialize RX		Does not have power, software corrupted		Cannot recieve	2	4	8		
		Initialize TX	G12	Does not initialize TX		Does not have power, software corrupted		Cannot transmit	2	4	8		
											0		
											0		
											0		

(H)Comm UHF radio

Operational mode	Description of operational mode	Function	Failure mode nr.	Failure Mode	Failure detection	Failure cause	Failure effect on other units	Failure effect on main function	Occurence (1-5)	Severity (1-5)	RPN=O*S	Failure minimizing measures	Notes
UHF RX	Receiving data from ground. ALWAYS ON		H1	Does not recieve data at all							0		
			H2	Receives corrupt data							0		
											0		
											0		
											0		
UHF TX	Transmits data from Flight computer to ground.		H3	Does not send data							0		
			H4	Sends corrupt data							0		
			H5	Send partial data							0		
			H6	Resends old data without being asked to							0		
											0		
											0		
											0		
											0		
											0		
Idle	Same as RX										0		
											0		
											0		
											0		
											0		
											0		
											0		
											0		
Safe Mode	Reboot and diagnostics; subsystem check-out. Initialize RX and TX		H7	Does not reboot							0		
			H8	Sends wrong telemetry							0		
			H9	Does not initialize RX							0		
			H10	Does not initialize TX							0		
											0		
											0		
											0		
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											0		
											0		

(I)ADCS

Operational mode	Description of operational mode	Function	Failure mode nr.	Failure mode	Failure detection	Failure cause	Failure effect on other units	Failure effect on main function	Occurence (1-5)	Severity (1-5)	RPN=O*S	Failure minimizing measures	Notes
Orbit mode	Orbit mode happens right after deployment, OFF for 45 min until detumbling automatically turns on	ADCS is off for 45 min right after deployment	I11	Attitude Control Failure Mode							0		
											0		
Detumble mode	Magnetorquers are on, de-spins the satellite after deployment. Automatically turns on 45 min after deployment; utilizes Earth's magnetic field	ADCS stops the satellite from spinning	I12	Magnetorquers do not dump reaction wheel momentum		Magnetorquers malfunctioning			2	5	10		
			I13								0		
			I14	Wrong actuator signals to magnetorquers		Signaling error			2	4	8		
			I15	Magnetorquers have wrong direction in magnetc field		Mistake in setup			1	5	5		
Idle mode	Magnetorquers are ON all the time. All sensors except for star-tracker and IMU are on. Constantly controls spacecraft against perturbations. Magnetorquers are on to dump momentum from reaction wheels	Makes the satellite orbit with a constant attitude	I16	Reaction wheels saturate		Magnetorquers malfunctioning, wrong measurements from sensors (AD)			2	3	6		
			I17	Reaction wheel does not spin up		Reaction wheels malfunction			1	3	3		
			I18	Magnetorquers dont work		Magnetorquers malfunction			1	3	3		
Velocity mode	Aligns the S/C z-axis along the velocity vector to minimize drag. Reaction wheels are ON	Attitude control	I19	Desired attitude not achieved		Reaction wheels malfunctioning			2	2	4		
User supplied vector	Uses reaction wheels and magnetorquers to align against an arbitrary user supplied position (i.e. point towards the Moon)	Pointing	I20	Does not point in right direction		Magnetorquers malfunctioning, reaction wheels malfunctioning, AD malfunctioning		MS-0-002, MS-0-004, MS-0-011	2	3	6		
Sun pointing	Nominal mode when not in eclipse. When sun is detected by sun sensors, the S/C uses reaction wheels to align against the Sun with the +Y-face vector parallel to sun vector (largest face 90 degrees)	Pointing	I21	Does not point in right direction		Magnetorquers malfunctioning, reaction wheels malfunctioning, AD malfunctioning			2	3	6		
Nadir	Points the camera straight down towards Earth's surface (center)	Pointing	I22	Does not point in right direction		Magnetorquers malfunctioning, reaction wheels malfunctioning, AD malfunctioning		MS-0-002	1	4	4		
Prepare slew	S/C uses reaction wheels to point to an user-specified pitch angle (e.g. 60 deg) along orbit track, while keeping roll and yaw angles (almost zero)	Pointing	I23	Wrong angle		Reaction wheels not accurate enough, AD malfunctioning		MS-0-002, MS-0-004, MS-0-010	1	4	4		
			I24	roll and Yaw angles not almost zero		Reaction wheels not accurate enough, AD malfunctioning		MS-0-002, MS-0-004, MS-0-010	2	3	6		
In track slew	S/C actuates the reaction wheels opposite way of orbit track about S/C y-axis, uses Reaction wheels to achieve <1 deg/s angular velocity. Angular velocities in x and y-axes are kept to a minimal	Slew	I25	Does not slew at correct rate		Reaction wheels not accurate enough		MS-0-002, MS-0-004, MS-0-010	1	4	4		
			I26	Does not keep y and x axes at minimal angular velocities		Reaction wheels not accurate enough			2	3	6		
Cross-track	S/C actuates the reaction wheels opposite way of orbit track about S/C y-axis while pointing at a roll angle (e.g. 10 deg), uses Reaction wheels to achieve <1 deg/s angular velocity. Angular velocities in x and z-axes are kept to a minimal	Slew	I27	Does not slew at correct rate		Reaction wheels not accurate enough		MS-0-002, MS-0-004, MS-0-010	1	4	4		
			I28	Does not keep z and x axes at minimal angular velocities		Reaction wheels not accurate enough			2	3	6		
Safe mode	Anomalies in subsystems, saturation. Turns off, reboots all sensors/reaction wheels/magnetorquers, goes back to detumbling mode	Reset			Does not reset						0		

(J)ADCS | | | | Attitude Determination Failure Mode | ADCS Failure Mode (total)

Function			Failure mode nr.	Failure Mode	Failure effect	Failure detection	Failure source	Failure effect on other units	Failure effect on main function	Occurence (1-5)	Severity (1-5)	RPN=O*S	Failure minimizing measures	Notes
Estimate angular velocity			J1	Fails to estimate angular velocity			Flaw in inertial measurement unit (IMU), error in signals between IMU and AD	AC: Most tasks		1	4	4		
Estimate magnetic field			J2	Fails to estimate magnetic field			Flaw in magnetometers, error in signals between magnetometers and AD	AC: Detumbling, Idle	MS-0-001	1	3	3		
Estimate sun vector			J3	Fails to estimate sun vector			Flaw in sun sensors, error in signals between sun sensors and AD	AC: Sun pointing		1	2	2		
Estimate position			J4	Fails to estimate position			Star tracker covered/blocked	AC: Any that requires pointing somewhere (sun pointing, user vector)	MS-0-004, MS-0-011	1	3	3		
Estimate attitude			J5	Fails to estimate attitude			Flaw in inertial measurement unit (IMU), error in signals between IMU and AD	Needed for all AC tasks	MS-0-002, MS-0-004, MS-0-010, MS-0-011	1	5	5		
												0		
												0		
												0		
												0		
												0		
												0		
												0		
												0		
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												0		

(K)Power	Magne												
Operational mode	Description of operational mode	Function	Failure mode nr.	Failure Mode	Failure detection	Failure cause	Failure effect on other units	Failure effect on main function	Occurence (1-5)	Severity (1-5)	RPN=O*S	Failure minimizing measures	Notes
Safe Mode	Reboots EPS, happens when too much power is drawn	Convert solar energy to power									0		
		Reboot EPS	K1	EPS is not rebooted	No response from satellite		All units fail	Total failure	2	5	10		
		Store power in batteries									0		
		Limit discharge of batteries									0		
											0		
											0		
											0		
											0		
											0		
Critical Mode	Power consumption is too high, dept of discharge is too high	Distribute power to critical subsystems	K2	Subsystems do not get power						4	0		
		Convert solar energy to power	K3	Solar energy is not converted					2	5	10		
		Charge batteries	K4	Batteries are not charged (same as solar energy not converted?)					2	5	10		
		Store power in batteries	K5	Some batteries fail					3	4	12		
		Cut power to non-critical subsystems	K6	All batteries fail					2	5	10		
		Limit discharge of batteries	K7	Batteries are discharged more than depth-of-discharge							0		
			K8	Subsystems that are not supposed to get power in critical mode get power(sdr)					1	4	4		
											0		
Nominal Mode	Normal operation. Draws current and voltage to a certain level	Distribute power to active subsystems	K9	Subsystems do not get power							0		
		Convert solar energy to power	K10	Solar energy is not converted							0		
		Store power in batteries	K11	Some batteries fail							0		
		Charge batteries	K12	Batteries are not charged (same as solar energy not converted?)							0		
		Limit discharge of batteries	K13	Batteries are discharged more than depth-of-discharge							0		
											0		
											0		
											0		
											0		
Extreme (?) Mode	Depth-of-discharge allowance is expanded (>15%)	Distribute power to active subsystems									0		
		Convert solar energy to power									0		
		Charge batteries									0		
		Store power in batteries									0		
		Allow more discharge of batteries, but not let it get to safe mode level									0		
											0		
Current Montioring	All power channels are monitored and found to be within current consumption limits.	Monitor current consumption of subsystems.	K14	A subsystem consumes more current than the threshold on the power channel	Monitoring of EPS telemetry	Short-circuit in subsystem	Affected subsystem will not be able to provide other systems with services	No image acquisition if the wrong subsystem fails	2	4	8	Following best practices when designing circuits	
		Disconnect a power channel if it consumes too much power.				Unexpected high peak power concumption in subsystem	Affected subsystem will be temporarily unabvail	Temporarily unavailable	3	2	6	Performing power analysis and measurements	
											0		
											0		
											0		

(L)Ground station: NTNU Trondheim

Operational mode	Description of operational mode	Function	Failure mode nr.	Failure Mode	Failure detection	Failure cause	Failure effect on other units	Failure effect on main function	Occurence (1-5)	Severity (1-5)	RPN=O*S	Failure minimizin	Notes
Standby/Idle		Ready to receive commands from ground station operator	L1	Does not react		Frozen software		Lose track of the satelite, no comms	2	2	4		
						Internet does not work		same	2	2	4		
											0		
RX	Receives telemetry, HSI data, tracks acitvely the spacecraft	Track satellite	L2	Tracks wrong satellite		Satellite points wrong way or recive weaker signal from our satellite than from an other stallite		Lose track of the satelite, no comms	2	4	8		
		Receives analog signal from satellite	L3	Does not recieve analog signal from satelite		Signal too weak, or signal too noisy or the antenna pionts wrong direction		We have no data or comms	1	4	4		
		Converts analog signal from satellite to digital data	L4	Receives noisy signal		Antenna not pointing correctly or a lot of interference		recive corrupted data	4	4	16	Use another ground station	
								Does not know health status of satelite					
		Decode digital signal	L5	Does not decode digital signal		Bug in decoder or noisy signal		Not contracting image, does not know health status of satellite	1	4	4		
		save recived raw data	L6	Does not save recieved data		Memory is full, or the memory is corrupted, can't access online data base		Losing data packages, noes not know health status, does not contract image	2	5	10	Have different places to save data, and always different places to save data	
		Sends data to operator	L7	does not send data to operator		No internet connection		does not get image(but its saved)	2	2	4		
		Provides operator with user interface	L8	does not provide operator with user interface		Frozen software		Image difficult to analyze, the operator will have to chek the lokal memory	2	2	4		
											0		
											0		
TX	Transmits mission plan data, software updates, does not need to track (?)	Transmits analog signal to satellite	L9	Transmit corrupted signal		Doesn't read command properly		satellite could go to safemode	1	2	2		
		Converts digital data to analog signal	L10	Does not convert digital data to analog signal		analog to digital converter not working properly		No signal is transmitted	1	2	2		
		Tracks satellite	L11	Does not track satellite		Bad pointing of antenna, weaker signal than from another satellite		No signal, does not recieve data	3	3	9	Two antennas tracking the satellite, bigger antenna	
		Provides operator with user interface	L12	Does not provide operator with user interface		Frozen software		Difficulties sending commands to the satellite	2	2	4		
		Code data	L13	Does not encode data		encoding does not work properly		Can not send commands, or commands are not understood by the satellite	1	2	2		
		Create mission plan	L14	Does not create mission plan		Wrong inputs		satellite does not know what to do/does nothing	2	4	8		
		Ensure software mechanism	L15	Can not ensure software update mechanism		no acknowledgement from satellate when sending update		Onboard software could be corrupted	4	3	12	Test updatemechanism on ground as if it was the real setup	

(N)Place failure modes which does not fit in any other subsystem/ component here

Operational mode	Description of operational mode	Function	Failure mode nr.	Failure Mode	Failure detection	Failure cause	Failure effect on other units	Failure effect on main function	Occurence (1-5)	Severity (1-5)	RPN=O*S	Failure minimizin	Notes
	Scheduler	Schedules operations for the day	N1	Does only work for one orbit							0		
											0		
											0		
											0		
											0		