Failure Modes and Effects Analysis Template

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See Configuration Management System for approval history.

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Change Record

REVISION	DATE	ECO#	DESCRIPTION OF CHANGE
A	1/1/2012	ECO-00299	Initial Release
B	6/12/2013	ECO-01114	Update examples and add DFMEA Checklist

FMEA Purpose: The purpose of FMEA analysis is to provide a systematic analysis method to identify potential failure modes of systems, components and/or assemblies. The analysis provides input to the design team on how to mitigate the risk of potential failures to an acceptable level. Failures should be prioritized according to how serious their consequences are, how frequently they occur and how easily they can be detected. Action to eliminate or reduce failures should begin with those with the highest priority.

FMEA – Item / Function Column:
Item: Description for the System/Assembly/Component
Function: What is the design supposed to do?
Write in physical, technical and measureable terms. May reference specification(s).

FMEA - Potential Failure Mode(s) Column:
How can the design fail to meet requirement(s)? Modes can be broken down into the following categories: Total failure, partial failure, intermittent failure, over-function and unintended function.

Example for a touch screen interface: Total Failure - Does not accept user input, Partial Failure - Some screen areas function while other do not, Intermittent Failure - Difficulty interpreting user entries, Over Function - Interprets single input as double press, Unintended Function - Misinterprets user entry. Failure modes should be specific, avoiding subjective terms like “bad”, “not right”, “too loose/tight”, “and improper”, etc. Reference requirement(s) where possible.

FMEA - Effects of Failure Column:
What is the effect(s) of the failure? To determine the effect(s), view the failure from the eyes of the end user and list effects in a manner that the customer would describe them. Here are examples of effects that might be encountered:

> Customer effect: noisy; premature failure; intermittent output; unable to output full power; unacceptable appearance; will not maintain power setting.

FMEA - Severity (SEV) Columns:
How severe is the failure? Severity is a numeric ranking of the seriousness of the failure. The number shall be assigned using the definitions given in the ratings table found on the Rating & Scoring Guide tab. Each category covers a range of events. The severity shall be evaluated relative to the pre-mitigation result and post-mitigation result.

FMEA - Potential Cause(s) of Failure Column:
What is the cause or mechanism of the failure? In this column we list at least one specific cause for each failure mode. Often there are multiple or many causes for any given failure mode, be sure to include all plausible causes. Be sure to identify the causes for the failure mode and not the individual effect.

FMEA - Occurrence (OCC) Columns:
How often do we expect to see the failure? Occurrence is a numeric ranking of the probability of the cause for the failure occurring. This ranking is assigned using definitions given in the ratings table found on the Rating & Scoring Guide tab. Each category covers a range of probabilities. The occurrence shall be evaluated relative to the likelihood of the failure occurring when it is caused by the "cause". If multiple causes are listed, the occurrence shall be based on the cause which would result in the highest occurrence rating.

FMEA - Control Column:
List the current system controls in place to prevent the failure mode. There are two types of design controls to consider:

Prevention: Prevent the cause/mechanism of failure or the failure mode from occurring, or reduce the rate of occurrence.
• For prevention controls, place a 'P' before each prevention control listed.
• Examples of preventative controls: What has been done to prevent the failure? Design Reviews, DFM (Design for Manufacturability), Engineering Builds, Drawing Control Notes (i.e. critical dimensions, coating/finishes, cleanliness, materials), Finite element analysis, Tolerance stack-up analysis, Simulations, Self-test/diagnostics, Redundancy, etc.

Detection: Detect the cause/mechanism of failure or the failure mode, and lead to corrective action(s).
• For detection controls place a 'D' before each detection control listed.
• Examples of detection controls: What tests will be run to assess the likelihood of a failure? Simulation and verification testing… Functional, Life, HALT (Highly Accelerated Life Test), HASS (Highly Accelerated Stress Screen), etc.

FMEA - Detection (DET) Column:
How likely will the failure be detected? Detection is a numeric ranking of the ability of the design to detect a potential cause/mechanism and subsequent failure mode. This ranking is assigned using definitions given in the ratings table found on the Rating & Scoring Guide tab.

FMEA - Scoring the SEV/OCC/DET Columns:
Now that the modes of failure and the effects have been determined, it will be necessary to decide which of these to focus upon for resolution. It would be inefficient to work on every failure mode and its potential effect, so a method of prioritization will include:

Severity of the effect (SEV)
Probability of the failure mode occurring (OCC)
Probability of failure detection (DET)

Within the FMEA Score Sheet is a tab containing the ranking criteria for the SEV (Severity), OCC (Occurrence), and DET (detection). The FMEA team agrees on the appropriate number for each column score, taking into account the perspective of the customer (internal or external).

FMEA – Scoring the RPN Column:
This index, called the Risk Priority Number (RPN), helps prioritize our actions for problem resolution (though safety issues must always receive attention and are indicated by a Severity (SEV) score of 4 or 5). The RPN is calculated automatically in the form; multiplying the SEV, OCC and DET:

Risk Priority Number (RPN) = SEV x OCC x DET

FMEA – Scoring the CRIT Column:
This index, called the Criticality Index (CRIT), helps further prioritize our actions for problem resolution given greater emphasis to the Severity and frequency of Occurrence. The CRIT is calculated automatically in the form; multiplying the SEV and OCC:

Criticality (CRIT) = SEV x OCC

FMEA - Analysis and Recommended Corrective Actions Column

The Risk Priority Number (RPN) and Criticality Index act as tools to help prioritize and focus the reduction of the overall risks associated with potential failure modes. Once all the RPNs are calculated, the FMEA team will outline recommended action(s) that should be taken to reduce the overall RPN for failure modes that are deemed unacceptable and whereby action(s) are feasible. The risk associated with each failure should be reviewed to ensure it is ALARP (As low as reasonably practicable). This may include evaluating the feasibility of each potential corrective action by comparing the cost associated in reducing risk further versus the potential benefit gained. Reduction of the RPN can be accomplished by lowering any of the three rankings (severity, occurrence, or detection) by the following methods:

A reduction in the Severity ranking (SEV) is often the most difficult to attain and will most likely require a design change.
A reduction in the Occurrence ranking (OCC) may accomplished by removing or controlling the potential cause/mechanisms of failure.
A reduction in the Detection ranking (DET) is accomplished by adding or improving prevention or detection controls.

In general practice, when a Criticality rating 15 to 25 or a Severity rate of 5 is assigned, special attention must be given to ensure the risk is addressed through design actions/controls regardless of the RPN. In all cases (Severity rankings of 4 or 5) where the effect of an identified potential failure mode(s) could be a potential hazard and cause injury, preventative/corrective actions shall be taken to avoid the failure mode by eliminating or controlling the cause(s), or appropriate operator protection should be specified. For these cases the failures will need to be addressed in the PHA process.

Guideline to Recommended Corrective Actions

Risk Priority Number

Severity (1-5) x Occurrence (1-5) x Detection (1-5)

Intolerable (75 - 125)
Review to determine if risk is ALARP (25 - 74)
Acceptable (1 - 24)

Criticality Index

Occurrence (OCC)

Frequent	5	5	10	15	20	25
Probable	4	4	8	12	16	20
Occasional	3	3	6	9	12	15
Remote	2	2	4	6	8	10
Improbable	1	1	2	3	4	5
		1	2	3	4	5
Severity (SEV)		Negligible	Minor	Moderate	Serious	Critical

Intolerable (15 - 25 and for all failure modes resulting in a SEV of 5)
Review to determine if risk is ALARP (4 - 14)
Acceptable (1 - 3)

FMEA - Work Team and JIRA #

Who should resolve the issues?

The FMEA team shall establish the ownership of the work team that will be responsible for the implementation of the specified corrective action(s). Upon assignment of responsibility, an entry will be made into JIRA to track the required corrective action(s) through resolution. The accountable work team and associated number assigned within JIRA shall be recorded onto the FMEA form.

Note: Work Team and JIRA #s shall only be required for failures where the FMEA team deems that corrective action will be required.

Failure Mode and Effects Analysis
Rankings and Scoring Guide

Severity Rankings: (Rankings of 4 or 5 will be carried over to the PHA due to potential for injury!)	
5	**Critical:** Safety issue and/or non-compliance with a government regulation, failure may cause serious injury or death to the customer or an employee.
4	**Serious:** Failure results in a loss or reduction of primary function and renders the product inoperable causing a high degree of customer dissatisfaction or may cause minor injury to the customer or an employee.
3	**Moderate:** Failure results in a partial malfunction of the product, the performance/functionality loss causes customer dissatisfaction.
2	**Minor:** Failure may not be readily apparent and/or may create a minor nuisance to the customer, but would have minor effects on the customer's satisfaction.
1	**Negligible:** No discernible effect, the failure would not be noticeable to the customer and would not affect the customer's process or product.

Occurrence Rankings (Likelihood of occurrence across the entire Observatory):	
5	**Frequent:** One occurrence every month
4	**Probable:** One occurrence every 1-12 months
3	**Occasional:** One occurrence every 12 months to 5 years
2	**Remote:** One occurrence every 5 to 10 years
1	**Improbable:** One occurrence in greater than 10 years

Detection Score:	
5	**Very Remote:** chance the design control will detect a potential cause/mechanism and subsequent failure mode.
4	**Low:** chance the design control will detect a potential cause/mechanism and subsequent failure mode.
3	**Moderate:** chance the design control will detect a potential cause/mechanism and subsequent failure mode.
2	**High:** chance the design control will detect a potential cause/mechanism and subsequent failure mode.
1	**Almost certain:** chance the design control will detect a potential cause/mechanism and subsequent failure mode.

RPN = (SEV)x(OCC)x(DET)

This value should be used to rank order the concerns in the process. Regardless of RPN, special attention should be given when severity and occurrence are high which is reflected by the Criticality Index (CRIT). Refer to the tables below for guidelines on the levels for recommendations for corrective actions/mitigation. Note: Whenever a failure poses a potential hazard to personnel, corrective action shall be taken and failures shall be addressed in a separate Hazard Analysis. To reduce Occurrence and increase Detection, process and/or design revisions are often required. In most cases, only design revisions can reduce the Severity ranking.

Risk Priority Number

Severity (1-5) x Occurrence (1-5) x Detection (1-5)

Intolerable (75 - 125)
Review to determine if risk is ALARP (25 - 74)
Acceptable (1 - 24)

Criticality Index

Occurrence (OCC)

Frequent	5	5	10	15	20	25
Probable	4	4	8	12	16	20
Occasional	3	3	6	9	12	15
Remote	2	2	4	6	8	10
Improbable	1	1	2	3	4	5
		1	2	3	4	5
Severity (SEV)		Negligible	Minor	Moderate	Serious	Critical

Intolerable (15 - 25 and for all failure modes resulting in a SEV of 5)
Review to determine if risk is ALARP (4 - 14)
Acceptable (1 - 3)

Failure Mode Effect Analysis (FMEA)

Document #: ________________ **Doc Date (Orig):** _______________ **Doc (Rev):** __________ **Facilitator:** __________________________

Type: ☐ SYSTEM ☐ ASSEMBLY ☐ COMPONENT ____________________________________ **Rev:** __

Team Members:

Pre-Corrective Action											Post Corrective Action							
Ref #	**Item Description / Function**	**Potential Failure Mode**	**Effects of Failure**	**SEV**	**Potential Cause(s) of Failure**	**OCC**	**Control**	**DET**	**RPN**	**CRIT**	**Analysis & Recommended Corrective Actions**	**Work Team**	**JIRA #**	**SEV**	**OCC**	**DET**	**RPN**	**Comments**
									0	0							0	
									0	0							0	
									0	0							0	
									0	0							0	
									0	0							0	
									0	0							0	
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Failure Mode Effect Analysis (FMEA)

Document #: __NEON.DOC.000808_____ **Doc Date (Orig):** ___1/23/2013_____ **Doc (Rev):** _____	**Facilitator:** ____Byron Murray_____
Type: ☐ SYSTEM ☑ ASSEMBLY ☐ COMPONENT _____Soil-Water Content Profile_____ **Rev:** __FPDR____4/23/2013	
Team Members: Aaron Joos ; Ed Ayres ; John Haywood ; Brad Jarvis; Asa Akers ; Hanne Buur ; Laura Leyba-Newton ; Lloyd Banta ; Alexander Cooper; Robin Hodson; Nicholas Applegate ; Michael Pursley ; Ty Guadagno	

Pre-Corrective Action											Post Corrective Action							
Ref #	Item Description / Function	Potential Failure Mode	Effects of Failure	SEV	Potential Cause(s) of Failure	OCC	Control	DET	RPN	CRIT	Analysis & Recommended Corrective Actions	Work Team	JIRA #	SEV	OCC	DET	RPN	Comments
1	Assembly, Soil Water Content Profile, CF00800000 / sensor assembly for soil water content profile	Parts will not fit together and mount properly	Not able to assemble	3	Mount holes under over sized, miss located or missing	1	Tolerance Analysis Completed, Inspection Procedures	1	3	3				1	3	3	9	5 tubes per site, 1 per soil plot, Geo probe for most installations, site specific requirements, pvc pipe stays in the ground, edge of soil pit, near arbor. Grape will be installed on unistrut at the arbor. 2 to 16 sensors per tube with 8 sensors as the average.
									0	0							0	
									0	0							0	
									0	0							0	
2	Assembly, Soil Water Content Profile, CF00800000 / sensor assembly for soil water content profile	Assembly not properly aligned, assembly damaged, cables damaged	Data loss / invalid data	4	Assembly components under/over sized/missing /miss aligned/sensor failure/component failure/miss calibrated	3	Material analysis & callout, Cable Routing and anchor points, Locking hardware, Cert of compliance will be requested, CVAL, Eng, SE, and mfg testing, Maintenance Procedures, Armored cables from sensor to Grape	1	12	12	Action Item: Owner Deployment, Reporter B Murray, DFMEA Soil Water Content Profile, Assembly Soil Water Content Profile CF00800000, Installation tool investigation for install and verification to ensure vertical +- 3 degrees.			4	2	1	8	The pn 0318950000 (Sensor TriSCAN Soil Water Content and Salinity Sensor) applies only to the actual blue sensor part of the entire assembly. Similarly, the other components have their own pns assigned and can be found in Agile under Sentek. Because each of the actual deployed assemblies will be unique, some to their individual plot, Angelo plans on assigning each completed sensor assembly for each plot its own assembly number. In the mean time I will make a dummy sensor assembly using the previously stated assembly number (CF00800000) and Lloyd and myself will start populating the BOM for that item.
									0	0	Action Item: Owner Engineering, Reporter B Murray, DFMEA Soil Water Content Profile, Assembly Soil Water Content Profile CF00800000, Design connector/cable to be field replaceable and make the part a FRU.						0	
									0	0	Action Item: Owner Engineering, Reporter B Murray, DFMEA Soil Water Content Profile, Assembly Soil Water Content Profile CF00800000, Field Deployment to drill Soil Water Content Holes at first arrival on site to allow for Science, manufacturing, CVAL, shipment of the configured sensors.						0	
									0	0							0	

Failure Mode Effect Analysis (FMEA)

Ref #	Item Description / Function	Potential Failure Mode	Effects of Failure	SEV	Potential Cause(s) of Failure	OCC	Control	DET	RPN	CRIT	Analysis & Recommended Corrective Actions	Work Team	JIRA #	SEV	OCC	DET	RPN	Comments
3	Assembly, Soil Water Content Profile, CF00800000 / sensor assembly for soil water content profile	Assembly becomes damaged or becomes unlevel from original installation or is not installed optimally	Loss or invalid data	4	1) Insufficient Material strength 2) Service/Installation (Over torque-Breakage, Under torque - Loss of hardware) 3) Corrosion 4) Stress Fatigue/Wear 5) Collision 6) Lightning Strike 7) Voids in the soil 8) Rocks against tube	4	1) Material Analysis & Callout 2) Locking hardware 3)Anchoring 4) Torques/Pattern specified on drawing 5) controlled installation process and tools	1	16	16	Action Item: Owner Engineering/Operations Reporter: B Murray, DFMEA Soil-Water Content Profile, CF008000000, Operations procedure to check oring every x number of years.			4	2	1	**8**	
											Action Item: Owner Engineering/Operations Reporter: B Murray, DFMEA Soil-Water Content Profile, CF008000000, Operations procedure / process to have shop vac to clean and maintain sensor tube.							
									0	0							0	
4	Assembly, Soil Water Content Profile, CF00800000, PCBA that NEON will be modifying with the One Wire Chip / sensor assembly for soil water content profile	PCBA Damage	Data loss / invalid data	3	NEON Assembly of One Wire Chip onto the pins of the backside of a connector	3	Certified Operators and Inspection, Epoxy of the chip, Conformal Coating of the PCBA.	2	18	9	Action Item: Owner Science, Reporter: B Murray, DFMEA Soil-Water Content Profile, Assembly, Soil Water Content Profile, CF00800000, PCBA that NEON will be modifying with the One Wire Chip. Need to pursue permission / warranty information / update to contract / agreement/ that NEON will be adding the One Wire Chip to a PCBA on the assembly.			3	2	2	**12**	

Failure Mode Effect Analysis (FMEA)

Document #: NEON.DOC.000309 **Doc Date (Orig):** 05/25/2012 **Doc (Rev):** A **Facilitator:** Asa Akers 5/2/2013

Type: System **Spectral Photometer** **Rev:** Engineering Final Design Review

Team Members: John Staarmann, Drew Schrupp, Aaron Joos, Ken Franzel, Tim Lucera, Guillermo Oviedo, Matt Ventimiglia, Asa Akers, Santiago Bonarrigo, Alan Tennery

Pre-Corrective Action											Post Corrective Action							
Ref #	Item/ Function	Potential Failure Mode	Effects of Failure	SEV	Potential Cause(s) of Failure	OCC	Control	DET	RPN	CRIT	Analysis & Recommended Corrective Actions	Work Team	JIRA #	SEV	OCC	DET	RPN	Comments
1	Assembly Spectral Photometer System, CD03060000, Highest level assembly of the Spectral Photometer	Parts will not fit together / mount properly in location	Inability to assemble / install correctly	3	Assembly components are undersized / oversized / mislocated / missing.	1	Tolerance Analysis Completed, Inspection Procedures	1	3	3								
2	Assembly Spectral Photometer System, CD03060000, Highest level assembly of the Spectral Photometer	Hardware falls from tower	Safety Issue / Loss or invalid data	5	1) Insufficient Material strength 2) Service/Installation (Over torque-Breakage, Under torque - Loss of hardware) 3) Corrosion 4) Stress Fatigue/Wear 5) Mechanical damage to assembly - environmental	2	1) Material Analysis & Callout 2) Torques/pattern specified on drawing 3) Material compatability analysis 4) Material analysis, inspection 5) Upon failure, hardware may be secured by cable / locking hardware	1	10	10							0	Will be addressed in PHA
3	Assembly, Spectral Photometer Control Mounting System, CD03060300, Mount for sensor control enclosure and associated hardware (w/ East shield) (**10**)	Parts will not fit together / mount properly in location	Inability to assemble / install correctly	3	Assembly components are undersized / oversized / mislocated / missing.	1	Tolerance Analysis Completed, Inspection Procedures	1	3	3								
4	Assembly, Spectral Photometer Control Mounting System, CD03060300, Mount for sensor control enclosure and associated hardware (w/ East shield) (**10**)	Assembly not properly aligned or damaged	Loose hardware, cable strain, data loss	4	1) Assembly components are undersized / oversized / mislocated / missing 2) Hardware failure (strength, torque, corrosion, fatigue) 3) Mechanical damage to assembly - environmental	2	1) Tolerance Analysis Completed, Inspection Procedures 2) Material compatability and strength analysis 3) Procedures in place for install/removal/maintenance	1	8	8								
5	Assembly, Spectral Photometer Control Mounting System, CD03060300, Mount for sensor control enclosure and associated hardware (w/ East shield) (**10**)	Assembly/components fall from tower	Loss or invalid data / Safety Issue	5	1) Insufficient Material strength 2) Service/Installation (Over torque-Breakage, Under torque - Loss of hardware) 3) Corrosion 4) Stress Fatigue/Wear 5) Mechanical damage to assembly - environmental	2	1) Material Analysis & Callout 2) Torques/pattern specified on drawing 3) Material compatability analysis 4) Material analysis, inspection 5) Upon failure,components may be secured by locking hardware	1	10	10							0	Will be addressed in PHA
6	Assembly, Spectral Photometer Robots, Mount, CD03060200, Corner mount arm/bracket and azimuth robot (**20**)	Parts will not fit together / mount properly in location	Inability to assemble / install correctly	3	Assembly components are undersized / oversized / mislocated / missing.	1	Tolerance Analysis Completed, Inspection Procedures	1	3	3							0	
7	Assembly, Spectral Photometer Robots, Mount, CD03060200, Corner mount arm/bracket and azimuth robot (**20**)	-Assembly not properly installed / aligned -Motor Assembly internally fails / damaged -Cables damaged	Data loss / invalid data	4	1) Assembly components are undersized / oversized / mislocated / missing 2) Hardware failure (strength, torque, corrosion, fatigue) 3) Mechanical damage to assembly - environmental 4) Improper routing of cabling	2	1) Tolerance Analysis Completed, Inspection Procedures 2) Material compatability and strength analysis 3) Procedures in place for install/removal/maintenance 4) Cables routed away from potential pinch/shear points and anchored. Strain relief in place.	1	8	8	Owner: Engineering, Reporter: B. Murray, Operations procedure for leveling Spectral Photometer Owner: ENG, Reporter: A. Akers, Specify how cables will be secured near mount arm to standardize routing.						0	

Failure Mode Effect Analysis (FMEA)

Ref #	Item/ Function	Potential Failure Mode	Effects of Failure	SEV	Potential Cause(s) of Failure	OCC	Control	DET	RPN	CRIT	Analysis & Recommended Corrective Actions	Work Team	JIRA #	SEV	OCC	DET	RPN	Comments
8	**Assembly, Spectral Photometer Robots, Mount, CD03060200, Corner mount arm/bracket and azimuth robot (20)**	**Robot parks in undesirable state (not at nadir)**	**Precipitation / animal contamination enters collimators (Calibration traceability issue)**	**4**	**1) Power failure to assembly during automatic routine 2) Disconnection / intermittent connection of power cables**	**2**	**1, 2) Loss of power to a sensor/grape/POE switch *may be* detected by a SOH scheme. What will be checked and what will not be checked is TBD.**	**3**	**24**	**8**	**JIRA New Feature request. Owner: ENG, Reporter: A. Akers, During power failure/UPS controlled shutdown, institute a process to prevent the sensor from stopping in a non-parked position.**						**0**	Added after PIDR based on discussion during the review. Any ability to falsify a "Wet Detection" signal to force sensor to park if the Site power fails (running on UPS)? **From EFDR DFMEA: ENG's preferred method is, upon power failure and UPS-powered shutdown, to determine when the sensor is parked, then shut off power to the unit before all site power is lost.**
9	Assembly, Spectral Photometer Robots, Mount, CD03060200, Corner mount arm/bracket and azimuth robot (**20**)	Assembly/component falls from tower	Loss or invalid data / Safety Issue	5	1) Insufficient Material strength 2) Service/Installation (Over torque-Breakage, Under torque - Loss of hardware) 3) Corrosion 4) Stress Fatigue/Wear 5) Mechanical damage to assembly - environmental	2	1) Material Analysis & Callout 2) Torques/pattern specified on drawing 3) Material compatability analysis 4) Material analysis, inspection 5) Upon failure,components may be secured by locking hardware / cable	1	10	10	Owner: Engineering, Reporter: B. Murray, Investigate Aeronet braided sleeving cable recommendation						0	Will be addressed in PHA
10	Sensor Acsry CIMEL Head, 0303660002, Spectral Photometer head (collimator, zenith motor, optics) (**30**)	Parts will not fit together / mount properly in location	Inability to assemble / install correctly	3	1, 2) Damage to mounting surfaces **3) Sensor head is not keyed when placed in clamp - can be misinstalled**	1	1) COTS part, assembly and fit would have been checked during MFG. 2) Components packaged securely for shipping **3) Documentation?**	1	3	3	Owner: MFG, Reporter: A. Akers, Retain original shipping box from CIMEL for future shipping needs to prevent damage to sensor. Owner: ENG, Reporter: A. Akers, Confirm CIMEL interface cable with 1-wire can be left at tower / CI isn't needing matching between chip and a specific sensor unit. **Owner: ENG, Reporter: A. Akers, Create sensor head installation and alignment procedure for OPS as a part of UAT.**						0	1-wire chip is in cable CA03070000 and will be left in control enclosure when sensor is swapped out. Chip will not follow a specific sensor. **Added after PIDR based on discussion during the review.**
11	Sensor Acsry CIMEL Head, 0303660002, Spectral Photometer head (collimator, zenith motor, optics) (**30**)	Sensor broken / internally fails	Loss of data / invalid data	4	1) Cable migration / pinching 2) Micro-switch for 'Park' position misadjsuted 3) Drive belts too loose (backlash gear adjustment) 4) Back-up nuts for motor arms loosen 5) Inconsistent filter quality (supplier/lot effects)	3	COTS part, "Full Swap Out" Any field servicable activities?	2	24	12	Owner: ENG, Reporter: A. Akers, Document which portions of sensor assembly should be removed/returned for various expected failures (e.g., motion issue may require both robots).						0	
12	Sensor Acsry CIMEL Head, 0303660002, Spectral Photometer head (collimator, zenith motor, optics) (**30**)	Collimator field of view insufficient	Invalid data	4	1) Animal activity (bird droppings, spiders, leaves, nest(?)) 2) Human activity (people on tower top during measurement, new buildings in area) 3) Canopy height growth over time	4		3	48	16	Owner: ENG, Reporter: A. Akers, Specify cleaning procedure for collimator (not to disturb lenses)						0	Collimator cleaning procedure (soft bottle brush) - what can / can't be cleaned? Lenses need to be left dirty for post-deployment cal correction Method to flag spectral photometer data if people activity is on top ML? (other than shut off ML) What can be done about a change in canopy height 20 years out?

Failure Mode Effect Analysis (FMEA)

Ref #	Item/ Function	Potential Failure Mode	Effects of Failure	SEV	Potential Cause(s) of Failure	OCC	Control	DET	RPN	CRIT	Analysis & Recommended Corrective Actions	Work Team	JIRA #	SEV	OCC	DET	RPN	Comments
13	Sensor Acsry CIMEL Head, 0303660002, Spectral Photometer head (collimator, zenith motor, optics) (**30**)	Sensor head / component falls from tower	Loss or invalid data / Safety Issue	5	1) Insufficient Material strength 2) Service/Installation (Over torque-Breakage, Under torque - Loss of hardware) 3) Corrosion 4) Stress Fatigue/Wear 5) Mechanical damage to assembly - environmental	1	1) Material Analysis & Callout 2) Torques/pattern specified on drawing 3) Material compatability analysis 4) Material analysis, inspection 5) Upon failure,components may be secured by locking hardware / cable	2	10	5	Owner: ENG, Reporter: A. Akers, Create inspection/replacement procedure for sensor head clamp since it will remain in field indefinitely						0	Will be addressed in PHA Lanyard for the sensor head was recommended to prevent falling, but not being adopted by ENG
14	Assembly, Spectral Photometer Control System, CD03060310, Enclosure and components for Spectral Photometer control and DAQ (**40**)	Parts will not fit together / mount properly in location	Inability to assemble / install correctly	3	Assembly components are undersized / oversized / mislocated / missing.	1	Tolerance Analysis Completed, Inspection Procedures	1	3	3							0	
15	Assembly, Spectral Photometer Control System, CD03060310, Enclosure and components for Spectral Photometer control and DAQ (**40**)	Assembly falls from tower	Loss or invalid data / Safety Issue	5	1) Insufficient Material strength 2) Service/Installation (Over torque-Breakage, Under torque - Loss of hardware) 3) Corrosion 4) Stress Fatigue/Wear 5) Mechanical damage to assembly - environmental	2	1) Material Analysis & Callout 2) Torques/pattern specified on drawing 3) Material compatability analysis 4) Material analysis, inspection 5) Upon failure,components may be secured by locking hardware / cables	1	10	10							0	Will be addressed in PHA
16	Assembly, Spectral Photometer Control System, CD03060310, Enclosure and components for Spectral Photometer control and DAQ (**40**)	Corrosion on unprotected electrical components inside enclosure	Loss of data / invalid data	4	Enclosure moisture seal points are insufficient / degrade	2	1) Box was initially NEMA4 rated;	2	16	8							0	Environmental testing needed? What are the mositure protection ratings of the Serial to Ethernet Bridge and the CIMEL white control box / roxtec board?

Failure Mode Effect Analysis (FMEA)

Ref #	Item/ Function	Potential Failure Mode	Effects of Failure	SEV	Potential Cause(s) of Failure	OCC	Control	DET	RPN	CRIT	Analysis & Recommended Corrective Actions	Work Team	JIRA #	SEV	OCC	DET	RPN	Comments
17	Sensor Acsry CIMEL Electronic Box, 0303660003, Control box for Spectral photometer (white)	Spectral Photometer doesn't GoSun correctly	**Will it still use the Quadcell to track and find the sun even if grossly out of position?**	3	1) Incorrect lat/long setting 2) Incorrect Day/time setting	2	1) Lat /long will be verified as part of acceptance. **What happens with replacement boxes?** 2) LC sets time of day - should always be correct to 1 second	2	12	6	**Owner: CVAL, Reporter: A. Akers, Define process that will be used to configure/reconfigure Lat/Long values on CIMEL control boxes for duration of NEON project (including future TBD relocatable sites).** **Owner: CVAL, Reporter: A. Akers, Create site-specific sheet to live inside enclosure door with CIMEL-formatted Lat/Long coordinates for that site procedure to check/update.** **JIRA New Feature request. Owner: ENG, Reporter: A. Akers, Write utility to allow field-verification of CIMEL Lat/Long for OPS usage during a control box swap out.** **Owner: S. Bonarrigo (LC), Reporter: A. Akers, Create SOH functionality to verify Lat/Long values in K7 data files matches expected Site Lat/Long values.**						0	**Lat/Long will be set and checked at Site acceptance - what happens when control Boxes get swapped - how will the Lat/Long values for each site be stored and checked that they are entered into the box? Who will do this config?**
18	Sensor Acsry CIMEL Electronic Box, 0303660003, Control box for Spectral photometer (white)	Daughter interface board becomes disconnected	Loss of signal/control of instrument. Loss of data/damage to sensor	4	Thermal cycling	3	1) Unplug / replug in sensor cable and connector panel	1	12	12	Owner: ENG, Reporter: A. Akers, Interface board on CIMEL control box can become unseated (common issue). Create OPS procedure to identify this failure and correct as needed.						0	
19	Sensor Acsry CIMEL Electronic Box, 0303660003, Control box for Spectral photometer (white)	Battery charge insufficient (4.8V)	Loss of data	4	Internal battery failure	3	1) Preventive Maintenance during Annual Calibration	1	12	12	Action Item: Owner: Engineering, Reporter B. Murray Replace 4.8V battery 1X per year during Assy, Spectral Photometer Control System CVAL.						0	
20	Sensor Acsry CIMEL Electronic Box, 0303660003, Control box for Spectral photometer (white)	Known' bug on Cimel units model CE318, LCD window displays only `noise' and the unit is not operational.	Sensor won't function, loss of data	4		3	1) Swap out Control box	1	12	12	http://ptr.neon.local/jira/browse/NCP-145						0	This is a known bug ! It arrives to the start up, supply on. Normally it doesn't arrive in field. What you have to do : remove the batteries and charger (if any) remove the circuit the RAM memory U7 62256 (see the photo)
21	Sensor Acsry CIMEL Electronic Box, 0303660003, Control box for Spectral photometer (white)	Internal Storage fills up	Missing data	4	1) Extended loss of power to DAS 2) DAS comm issue	3	1) External Site generator can be brought to site 2)	1	12	12							0	Added after PIDR based on discussion during the review. What is duration that storage will keep? How will it handle data in excess of this? Answer: it will handle roughly one day's worth of data before it begins scrolling off the oldest files

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22	Assembly, Spectral Photometer Wetness probe, CD03060400, Detects wetness to prevent photometer collimator from filling with precipitation (**60**)	Sensor fails to detect precipitation event	invalid data, potential equipment damage (water buildup in collimators)	4	1) Gland nut looses, probe rotates/faces down 2) Probe blocked from seeing mositure from foreign object (bird droppings, spider web, leaves, etc.) 3) Sensor fails (how?)				0	0	Owner: A. Akers:/ENG, Reporter A. Akers, Identify how to detect if wet sensor is not functioning; create design improvements/procedures to minimize occurences. Owner: D. Schrupp, Reporter A. Akers, Review design to determine benefit of installing Wet Sensor at an angle per CIMEL recommendation (to induce beading on tip)						0	Robustness tests: Can Wet Sensor fail to not show when precipitation is occuring (false negative)? Is this good design feature to have (instrument protection over data collection)? Can Wet Sensor fail to indicate precipitation when there is none (false positive)? How does the system control if it's unplugged? What effect would mechanical damage to probe cause?
23	Assembly, Spectral Photometer Wetness probe, CD03060400, Detects wetness to prevent photometer collimator from filling with precipitation (**60**)	Sensor incorrectly reports precipitation event	Loss of data (sensor never attempts data acquisition)	4	1) Excessive humidity / condensation in area **(Is probe generally exposed to line of sight of sun?**)				0	0	**Owner: ENG, Reporter A. Akers, Create wet sensor cleaning procedure (most critical in salty/humid environments)**						0	**EFDR DFMEA: Guillermo reported the wet sensor may not be effective during some snow events. It can also permenantly be triggered in humid, salty environments where conductive buildup is on tip. Cleaning is critical!**
24	Assembly, Shield West Spectral photometer, CD03200000, radiation shield for control enclosure (**50**)	Parts will not fit together / mount properly in location	Inability to assemble / install correctly	3	Assembly components are undersized / oversized / mislocated / missing.	1	Tolerance Analysis Completed, Inspection Procedures	1	3	3							0	
25	Assembly, Shield West Spectral photometer, CD03200000, radiation shield for control enclosure (**50**)	Assembly falls from tower	Exposure of Control Enclosure to direct sunlight / Safety issue	5	1) Insufficient Material strength 2) Service/Installation (Over torque-Breakage, Under torque - Loss of hardware) 3) Corrosion 4) Stress Fatigue/Wear 5) Mechanical damage to assembly - environmental	2	1) Lanyard secures shield to main assembly	1	10	10							0	Will be addressed in PHA
26	Bridge, Ethernet to Serial with PoE, XXXXXXXXX, converts Serial to Ethernet (short term solution until Grape is enabled to do this)	Bridge damaged / broken	Loss of data	4	1) Internal failure (MTBF)	2	1) COTS part 2) MFG testing	1	8	8	Owner: ENG, Reporter A. Akers, If assemblies will be deployed with a Serial to Ethernet Bridge, specify applicable configuration procedure.	**Can be deleted? Ask Santiago.**					0	**Will this fit in Enclosure CD03060310?**
27	PoE splitter, 48VDC output to both Grape and Bridge	Splitter damaged broken	Loss of data	4	1) Internal failure (MTBF)	2	1) COTS part 2) MFG testing	1	8	8		**Can be deleted? Ask Santiago.**					0	**Will this fit in Enclosure CD03060310?**

Stage	Task	Subsystem #1	Subsystem #2	Subsystem #3
	NEON Doc #	NEON.DOC.xxxxxx	NEON.DOC.xxxxxx	NEON.DOC.xxxxxx
CDR	Schedule DFMEA one week prior to CDR (Enter Date held)	m/d/yy	m/d/yy	m/d/yy
	Review Sensor Requirements	x		
	Browse sensor Data Sheet			
	Discuss initial design concepts with ENG (Mechanical, Electrical)			
	Get any conceptual drawings from ENG to use for DFMEA meeting			
	Prepare "DFMEA Initial (CDR).xls" file. **See comments for things to consider.**			
	One day prior to DFMEA meeting, e-mail file out to team			
	Print out "DFMEA Initial (CDR)" (approx 10 copies)			
	Hold DFMEA meeting, take notes			
	Integrate notes into "DFMEA (CDR)" file			
	Create blank Critical Parts file, populate with any known Part numbers (Optional)			
	Create DFMEA slides for review			
	Back up files in N:/SYS Meas Sub-system folder			
	Integrate slides into CDR presentation			
	Present DFMEA at CDR, note suggested changes			
	Incorporate any changes into "DFMEA (post-CDR)"			
	Prior to checking file into Agile remove the NEON Cover Sheet, Examples, and DFMEA Checklist. The DFMEA checklist should be saved off as a separate file so that you can track your DFEMEAs			
	Obtain a document number and Check file into Agile using NEON.DOC.004254 as a guide.			
	Send Action Items to admin contact for addition into 'the file'			
PIDR	Schedule DFMEA one week prior to PIDR (Enter Date held)	m/d/yy	m/d/yy	m/d/yy
	Check CDR DFMEA out of Agile and review for familiarity.	x		
	Request assembly and component Part Numbers from ENG for reference in DFMEA.			
	Review CDR DFMEA Action Items for familiarity.			
	Review Critical Parts file.			
	Print out "DFMEA (CDR)" or "DFMEA (post-CDR)" whichever is most recent (approx 10 copies).			
	Hold DFMEA meeting, completing the following: - Review CDR as-left design - ask ENG for any changes to this. - Review CDR DFMEA action items - ask for updates - Review Critical Parts list - get a list of all Part Numbers from ENG			
	Integrate notes into new "DFMEA (PIDR)" file.			
	Update Critical Parts file (confirm with Byron for 'Quality' vs 'Technical' parts).			
	Create DFMEA slides for review.			
	Back up files in N:/SYS Meas Sub-system folder			
	Integrate slides into PIDR presentation.			
	Present DFMEA at PIDR, note suggested changes.			
	Incorporate any changes into "DFMEA (post-PIDR)".			
	Check file into Agile.			
	Send Action Items to admin contact for addition into 'the file'.			
EFDR	Schedule DFMEA one week prior to PIDR. (Enter Date held)	m/d/yy	m/d/yy	m/d/yy
	Check PIDR DFMEA out of Agile and review for familiarity.	x		
	Request any new assembly and component Part Numbers from ENG for reference in DFMEA.			
	Review PIDR DFMEA Action Items for familiarity.			
	Review Critical Parts file.			
	Print out "DFMEA (PIDR)" or "DFMEA (post-PIDR)" whichever is most recent (approx 10 copies).			
	Hold DFMEA meeting, completing the following: - Review PIDR as-left design - ask ENG for any changes to this. - Review PIDR DFMEA action items - ask for updates - Review Critical Parts list - get a list of all Part Numbers from ENG **- Add Post-Corrective Action Scoring where possible**			
	Integrate notes into new "DFMEA (EFDR)" file.			

Notes
To add more subsystems, Insert columns between existing subsystems to copy all formatting.
Enter an "x" in each cell as that task is finished; cell with turn green.

	Update Critical Parts file (confirm with Byron for 'Quality' vs 'Technical' parts).			
	Create DFMEA slides for review.			
	Back up files in N:/SYS Meas Sub-system folder			
	Integrate slides into EFDR presentation.			
	Present DFMEA at EFDR, note suggested changes.			
	Incorporate any changes into "DFMEA (post-EFDR)".			
	Check final revision of DFMEA excel file into Agile.			
	Review Action Item Excel file for resolution of AIs and create list of AIs that need a JIRA ticket			
	Create Post-corrective action scoring values			
	Open JIRA tickets for any unresolved Action Items			
	Set flags for all Quality Critical Parts in Agile			
	Do 'Unknown Action' for all Technical Quality Parts			