NEON QUALITY PLAN, OPERATIONS

PREPARED BY	ORGANIZATION	DATE
Joe Harpring	NEON Program Management	05/07/2018

APPROVALS	ORGANIZATION	APPROVAL DATE
Dr. Sharon Collinge	NEON Observatory	06/19/2018
Dr. Rick Farnsworth	NEON Program Management	07/13/2018
Ellen Baptiste Carpenter	NEON Program Management	06/26/2018

RELEASED BY	ORGANIZATION	RELEASE DATE
Judy Salazar	CM	07/13/2018

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Change Record

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1 OVERVIEW

1.1 Background

> "The National Ecological Observatory Network (NEON) is a continental-scale ecological observation facility. NEON collects high-quality, standardized data from 81 field sites (47 Terrestrial and 34 Aquatic) across the United States (including Alaska, Hawaii and Puerto Rico). All sites implement standardized Data collection methods, which include in situ instrument measurements, field sampling and airborne remote sensing. Strategically selected field sites represent different regions of vegetation, landforms, climate, and ecosystem performance." [1]

The NEON Quality Plan for Operations provides mechanisms for ensuring objectives and requirements for NEON Operations are realized. This Quality Plan also serves to ensure excellence in operational performance by monitoring and improving process effectiveness and management of risk.

This Quality Plan defines the system for continually assuring and improving performance by addressing the needs of all stakeholders, who also may be referred to as interested parties. The following principles have been identified to facilitate the achievement of this Quality Plan.

- Risk-Based Thinking: Risk-based thinking acts as a preventive tool by determining risks as a basis for planning and for implementing operational processes. It is essential for achieving planned outputs, and is an integral part of all planning and operations.
- Customer Focus: Battelle depends on understanding our customers and their needs. We continually strive to meet their requirements and exceed their expectations.
- Leadership: Battelle management sets the purpose and objectives of the organization, provides direction to the organization, and ensures the internal environment within the organization allows and encourages employees to become fully committed and involved in achieving those objectives.
- Involvement of People: Battelle personnel are involved at all levels and shall utilize their abilities to maximize the benefits to the organization and our customers.
- Mutually Beneficial Supplier Relations: Battelle is committed to partnership with external product and service providers, assuring mutual growth, benefit, and creating value for our customers.
- Process & Systems Approach: Desired results are more efficiently achieved when resources and activities are managed as a *process*; and a *system* of interrelated processes for a given objective contributing to the effectiveness and efficiency of the Observatory.

[1] ER [06], *Executive Summary: 2018 NEON Community Engagement Assessment Report*

- Continual Improvement: Effective decisions are based on the logical or intuitive analysis of data and information. Battelle follows the Plan, Do, Check, Act (PDCA) approach to continual improvement.

1.2 Scope

The NEON Quality Plan for Operations applies to all activities supporting NEON, at the headquarters location in Boulder, Colorado and all satellite offices and facilities within the Observatory, as well as suppliers contracted to provide sample analysis and archiving services.

Elements of the Quality Plan are invoked for specific activities according to their applicability and the degree to which the activities' importance, complexity, and risk deem them necessary. Considerations include:

- The relative importance to safety, security, and integrity of data, infrastructure, and personnel
- Compliance with Battelle and other institutional policies and regulations
- Impact to NEON mission and/or program

Activities to re-establish damaged sites, relocate sites, and/or changes in infrastructure and technology during Operations will follow the quality planning requirements documented in AD [09] NEON.DOC.000006; *NEON Program Quality Plan, Construction*. These quality requirements include design, acceptance, installation and verification activities.

1.3 Applicable Documents

Applicable documents contain information that shall be applied in the current document. Examples include higher level requirements documents, standards, rules and regulations.

Table 1-1: Applicable NEON Program Documents

AD [01]	NEON.DOC.000149 Battelle NEON Concept of Operations (CONOPS)
AD [02]	NEON.DOC.050000 NEON Operations and Maintenance Plan
AD [03]	NEON.DOC.000008 NEON Acronym List
AD [04]	NEON.DOC.000006 NEON Program Quality Plan, Construction
AD [05]	NEON.DOC.004982 NEON Battelle Operations Risk Register
AD [06]	NEON.DOC.000014 NEON Contingency Management Plan
AD [07]	NEON.DOC.000243 NEON Glossary of Terms
AD [08]	NEON.DOC.002241 NEON Data Product Traceability - Level 1, 2, & 3 Data Products
AD [09]	NEON.DOC.004260 NEON Commissioning Strategy and Framework
AD [10]	NEON.DOC.001993 NEON Qualification Plan – Initial Observatory Capability
AD [11]	NEON.DOC.001271 AOS/TOS Protocol and Procedure: Data Management

1.4 Reference Documents – NEON, Battelle Ecology, and Battelle

Reference documents contain information complementing, explaining, detailing, or otherwise supporting the information included in the current document.

Table 1-2: Reference NEON Program Documents

RD [01]	NEON.DOC.000004 NEON Configuration Management Plan
RD [02]	NEON.DOC.000026 NEON Scope Management Plan
RD [03]	NEON.DOC.000106 NEON Manufacturing Quality Plan
RD [04]	NEON.DOC.000129 NEON Data Management Plan
RD [05]	NEON.DOC.000621 NEON Supplier Quality Management Handbook
RD [06]	NEON.DOC.004104 NEON Science Data Quality Plan
RD [07]	NEON.DOC.004200 NEON Systems Engineering Management Plan (SEMP)
RD [08]	NEON.DOC.004982 NEON Battelle Operations Risk Register
RD [09]	NEON.DOC.005502 Calibration and Validation Laboratory Management Plan
RD [10]	NEON.DOC.005508 Calibration and Validation Laboratory Sensor Calibration Plan
RD [11]	NEON.DOC.011081 NEON Algorithm Theoretical Basis Document (ATBD) – QA/QC Plausibility Testing
RD [12]	NEON Strategic Engagement Plan dated 04/15/2018
RD [13]	NEON.DOC.000001 NEON Observatory Design

1.5 External References – Customer, ISO Standards, and Regulatory

External references contain information pertinent to this document, but are not NEON configuration-controlled. Examples include manuals, brochures, technical notes, and external websites.

Table 1-3: Reference Documents from External Sources

ER [01]	ISO 9001:2015 Quality management systems - Requirements
ER [02]	ISO 9000:2015 Quality management systems - Fundamentals and vocabulary
ER [03]	National Science Foundation (NSF 15-089) Large Facilities Manual
ER [04]	Battelle Policy Manual 2018 v1.0
ER [05]	Battelle Cyber Security Standards Book
ER [06]	Executive Summary: 2018 NEON Community Engagement Assessment Report (Battelle)
ER [07]	ISO 5725-1: Accuracy (trueness and precision) of Measurement Methods and Results
ER [08]	ISO 8000-1:2011: Data Quality
ER [09]	Committee on Data Management and Computation, National Research Council; Data Management and Computation, Issues and Recommendations
ER [10]	ISO/IEC Guide 98-3:2008: Guide to the Expression of Uncertainty in Measurement (GUM)
ER [11]	ISO Guide 99: International vocabulary of basic and general terms in metrology (VIM)

2 ACRONYMS, TERMS AND DEFINITIONS

For a list of definitions of acronyms please reference AD [03] NEON.DOC.000008 *NEON Acronym List,* and AD [07], NEON.DOC.000243 *NEON Glossary of Terms.*

NEON Program – This includes the entire Observatory at all phases of its lifecycle, from initial concept through the planned operational life of the observatory.

NEON Project – In this document refers to the Operations phase of the NEON Program and those elements applicable to the supporting daily operations and data delivery for NEON.

2.1 Data Quality

From ER [08], ISO 8000-1:2011: *Data Quality:*

Data quality refers to the condition of a set of values of qualitative or quantitative variables. There are many definitions of data quality but data is generally considered high quality if it is "*fit for [its] intended uses in operations, decision making and planning.*"

Data quality includes the following characteristics:

- Completeness
- Validity
- Accuracy
- Consistency
- Availability
- Timeliness

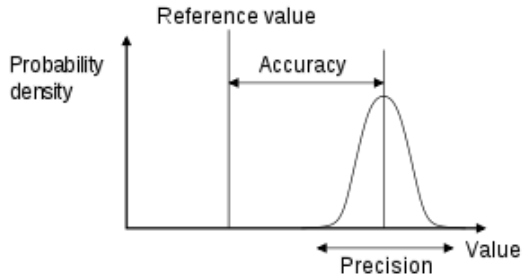
2.1.1 Accuracy and Precision

From ER [07]: ISO 5725-1: Accuracy (trueness and precision) of Measurement Methods and Results:

Accuracy is a description of systematic errors, a measure of statistical bias; as these cause a difference between a result and a "true" value. *Precision* is a description of random errors, a measure of statistical variability about a reference, or nominal value.

Given a set of data points from a series of measurements, the set can be said to be precise if the values are close to the mean value of the quantity being measured, while the set can be said to be accurate if the values are close to the true value of the quantity being measured.

Figure 2-1: Illustration of Accuracy v. Precision, Source: ISO 5725-1



NOTE: *Accuracy and Precision are defined in ER [10], ISO/IEC Guide 98-3:2008 Guide to the Expression of Uncertainty in Measurement (GUM), also released as JCGM 100:2008, and in ER [11], ISO Guide 99: International vocabulary of basic and general terms in metrology (VIM), also released as JCGM VIM. ISO 5725 is cited as the referential standard in ER [11].*

2.1.2 Quality Assurance

Assurance is *planning*. Quality Assurance – and Data Quality Assurance – are the planning and preparation to achieve the quality required.

2.1.3 Quality Control

Control is *checking*. Data Quality Control is the active checking, *in the moment of creation, collection, ingestion, or analysis,* whether the data conforms to requirements *at that step in the process*.

3 PERFORMANCE EXCELLENCE

3.1 Performance Objectives

Management ensures quality objectives, including those needed to meet product requirements, are established at relevant functions and levels within the organization. The quality objectives are measurable, consistent, and defined. Metrics for performance are established and communicated at regular intervals.

3.2 Planning

Battelle has defined and documented activities for Performance Excellence. Those activities include any requirements necessary to maintain the quality and delivery of the product and maintaining the integrity of the Observatory.

Quality and management plans describe processes necessary to produce required outputs, degree of authority, applicable techniques, timely revision to processes, and responsibility for each function affecting quality activities.

Changes to data products and affected processes require approval by relevant groups. Changes of scope, budget, schedule, and changes affecting documented processes and protocols must be processed in accordance with the change management process. When defined thresholds for budget, schedule, process change, or risk assessment require it, the approval process must include the Program Change Control Board (PCCB). Risk assessment and mitigation is documented in AD [05] NEON.DOC.004982, *NEON Battelle Operations Risk Register.*

Battelle management ensures processes impacting the value of our products are identified. Annual planning is conducted to maintain the link between strategic objectives and specific performance objectives.

Input relating to Operations requirements shall be established and reviewed for completeness and adequacy, and include:

a) Required resources and work environment
b) Data Product- and Customer- specified requirements
c) Legal and other applicable requirements
d) Mitigation plans based on risk assessment AD [05]
e) Required verification, validation, monitoring, measurement, inspection and test activities specific to the product and the criteria for product acceptance
f) Management of Change, to include new design and development requirements
g) Records needed to provide evidence sampling designs meet the science objectives

For OS data collection, incomplete, vague or conflicting information shall be resolved prior to the start of data collection, or during the collection season, as managed through the incident management process.

Procedures, Integrated Product Teams (IPT), Technical Working Groups (TWGs), and external advisory committees are established for the resolution of ambiguous, incomplete or conflicting requirements, and supporting changing technical needs like advancements in science.

Design requirements, methods, assumptions, analysis and calculations shall be documented. The control, review and verification of the design of data products and collection methods shall be conducted and documented to ensure that specified requirements are met by internal or external qualified personnel. The assignment of responsibilities may be updated as required.

4 COMMUNICATIONS

Battelle management ensures appropriate communication processes are established within the organization and communication takes place regarding the effectiveness of the Observatory Operations.

4.1 Internal Communication

Battelle ensures internal communication is executed through the use of appropriate Integrated Product Teams (IPTs), steering committees, service requests, electronic communications (i.e., email and discussion boards), web-based collaborative platforms, program reviews, and regularly scheduled meetings with documented meeting notes.

4.2 External Communication

Battelle ensures external communication is executed through processes and procedures to establish and assess customer satisfaction, contract review, supplier agreements, and customer notifications. Additionally, external communication is assured through forums, committees, technical working groups, advisory group meetings, scheduled meetings and reviews, the Observatory website and data portal (NEONScience.org), web-based collaborative platforms, and communications with external customers.

5 LEADERSHIP AND COMMITMENT

Battelle leadership is committed to performance excellence, continual improvement and risk management by dedicating the resources for quality-related activities:

- Communicate to the organization the importance of meeting customer, quality, statutory, and regulatory requirements
- Establishing key performance indicators (KPIs)
- Conducting reviews to compare results to established objectives and determining subsequent actions for continual improvement and risk mitigation
- Ensuring the availability of resources necessary for effective operation and control of the Observatory and the data it produces

This Quality Plan for Operations aims to ensure NEON provides the broad scientific community with quality research data over the life of the project. The quality of the data will be measured, assessed and controlled at the data product levels.

The Program Management Office (PMO) ensures the data products and supporting services provided by NEON meet or exceed their requirements. Quality functions are integrated into the entire Observatory, at every step in the data stream, allowing for traceability, monitoring and control.

The guiding principles recommended by the Science, Technology, & Education Advisory Committee (STEAC), to maximize NEON utility, are:

1. Maintenance of long-term, high quality data
2. Focus on regional to continental-scale observations and questions
3. Robust coordination of spatiotemporally-distributed observations across sites
4. Prioritization of time-sensitive data and leveraging of future discoveries
5. Synergies with other observatories
6. High societal relevance

These principles help prioritize NEON science and data quality requirements.

5.1 Customer Focus

Battelle management has established customer satisfaction as a performance objective, and shall demonstrate performance excellence through the use of:

- Regularly scheduled reviews of performance against requirements
- Assessing customer satisfaction through surveys and communication

5.1.1 Community Engagement

NEON Community Engagement follows the Context, Input, Process, and Product (CIPP) model for evaluation to guide the evaluation process for its engagement activities (ER [06]). This model uses a systems approach that identifies stakeholder needs (context evaluation), develops resources that meet those needs (input evaluation), makes iterative adjustments over time (process evaluation), and identifies the final intended and unintended outcomes (product evaluation).

Battelle has established and continues to utilize community engagement to:

- Build a robust, active, and inclusive NEON user community
- Increase awareness of the Observatory and its 30-year mission
- Drive continual Improvement of the Observatory's data products and operational efficiencies
- Develop future users of NEON
- Optimize NEON

External advisory committees and working groups, such as the STEAC and TWGs are established to:

- Assess KPIs of science performance at both individual site and observatory levels
- Help Battelle staff prioritize and drive effective continual improvement in data quality
- Assist staff with proposed changes to tolerances for performance or derived tolerances
- Assist staff with proposed changes in methods or technologies used to collect, evaluate, integrate, post, and preserve data products' availability and applicability
- Review procedures for verifying requirements are met
- Serve as an interface to the broader ecological community on issues related to NEON Science

The outputs of these committees, and action items, are communicated to Battelle management and the National Science Foundation, at scheduled intervals.

5.2 Responsibility and Authority

The responsibility, authority, and interrelation of all personnel who manage, perform, or verify work affecting product quality and delivery, was defined and documented. Appropriate personnel have the authority to:

a) Initiate action to prevent incidence of any product, process, or quality related non-conformance
b) Identify and record any problems related to the product, process, or quality system
c) Initiate, recommend, or provide solutions through designated channels
d) Verify the implementation of solutions
e) Control further processing or delivery of non-conforming product until the deficiency or unsatisfactory condition has been corrected.

The NEON Observatory Director, Program Management Office (PMO), Quality Manager, domain managers, and functional managers are responsible for identifying activities subject to Quality Plan requirements, and for justifying the degree of rigor to be applied.

6 NEON OPERATIONS ORGANIZATIONAL SUPPORT

6.1 Provision of Resources

Project managers identify resource needs based on project requirements. Battelle management ensures the provision of adequate resources to meet project requirements, and in coordination with project managers, provides applicable indoctrination and training of employees involved in the development, collection, processing, inspection, preserving and posting of NEON data products. This includes resources needed to assess and improve the operation and outputs of the Observatory.

Integrated Product Teams (IPT) may be established as needed in support of the Observatory under the direction of the NEON Operations PM. IPTs are multidisciplinary, with staff matrixed from organizations across Battelle in support of NEON. Each IPT is a standing body. The IPT is focused on development, review and decision making, and all team members work in a collaborative forum. The Operations IPT, chaired by the Operations PM, governs all IPTs created in support of the NEON Operations Project. A comprehensive list of active IPTs is maintained and each IPT will have a charter which defines roles and responsibilities, membership, products and schedule. IPTs organize the formation and chartering of Working IPTs (wIPTs).

6.1.1 Personnel

Personnel performing work affecting conformity to product requirements are competent on the basis of appropriate education, training, skills and experience.

Documented procedures for hiring and contracting competent personnel, and assessing the training needs of employees are established and maintained.

6.1.2 Infrastructure

Project management determines the infrastructure needed to operate and achieve conformity to project requirements. Infrastructure can include the following physical and environmental factors:

- Buildings, workspace, transportation, and associated utilities
- Collection, preservation, and measurement equipment (hardware and software)
- Supporting services (information and communication technology, maintenance)
- Transportation resources (vehicles)

6.2 Competence

Training requirements are identified and provided in accordance with documented procedures. Each employee, when hired, will receive general systems and processes training specifically identified for their job function.

When an employee is accepted into a position, his/her previous training record will be reviewed. New training requirements are identified and training is scheduled on a timely basis. Periodic re-training will be conducted to meet changes and enhancements in relevant processes.

When training requirements for a position include training from a customer or a supplier for a given product, process, or equipment, such training will be included in the training program, and the results documented in the employee's training record.

Where education and/or experience is required by job description: diplomas, certifications, transcripts, and verified resumes are used to ensure the necessary requirements have been attained.

Program training requirements for NEON Operations are defined in the Project Management Plan and communicated to respective Battelle Management and staff by the Project Manager. Each manager, or delegated supervisor, is responsible for ensuring training needs, planning and conducting specialized or general training to the requirements of staff job responsibilities are completed. The Project Manager and Battelle Management evaluate the effectiveness of the training actions taken. This includes ensuring that personnel are aware of the relevance and importance of their activities and how they contribute to achieving NEON performance objectives.

The effectiveness of personnel training is critical to the performance of the Observatory. The effectiveness of employee training is continually evaluated. Methods of evaluation may include:

- Supervisor evaluation
- Monitoring process performance
- Corrective actions (i.e. from audits and customer returns)
- Management Review

Required qualifications for specific tasks affecting conformity to product requirements are documented and appropriate records of training, education, skills, and experience are maintained.

6.3 Awareness

Employees are trained to perform their duties effectively and safely to achieve performance objectives, aware of the importance of their work to the Observatory, and implications for not conforming to requirements.

7 DOCUMENTATION AND TRACEABILITY

The Observatory determines the extent and requirements of documented information – including requirements, protocols, definition documents, plans, and work instructions – needed to maintain effective operation of the Observatory.

Management ensures all documented information has appropriate identification, description, format, media type, and is reviewed and approved for suitability and adequacy.

When documented information is released, revised, or made obsolete, revision control is a requirement.

7.1 Control of Documented Information

Documented information required for Observatory Operations is controlled to ensure it is suitable and available for use, where and when it is needed, and is adequately protected from loss of confidentiality, improper use, or loss of integrity.

Records established to provide evidence of conformity to requirements and the effective operation of the Observatory shall be controlled.

Records shall remain identifiable, retrievable, and legible; in accordance with Observatory, Contractual, and Battelle Corporate documented requirements. Requirements address the necessary controls and responsibilities needed for identification, collection, storage, protection, retrieval, retention time and disposition of records.

7.2 Traceability of Documented Information

7.2.1 Traceability of Data Products

The Science Traceability Matrix (STM), with the Observatory Systems Requirements, document the logical flow from high-level objectives through science objectives, measurement objectives, measurement requirements, to instrument and observation requirements, resulting in data products able to address NEON's mission.

The STM framework describes the high level design criteria against which NEON's design is evaluated: Grand Challenges, NEON's Mission, and RD [13], *NEON Observatory Design*.

Every data product posted to the portal for consumption shall be traceable to documented QA/QC through a framework illustrating the entire information stream, from planning to publication; ensuring training, calibration, data entry, assessments are validated and verified in compliance to the Algorithm Theoretical Basis Documents (ATBDs), protocols, and other Observatory requirements.

8 MANAGEMENT OF RISK AND CHANGE

8.1 Risk Assessment and Management

The Observatory maintains a procedure for identifying and controlling risk associated with impact on delivery and quality: AD [05] NEON.DOC.004982, *NEON Battelle Operations Risk Register.*

This procedure identifies the techniques and tools, and appropriate application for risk identification, assessment, and mitigation.

Risk assessment associated with product delivery includes but is not limited to:

a) Facility and equipment availability and maintenance
b) Supplier performance and material availability and supply
c) Risk assessment associated with product quality includes:
   - Delivery of nonconforming product
   - Availability of competent personnel

Records of risk assessment and mitigation are maintained in accordance with requirements.

8.1.1 Mitigation Planning

In order to secure data quality and delivery of data products, risk mitigation planning will be documented, and risks addressed, as part of change planning.

Mitigation planning shall:

a) Identify significant risk scenarios to quality and delivery
b) Identify actions to mitigate significant risks
c) Assign responsibilities and authorities to actions
d) Establish internal and external communication controls

8.2 Change Management

Changes to Observatory requirements, methods (including Algorithm Theoretical Basis Documents), protocols, technologies, and sites, require the same controls as the original design and development.

All changes shall be:

a) Identified
b) Documented
c) Reviewed
d) Verified and validated when appropriate
e) Approved prior to implementation

The review will include evaluation of the effect of the changes on NEON operability and/or the NEON data or its suitability for use by the scientific community.

Records of the results of the review and any necessary changes are maintained.

9 MEASUREMENT TRACEABILITY AND CONTROL

Measurement traceability is an essential input to NEON data products and is necessary to provide confidence in the validity of measured results. Battelle management, scientists, and engineers have determined the measurement traceability requirements and associated equipment needed to provide evidence of conformity to Observatory requirements. Equipment used for measurement traceability are:

- Calibrated or verified, or both, at specified intervals against measurement standards traceable to international or national measurement standards. When no such standards exist, the basis used for calibration or verification are retained as documented information
- Verified against identified criteria when calibration protocols are proprietary or otherwise not available.
- Uniquely identified to include calibration status
- Safeguarded from adjustments, damage, or deterioration that would invalidate the calibration status and subsequent measurement results
- Used within required environmental conditions

When equipment is found to be out of calibration or unfit for its intended purpose, an assessment will be conducted to determine if the validity of previous measurements were adversely affected and appropriate action(s) are taken as necessary, including notification to the customer and end users if suspect product was made available on the portal.

When used for measurement traceability, the ability of computer software to satisfy the intended application is confirmed prior to initial use and reconfirmed as necessary.

NOTE: *Verification of suitability of proprietary measurement equipment and evidence of its conformity to requirements may be limited by contract or licensing agreement; however, the licensee is required to demonstrate the limitations imposed by the contract.*

When equipment providing measurement traceability is provided from a source external to Battelle, including third-party, proprietary, employee- and customer-owned equipment, Battelle verifies that the equipment is suitable and provides evidence of conformity to requirements of this section.

Battelle maintains a registry of the required equipment used for measurement traceability and records of results of calibration and verification.

10 PERFORMANCE MONITORING, MEASURING, EVALUATION, AND IMPROVEMENT

10.1 Customer Satisfaction

Battelle management and Project management monitor the level of satisfaction of our NEON customers, i.e. NSF and NEON data users, based on their perceptions of the degree to which their needs and expectations are fulfilled. and Battelle Leadership determines the process for obtaining, monitoring and reviewing customer feedback. Methods for obtaining customer feedback include, but are not limited to:

- Feedback attained from direct interaction with customers, including members of the scientific community, educational institutions, government organizations, and data users.
- Feedback attained from community engagement activities, such as hosting tours of NEON sites and facilities, attending conferences and expositions, and other outreach
- Online feedback via the NEONScience.org and data portal websites and community message boards
- Feedback through engagement with Technical Working Groups and advisory committees
- Formal Surveys, i.e. Battelle Customer Surveys, Data User Surveys, etc.

Project Management and the Quality Manager analyze customer feedback and survey results upon receipt and determine response actions as necessary. Project Manager or delegate provide a response to customers on feedback received. All customer complaints and/or feedback indicating dissatisfaction are reported to the Quality Manager and will be addressed through Battelle's corrective action process. The Quality Manager communicates customer satisfaction results to Battelle management and Project Management on a regular basis. Customer feedback results in continuous improvement of NEON processes and operations as necessary.

10.2 Performance Assessments (Audits)

Battelle has an established assessment program defining responsibilities for planning, conducting, and documenting assessments. NEON assessments verify conformance to the requirements of this Quality Plan, the Observatory, NEON processes, and the contract. Assessment planning takes into consideration the results of previous assessments and criticality of the process being assessed.

The assessment program identifies the criteria, scope, frequency, and methods to ensure that all processes claiming conformity to the requirements are assessed.

Outsourced activities impacting the quality of the data products are assessed on a scheduled basis.

10.2.1 Performance of Internal Assessment

Assessments are performed by competent personnel independent of those who performed or directly supervised the activity being assessed to ensure objectivity and impartiality of the assessment process. Records of the assessments provide objective evidence of conformity to requirements.

The results of internal assessments and the status of corrective actions are maintained and reported to Leadership at regular intervals.

10.3 Process Evaluation

When planned results are not achieved, correction and corrective action are taken, as appropriate.

10.3.1 Analysis of Data

Analysis of performance metrics, KPI's, and assessments, shall be reported to leadership. The analysis includes data generated from monitoring and measurement, internal assessments, management reviews, customer feedback, and other relevant sources.

The data analysis output provides information relating to:

a) Customer satisfaction
b) Conformity to requirements
c) Nonconformities after delivery, such as data products posted to the portal
d) Characteristics and trends of processes and products including opportunities for improvement
e) Performance of outsourced analyses, collections, and archiving
f) Performance objectives (KPI's)

Battelle uses data-based analysis and decision making to evaluate where continual improvement of Observatory operations is possible and warranted.

10.4 Improvement

Battelle continually improves the effectiveness of Operations through the use of quality objectives, assessment results, analysis of data, corrective actions, risk mitigation, and management review.

10.4.1 Corrective Action

Corrective action is taken to correct nonconformities, both for internal and outsourced activities, to eliminate the causes of nonconformities and minimize the likelihood of recurrence. Corrective actions taken are appropriate to the effect(s) of the nonconformity encountered. When a nonconformity occurs, including any arising from complaints, the Observatory will address the nonconformity through a corrective action process which includes:

1) Reacting to the nonconformity and, as applicable
    (a) taking action to control and correct it
    (b) dealing with the consequences
2) Evaluating the need for action to eliminate the cause(s) of the nonconformity in order that it does not occur elsewhere by
    (a) reviewing, analyzing the nonconformity
    (b) identifying the causes of the nonconformity
    (c) determining if similar nonconformities exist or could potentially occur
3) Implementing any action needed
4) Identifying the timeframe and responsible person(s) for addressing actions to be taken
5) review the effectiveness of any corrective action taken
6) update risks determined in planning, if necessary;
7) Change management, when the corrective actions require new or changed protocols, processes, or documented information.

Records of the activities for control of a nonconforming process are maintained. Records identify the activities performed to verify effectiveness of the corrective actions taken.

11 DATA QUALITY REQUIREMENTS SUMMARY

11.1 Types and Sources of Data

There are three base types of data:

1. **Instrumented observations**: Data from sensors that may be installed at Terrestrial Instrumented Systems (TIS), Aquatics Instrumented Systems (AIS), and Mobile Deployment Platforms (MDP), including data from remote sensors on Airborne Observation Platforms (AOP).
2. **Human-made observations**: Data from observations made by humans.
3. **External/Other data sets**: Generally supporting data not from monitoring or sampling: ancillary information, such as calibration, protocols, and algorithm documentation. This includes analysis and curation data sets from contracted facilities and laboratories.

Data provided to the Cyberinfrastructure is captured from five distinct sources:

1. AOP data, generated in discrete increments during each AOP flight.
2. The Instrumented Systems (IS) infrastructure, which stream data continuously as generated by the sensors.
3. Mobile data recorders, paper data sheets, and/or other data sources that Field Science staff utilize in the domains to record field samples and data.
4. Calibration, Validation and Assessment Laboratory (CVAL) records, providing instrument calibration data, and performance assessment results of contract laboratories.
5. Outsourced analytical and bio-archive facilities, performing sample analyses or curation activities and transmit analytical data, curation data, calibration data, and metadata.

11.2 Data Products

A significant aspect of the information infrastructure is the generation of data products comprised of NEON-collected data (both from automated sensor inputs as well as manually measured and collected), combined with standardized and standards-based metadata and ancillary information, such as calibrations, protocols, and algorithms. The data products fulfill NEON's mission of providing a foundational platform for large-scale ecology.

In order to maintain the large array of information NEON gathers, its data products are organized into a set of five product levels. These levels are derived from ER [09] Committee on Data Management and Computation, National Research Council; *Data Management and Computation, Issues and Recommendations*, and serve to delineate low-level, raw data, from integrative data products.

Table 111-1: NEON Data Products Level Definitions

NEON Data Product Level Definitions	
Level 0	Raw data from instrument or human-made observations.
Level 1	Calibrated data generally from a single instrument, observer, or field sampling area. These data may include information on data quality.
Level 2	Combinations of level 1 data used to create a gap-filled data stream that may replace a level 1 product. Generally, products at this level will reflect a stream from a single instrument, observer, or field sampling area. Annotations will indicate the gap filling approach employed.
Level 3	Level 1 and/or 2 data mapped on a uniform space-time grid.
Level 4	Derived products using levels 1, 2 and/or 3 data. Products at this level may combine observations from more than one instrument, observer, and/or sampling area.

Data Products must be:

1. Traceable within the STM to the Grand Challenges
2. Documented in appropriate protocols, with qualification and acceptance by the stakeholders, including the scientific community
3. Documented in ATBD for calculated data products
4. Documented in User Guides, available publicly on the portal or otherwise, that include the protocol description and data dictionaries, as appropriate to the data product
5. Qualified and commissioned in compliance to AD [09], NEON.DOC.004260, *NEON Commissioning Strategy and Framework*
6. Shown to demonstrate capability in compliance to requirements

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NOTE: *In such instances, containment and corrective action of data suspected to be nonconforming must be documented.*

11.3 Sensor-Based Data Products

Additional requirements for sensor-based data products include:

1. Traceability to the particular sensor qualification
2. Metadata support for sensor traceability, to include the exact sensor ID, location, date, and time for each measurement
3. Documented sensor calibration and verification processes
4. Sensor maintenance protocols, training, and records of maintenance
5. Data accuracy reviews for all systems and a data assessment plan when a sensor is found to be nonconforming (out of calibration)

NOTE: *Where possible, sensors selected for integration into the Observatory shall be Commercial Off-The-Shelf (COTS), and have appropriate specifications for use and performance. All sensors shall be verified and qualified through science commissioning and system installation and verification plans.*

11.4 Observation-Based Data Products

Additional requirements for observation-based data products include:

1. Traceability to a protocol documenting the observational data collection
2. Metadata traceable to the technician who made the observation, location, date, and time
3. Position description of personnel qualified to make the observation
4. Training and assessment documentation of those personnel in item #3
5. Where measuring and monitoring equipment are used (measuring tapes, scales, etc.), means to ensure calibration or confirmation of the equipment shall be maintained

11.4.1 Observational System Data Management in Field Science

Field Science shall provide and implement Observational Systems (OS) data management protocols, including AD [11], NEON.DOC.001271 *AOS/TOS Protocol and Procedure: Data Management*, documenting standardized data capture and quality assurance. These protocols define how NEON addresses four primary quality assurance issues:

1. **Referential Quality** – Includes traceability, for items such as:
    a. Duplicate records or sample ID's
    b. Orphan records - without a sample ID or collection record
    c. Childless records - sample ID or collection records without data
2. **Process Quality** – Data collection deviated from the protocol, schedule or other guidance. Examples include:
    a. Incomplete samples
    b. Sample timing versus schedule
3. **Data Quality & Tolerance** – Ensuring data collected are 'reasonable'. Examples include:
    a. Threshold checks against individual measurements
    b. Data context limits – significant digits, data type, etc.
    c. Trend analysis against historical norms for the site/season
    d. Checks for reasonableness of qualitative measurements
4. **Operational Analysis** – Assurance of provisions and training:
    a. Assessments of job descriptions, training, and assessments of individuals
    b. Measurement equipment calibration and confirmation programs are maintained
    c. Provisions are functional, capable and suitable for their use

Section 11.5 outlines the verification and validation methods applied to address these quality issues.

12 SCIENCE OPERATIONS MANAGEMENT

Below are visual representations of Science Operations Management (SOM), from NEON.DOC.004101, *NEON Science Data Quality Plan*, RD [06], assuring quality along the data stream from field to portal:

Figure 12-1: Visual Representation of OS SOM from RD[06]

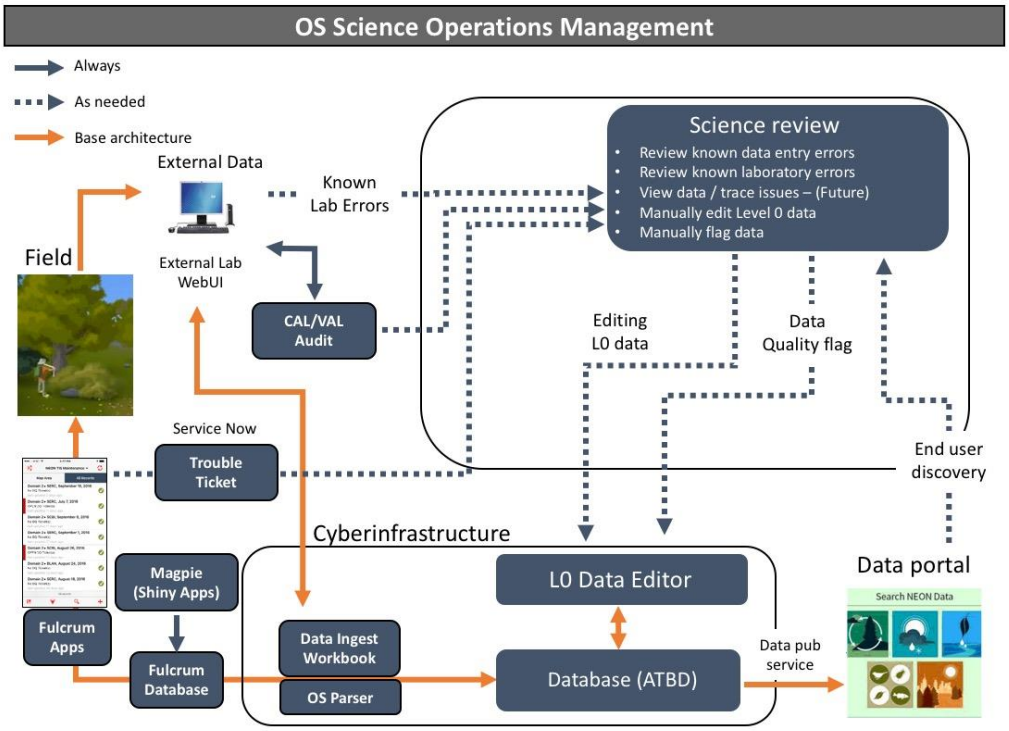

Figure 12-2: Visual Representation of IS SOM from RD [06]