NEON SENSOR COMMAND, CONTROL AND CONFIGURATION (C3) DOCUMENT: SUBSURFACE MOORED SENSOR ARRAY

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Change Record

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A	04/28/2022	ECO-06803	Initial release.

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1 DESCRIPTION

1.1 Purpose

This document specifies the command, control, and configuration details for operating a NEON sensor used for instrumental observations. It includes a detailed discussion of all necessary requirements for operational control parameters, conditions/constraints, set points, and any necessary error handling. All Level 0 Data Products generated by the sensor should be identified.

1.2 Scope

This document specifies the command, control, and configuration that are needed for operating this sensor. It does not provide implementation details, except for cases where these stem directly from the sensor conditions as described here.

A complete set of the Level 0 data products generated in this document can be found in the appendix.

The Subsurface Moored Sensor Array assembly will consist of the following Data Generating Devices (DGD) based on Data Generating Device DGD List and Hierarchies doc (AD [05]):

DGD Agile PN	DGD Agile Description
0317730400	levelTROLL 400
0378610000	Onset HOBO U24-001

Further detailed sensor info under each DGD is as follows:

1. DGD sensors placed on the assembly:
    a. 0317730400 levelTROLL 400, latest firmware version
    b. 0378610000, Onset HOBO U24-001, firmware version 2

Other important parts that are not a DGD:

The sensor mounting assembly, which includes an anchor, a stainless steel cable with mounting loops, and a float. Sensors mount on fixed points at known relative distances along a taut cable between the anchor and float. Assemblies at the deep lakes (non-D09) include a spare, 'loose' cable between the anchor and float that easily disconnects from the float and attaches to a winch to retrieve the anchor. D05-CRAM and D09 lakes must use stainless steel cable to prevent rodent damage.

The number of sensors/loggers deployed on an assembly vary by site. The relative spacing is defined in RD [03]. Sensor/logger mounting positions are designed to be flexible if needed. Changing lake water levels may require temporary removal or adjustment in sensor/logger position(s).

2 RELATED DOCUMENTS AND ACRONYMS

2.1 Applicable Documents

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

AD [01]	NEON.DOC.000001	NEON Observatory Design (NOD) Requirements
AD [02]	NEON.DOC.000291	NEON Configured Sensor List
AD [03]	NEON.DOC.005003	NEON Scientific Data Products Catalog
AD [04]	NEON.DOC.005005	NEON Level 0 Data Products Catalog
AD [05]	NEON.DOC.001104	Data Generating Device DGD List and Hierarchies

2.2 Reference Documents

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

RD [01]	NEON.DOC.000008	NEON Acronym List
RD [02]	NEON.DOC.000243	NEON Glossary of Terms
RD [03]	NEON.DOC.000262	Tier 4 – AIS Requirements Module
RD [04]	NEON.DOC.001843	Tier 5 – AIS Requirements Module
RD [05]	NEON.DOC.005332	NEON Standard Operating Procedure: Subsurface moored sensor array

2.3 Acronyms

Acronym	Explanation
ATBD	Algorithm Theoretical Basis Document
C^3	Command, Control, and Configuration Document
CI	NEON Cyberinfrastructure group
CVAL	NEON Calibration, Validation, and Audit Laboratory
DPS	NEON Data Products group
ENG	NEON Engineering group
L0	Level 0
L1	Level 1
SOP	Standard Operating Procedures
QA/QC	Quality Assurance/Quality Control
TIS	Terrestrial Instrument System

3 LEVELTROLL 400 INTRODUCTION (0317730400)

3.1 LevelTROLL 400 Overview of Sensor configuration (0317730400)

The sensor configuration and sensor command and control described here are related to non-vented pressure and temperature of surface water. The parameters will be measured by the LevelTROLL at a known position on the subsurface moored taut line relative to the Onset U24-001 temperature and conductivity sensors. The depth of water above the LevelTROLL shall never exceed the 11m pressure rating of the sensor (RD [03]). The sensor will communicate via manual download and upload by Field Science (FS). The LevelTROLL holds its calibration constraints within internal memory and performs the analog to digital data conversion internally before any data output occurs. Both sensors shall have their timestamps set to UTC time during each FS visit. Table 1 below details the data measurement streams and associated L0 data product ID's.

Table 1. Level TROLL 400 sensor configuration settings

Parameter	Default Setting
Raw data (and units) acquired from Level TROLL 400 sensor	Pressure (kPa) Temperature (C)
Logging Method	Long-Term Monitoring - Linear
Data Acquisition Rate	Take and store a measurement every 30 minutes
Start Condition	Manual
Device address	1
Baud Rate	9600
Data bits	8
Parity Bits	None
Stop bits	1
Mode	Modbus-ASCII

3.2 LevelTROLL 400 Command and Control (0317730400)

The LevelTROLL will not be connected to a location controller during deployment and Field Science will need to initiate logging mode prior to deployment and following deployment. Data will be transmitted to HQ via a "sneakernet", using the device manufacturer's software to manually download data during periodic maintenance intervals.

3.2.1 LevelTROLL 400 Error handling

The LevelTROLL does not report errors that need to be addressed, but does include quality codes for the collected data which will be output as a data stream. The following codes apply to all Data Quality ID data streams.

Table 2. Data quality codes

Id	Name	Description
0	Normal	Parameter measured without errors using a current calibration.
1	User Uncal	Parameter measured without errors using an expired user calibration.
2	Factory Uncal	Parameter measured without errors using and expired factory calibration.
3	Error	Parameter measured with error, sentinel value supplied.
4	Warm-up	Sensor is warming up, sentinel value supplied.
5	Disabled	Sensor is disabled, sentinel value supplied.
6	Calibrating	Sensor is calibrating, calibration value supplied.
7	Off Line	Device is off line, sentinel value supplied.
8	Warning	Parameter measured without errors but does not meet normal quality criteria.

3.2.2 LevelTROLL 400 Sensor controls specification

The sensor needs to be set to logging mode by Field Science prior to deployment. Following refresh, logging mode should be turned off to prevent battery drawdown during storage [RD 05].

4 ONSET HOBO U24-001 INTRODUCTION (0378610000)

4.1 Onset HOBO U24-001 Overview of Sensor configuration (0378610000)

The sensor configuration and sensor command and control described here relate to surface water conductivity and temperature. The parameters will be measured by the HOBO U24-001 at multiple depths along a subsurface moored floating cable. Each sensor will communicate data via manual download and upload by Field Science (FS). The HOBO U24-001 holds its calibration constraints within internal memory and performs the analog to digital data conversion internally before any data output occurs. Note that the conductivity reading may be set to a specific range, low *and/or* full, that will be specific to each site. Additionally, CVAL shall apply additional calibration coefficients to the L0 data Table 1 below details the data measurement streams and associated L0 data product ID's.

Table 3. Sensor configuration settings for D18-TOOK. Note that this excludes the full range conductivity.

Parameter	Default Setting
Data Acquisition Rate	1 reading per 30 minutes
Raw data acquired from HOBO U24-001 sensor	lowRangeConductivity temperature
Measurement mode	Logging

Table 4. Sensor configuration settings for D05 & D09

Parameter	Default Setting
Data Acquisition Rate	1 reading per 30 minutes
Raw data acquired from HOBO U24-001 sensor	lowRangeConductivity fullRangeConductivity temperature
Measurement mode	Logging

4.2 Onset HOBO U24-001 Command and Control (0378610000)

The HOBO U24-001 will not be connected to a location controller during deployment and Field Science will need to "launch" the logger prior to deployment and following deployment. Data will be transmitted to HQ via a "sneakernet".

4.2.1 Onset HOBO U24-001 Error handling

The HOBO U24-001 does not report errors that need to be addressed.

4.2.2 Onset HOBO U24-001 Sensor controls specification

The sensor needs to be "launched" by field science prior to deployment and following deployment to prevent battery drawdown during storage [RD 05].

5 ASSEMBLY INTEGRATION

The subsurface-moored sensor assembly of Onset U24-001 temperature and conductivity sensors strung along a taut line in the vertical direction requires knowing the depth of each sensor. By positioning a levelTROLL 400 at a known reference distance relative to each Onset U24-001, each temperature/conductivity measurement's corresponding water depth may be calculated. Note that the non-vented levelTROLL 400 pressure transducer data must be corrected by nearby barometric pressure to estimate water depth of each individual temperature/conductivity sensor. Also, note that calibration coefficients will be applied to temperature data from the Onset U24-001 to reduce the sensor's uncertainty.

The assemblies design allows sensor positions to change or removed/added if needed. A configuration may need to change if lake water levels change so much that the spacing no longer monitors the depth range of interest. For example, if PRPO water levels drop so much that the distance between the anchor and the float must be shortened to ensure the assembly remains below the ice, the total number of HOBOs could be reduced from four to three, or a mounting position could be moved to a carefully measured location in-between the updated length of cable between the anchor and float. The relative spacing between Onset HOBO U24 data logger mounting locations are provided in **Table 5**. The single levelTROLL at each assembly may be placed by Field Science at any mounting location in the upper 11m of maximum water level based the sensor's maximum pressure rating. Field Science notes the levelTROLL depth position as defined in the SOP RD [05].

Table 5. Original site configurations of the Onset HOBO U24-001 data loggers as distance above the lake bottom. While exact lake bottom measurements are unattainable, the relative sensor distances are important. Note that changing conditions, such as lake levels, may require modifications to these original positions throughout NEON operations.

Site	Total # of Onset HOBO U24 data loggers	Original relative mount height, in meters
CRAM	10	2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 13.0, 13.5, 14.0, and 14.5 m
LIRO	10	2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 7.5, and 8.0, 8.5 m and 9.0 m
PRPO	4	0.10, 0.20, 0.40, and 0.60 m
PRLA	7	0.10, 0.30, 0.50, 0.80, 1.00, 1.30, and 1.60 m
TOOK	10	2.5, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 10.0, 12.0, and 16.0 m

6 APPENDIX

6.1 List of Level 0 data products

Table 6. List of Level 0 data products associated with DPName: Temperature and conductivity at specific depth in surface water. Note that some sites may be expected to return only one of the conductivity ranges from the HOBO (e.g. lowRangeHobo at D18-TOOK). All temperature, conductance, and pressure designated data streams in the table below will be calibrated, but additional CVAL calibrations may be applied to reduce data stream uncertainty.

DGD Agile PN	DPNumber	Stream	fieldName	description	Acquisition frequency (Hz)	dataType	units
0378610000	NEON.DOM.SITE.DP0.20055.001.01378.HOR.VER.000	2	surfaceWaterTemperature	Temperature in surface water	One reading per 30 minutes	real	celsius
	NEON.DOM.SITE.DP0.20055.001.03883.HOR.VER.000	0	lowRangeHobo	Conductivity returned from a hobo logger for the low range	One reading per 30 minutes	real	microSiemensPerCentimeter
	NEON.DOM.SITE.DP0.20055.001.03868.HOR.VER.000	1	fullRangeHobo	Conductivity from a hobo logger for the full range	One reading per 30 minutes	real	microSiemensPerCentimeter
	NEON.DOM.SITE.DP0.20055.001.01846.HOR.VER.000	3	collectDateTime	Date and time of the collection event	One record per 30 minutes	dateTime	GMT
0317730400	NEON.DOM.SITE.DP0.20055.001.01378.HOR.VER.000	2	surfaceWaterTemperature	Temperature in surface water	One reading per 30 minutes	real	celsius

DGD Agile PN	DPNumber	Stream	fieldName	description	Acquisition frequency (Hz)	dataType	units
	NEON.DOM.SITE.DP0.20055.001.01379.HOR.VER.000	0	surfaceWaterPressure	Pressure of surface water	One reading per 30 minutes	real	kilopascal
	NEON.DOM.SITE.DP0.20055.001.01846.HOR.VER.000	5	collectDateTime	Date and time of the collection event	One record per 30 minutes	dateTime	GMT
	NEON.DOM.SITE.DP0.20055.001.05756.HOR.VER.000	4	internalBatteryPercentUsed	Percent of internal troll battery used	Two records per log (~4 records per year)	real	percent

6.2 Assembly schematic drawing

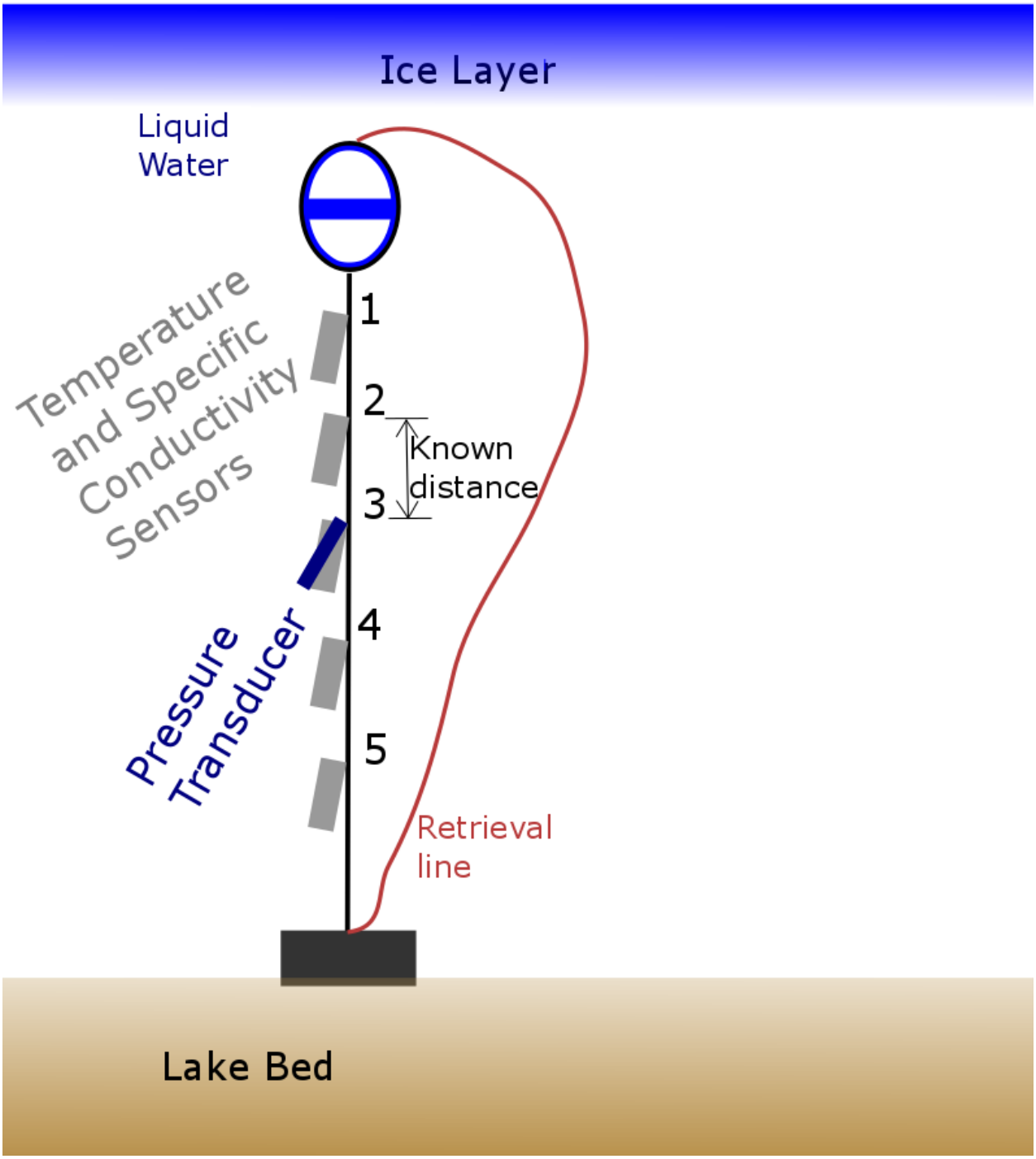

Figure 1 . Subsurface-moored assembly design and sensor assembly. A float and anchor creates a taut line to which sensors may be mounted. Precise measurements between temperature/conductivity

sensors (HOBO U24-001) and the pressure transducer (LevelTROLL 400) allows sensor depths to be determined when data are coupled with barometric pressure during algorithm application. A main cable line connects from the anchor to the float. At deeper lake sites (e.g., D18, D05), a spare retrieval line also connects from the anchor to the top of the float.

6.3 List of materials used in assembly

NEON deploys assembly designs specific to each site. The anchor, float, and presence/absence of a retrieval line vary. However, the assembly includes consistent components between the anchor and float (Figure 1). The "main line" connects the anchor to the float, and sensors hang off the main line via "side connectors". Multiple side connectors are affixed to the main cable using wire rope clips at carefully measured intervals. See **Table 5** for the total number of HOBO sensors, which also corresponds to the total number of side connectors, and RD [04] for relative spacing. Refer to Table 7 for materials used in assembly design, and Sections 6.3.1 and 6.3.2 for the material quantities.

Table 7 Materials used for assembly construction

ITEM	DESCRIPTION	SITES	SOURCE	POSITION
B1140	Rolyan buoys, mooring buoy light duty. 30 lbs submerged buoyancy, 13" diameter, 16" overall height	D05, D18	Rolyan buoys	Main assembly top
Generic 50 lb kettlebell	AmazonBasics Cast Iron Kettlebell - 50 Pounds, Black	D05, D18	Amazon	Main assembly bottom
Chain	~ 18 inch long Stainless steel chain for looping through kettlebell anchor and connecting to cable via shackle	D05, D18	Hardware store	Main assembly bottom
Anchor	10lb mushroom anchor	D09	D09 on-site	Main assembly bottom
Small Floats	Small swimming pool floats	D09	D09	Main assembly top
SLNS18	1/8" S/S OVAL SLEEVE T-304 (for swage-locking)	All	Miami Rope & Cordage	Side connector, main assembly
WRCS18SUN	1/8" S/S WIRE ROPE CLIP TYPE 304, 5.5mm nuts	All	Miami Rope & Cordage	Side connector, main assembly
S0114-0006	1/4" S/S WIDE D-SHACKLE T316	All	Miami Rope & Cordage	Side connector, main assembly

THSHW316SUN	3/16" S/S HEAVY DUTY WIRE ROPE THIMBLE T-316	All	Miami Rope & Cordage	Side connector, main assembly
ACS71918	1/8” 7x19 SS aircraft cable T-304	All	Miami Rope & Cordage	Main line, side connectors, retrieval line

6.3.1 Main assembly

The main assembly cable includes:

- 1x anchor
- 1x float
- 1x 18” stainless steel chain for connecting anchor to cables
- 1x or 2x 7x19 stainless steel aircraft cable at least 2m longer than deepest historic lake depth (two if retrieval line is used)
- 2x or 4x 3/16” SS thimble for each end of the cables (four if a retrieval line used)
- 2x or 4x 1/8” SS Oval sleeves (four if a retrieval line used)
- 2x or 4x wire rope clips to adjust cable lengths (four if a retrieval line used)
- 2x or 4x wide D-shackle for securing thimbles to chain or float connections (four if a retrieval line used)

The main line’s cable should be extra long by at least 2 meters more than maximum lake depth so that length adjustments can be made if needed.

One end of the main cable has a permanent thimble installed with oval sleeves. This is for the float end. A wide D-shackle loops through the cable and connects to a loop on the float. The other end also has a thimble but is secured using wire rope clips. A wide D-shackle connects the thimble to the anchor (e.g. serves as the missing link in the chain wrapped around the kettlebell anchor handle). The wire rope clips at the anchor end allows the total length of the assembly from anchor to float to be adjusted.

At the deep lake sites (D05, D18), a spare retrieval line connects from the loop at the top of the float to the chain around the kettlebell anchor handle. It also uses thimbles with a wide D-shackle to secure to top of the float and the chain around the anchor handle. The spare retrieval line should be at least 2 meters longer than the maximum lake depth to ensure easy retrieval. D05 must use a winch mounted to the pontoon buoy to retrieve the subsurface moored assembly with the retrieval line.

All D-shackles have a pin that screws in/out. Small 18-gauge wire is used to secure the pin snaking the wire through a hole in the pin's handle and then wrapping the wire around the inside of the D-shackle and closing with a couple twists.

6.3.2 Side connectors

Each side-connector to the main line (**Error! Reference source not found.**) consists of:

- 13 cm of 1/8" 7x19 SS aircraft cable
- 1x 3/16" SS thimble
- 2x 1/8" SS Oval sleeves
- 2x Wire Rope Clips for each side-connector to connect to the main cable
- 1x ¼" wide D-shackle loops through the thimble for connecting to an individual data logger. One Side-connector will hold two dataloggers – an Onset HOBO U-24 AND a levelTROLL 400. All other side connectors hold just one U-24 logger.
- 18 gauge stainless steel wire to secure pin in D-shackle from falling out

The length of the side connector measured from the inside rounded curve of the thimble to the bare end of the cable should be 10.2 cm. This also corresponds to 6.0 cm from the edge of the thimble to the end of the cable (**Error! Reference source not found.**A). A consistent side connector dimension ensures standard relative logger positioning across an assembly.

Figure 2. (A) image of a single side connector. (B) Two side connectors attached to a main line.

7 BIBLIOGRAPHY

In-Situ Inc. Level TROLL 400,500, 700, 700H Instruments, Operator's Manual, Revision 2019-05-06

HOBO U24 Conductivity Logger Manual, version 15070-I