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µSPEC

The μSPEC User's Manual

An In-situ Marine Optics Instrument

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1.0	17/01/2020	New document	M. Slivkoff, W. Klonowski

Thank you!

We would like to express our most sincere thanks for choosing the In-situ Marine Optics μSPEC instrument. Both being directors, managers, engineers and technicians in the marine optics field, we recognise the importance of having a dependable, high quality and intuitive product to work with as well as excellent documentation through the learning process and beyond. Our goal is to always learn new things and improve ourselves, our products and our documentation, so we welcome user's feedback at: support@insitumarineoptics.com
Happy photon collecting...

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Chapter 1

Introducing the μSPEC Radiometer

The μSPEC is a hyperspectral light sensor designed for both in-air and in-water deployments. It measures light using and embedded, high-sensitivity, ultra-compact visible spectrometer with a dedicated high-resolution 16-bit analog to digital converter. The μSPEC comes pre-configured to measure either irradiance or radiance. The planar irradiance μSPEC variant optical window is a Teflon diffuser that collects photons from the hemisphere and weights these photons with respect to the angle of incidence (cosine weighting). The radiance μSPEC variant measures photons through a quartz window through a restricted angle field of view.

The μSPEC sensor is small enough to be mounted on a pole or mast and is fully submersible to 300m for extended periods. For the planar irradiance sensor, the diffuser must be flat with the horizon in order to obtain the most accurate measurements. All sensor variants contain an internal Real Time Clock (RTC), and provide tilt information which is useful for quality controlling the radiometric measurements.

The μSPEC comes in different form factors depending on the chosen options. The μSPEC ordering code **B** variants feature a rechargeable internal lithium ion battery and the ordering code **L** variants feature internal data storage. These variants are designed to be configured and recharged by a cable prior to deployment. Downloading the logged data can be performed wirelessly in air through WiFi, or through a serial configuration cable. The white, external switch switches between Off (0), Logging (1) and WiFi (W) download mode (see Fig.

1.2). During logging, serial data can also be streamed out of the device via the underwater connector. All μSPEC variants stream serial data upon power-up.

Order Code:
μSPEC_<OPTIONS>_<GEOMETRY>,

where <OPTIONS> include:
L - Logging (internal SD card)
P - Pressure
T - Temperature
B - Battery
W - Wiper (Copper wiper and faceplate)
S - Shutter (Black non-wiping shutter and faceplate)

where <GEOMETRY> denotes:
I - Irradiance (Planar)
R - Radiance

i.e.
μSPEC_LPTBW_I describes:
internal **L**ogging, **P**ressure, water **T**emperature, internal **B**attery with copper lens **W**iper. The sensor is an **I**rradiance sensor.

1.1 Diagrams

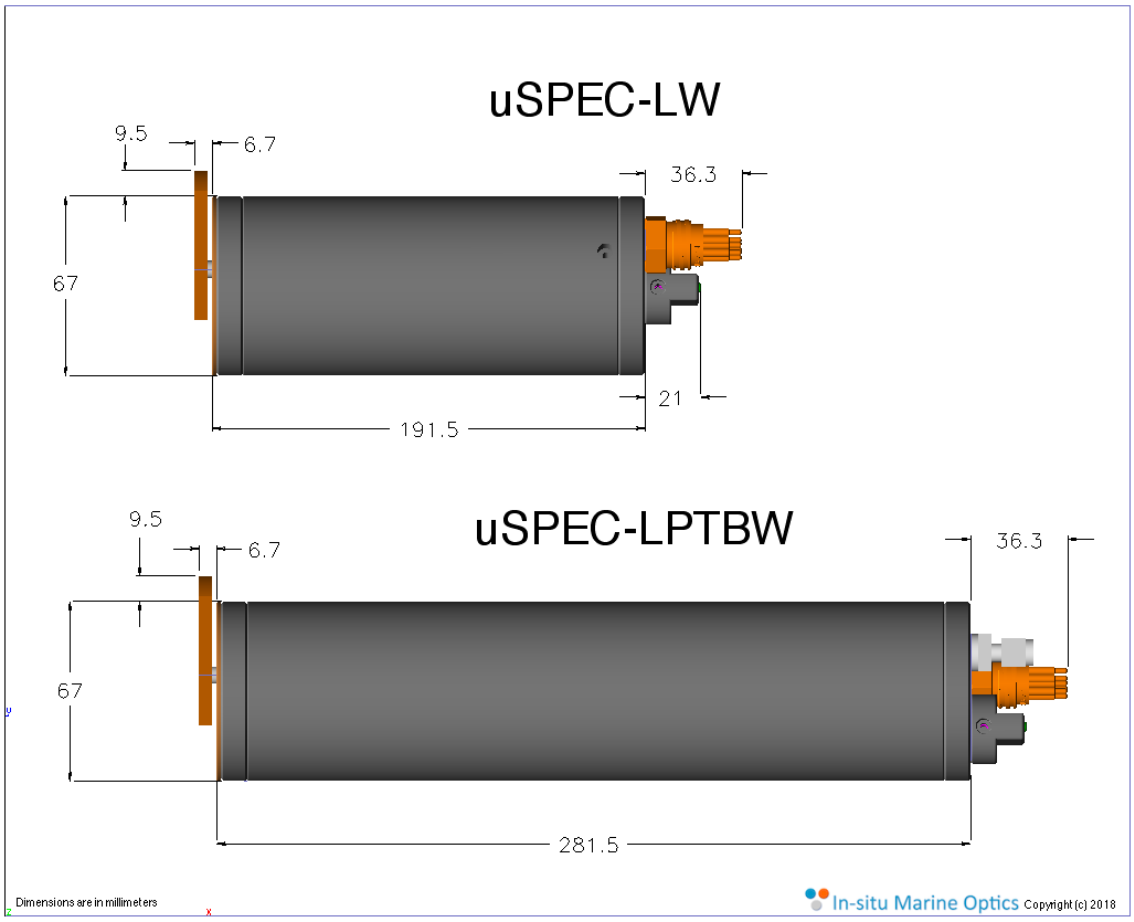

Figure 1.1: Dimensional drawings of the two different form factor μSPECs. (Top) shows the“sensor head" form factor and (bottom) shows the longer internal battery option (option code **B**) housing.

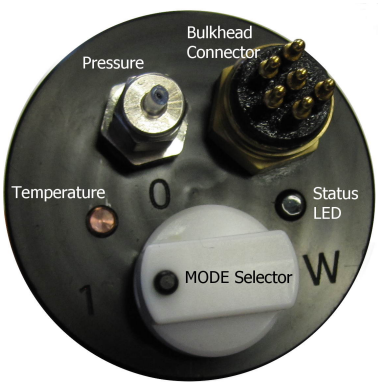

Figure 1.2: End cap of an μSPEC-LPT sensor. The unit samples when the Mode Selector is in position 1, and is off when position 0. The WiFi download mode is engaged when in position W. LED status indicator descriptions are shown in Appendix Table A.1

Pin	μSPEC	μSPEC_B
1	Ground	Ground
2	RS232 TX (DB9 3)	RS232 TX (DB9 3)
3	No Connection	Battery
4	Vin (7-24VDC)	Vin (7-24VDC)
5	RS232 RX (DB9 2)	RS232 RX (DB9 2)
6	No Connection	Battery Thermistor

Figure 1.3 & Table 1.1: Male (protruding) MCBH6M bulkhead connector pin configurations for μSPEC sensor variants. (see Fig. 1.2 for bulkhead connector location.)

1.2 Delivery Checklist

The standard μSPEC purchase ships with the Sensor, an unterminated MCIL-6F cable and a USB Disk with Software and Manual. In addition, the internal battery variants delivery contains:

- μSPEC Config / Charge Cable (instead of the unterminated MCIL-6F)
- Turtle battery charger and DC power adaptor
- FTDI USB to Serial Converter (UC232R-10)

Figure 1.4: The μSPEC-LPTBW-I Sensor with the shutter open.

Figure 1.5: The internal battery variant configuration / charge cable.

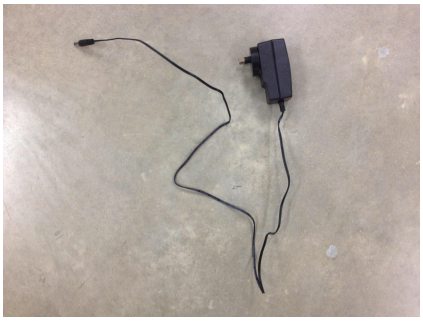

Figure 1.6: Mains AC to 24VDC Charger Power Adaptor.

Figure 1.7: The “Turtle” charger with LED status indicator.

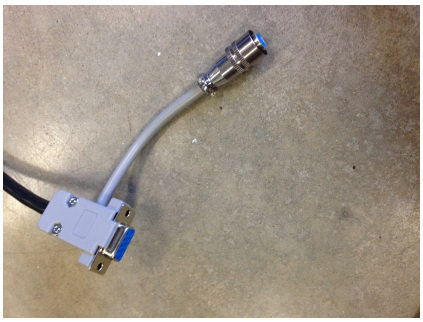

Figure 1.8: Configuration / Charge cable showing the RS232 serial and Turtle Charger connectors.

Figure 1.9: The USB-to-serial adaptor which plugs into the RS232 serial end of the Config / Charge cable.

1.3 Other Useful Equipment

Some user-specific or optional items that may be useful but are NOT included in the μSPEC purchase are:

- Windows XP, 7, 8.1 or 10 Control PC with at least a 1 GHz Pentium processor, 512 MB of RAM, and 600 MB of free hard drive space. Microsoft .NET Framework version 4.6 (to initialise μSPEC operation modes, and optionally control data collection), and WiFi adapter for faster downloading.
- Spray / squirt bottle containing pure water (cleaning the housing / optical windows).
- Delicate task wipes i.e. Kimwipes (optical window cleaning).
- Isopropyl alcohol or similar lens cleaner (optical window cleaning).
- Contact cleaner (electrical connector cleaning).
- Silicon spray (waterproof connector lubrication).
- DC 200 XIAMETER PMX-200 20cs silicon oil (for servicing μSPECs with the Pressure port option)
- Thin rubber strips (protecting the μSPEC sensor and mounting surface from scratches).
- 1-2 medium-large hose clamps $\gtrapprox$ 80 mm diameter (for mounting the μSPEC sensor to a pole/mast or mooring frame).

- Copper tape (for wrapping sides of the plastic housing to minimise bio-fouling during long deployments).

Chapter 2

Operating the μSPEC

2.1 Connecting the μSPEC to the Config / Charge cable

The μSPEC needs to be connected to the Configuration / Charge cable for battery charging, logger configuration and real-time operation. It is to remain dry and should be reserved for in-lab benchtop testing, battery charge and configuration applications only. The Configuration / Charge cable is a 6-conductor cable with a Grey D-SUB RS232 connector with a side-protruding cable. (See Figs. 2.1 and 2.2). One side of the 'Y' end features a serial DB-9 connector to attach to the PC via the USB to Serial converter and the other side features a silver circular connector which connects to the Turtle Charger. The grey "Turtle" charger shell has an LED indicator which communicates the information in Appendix Table B.1. Depending on charge state, the battery may take up to 4 hours for a full recharge. It is highly recommended to recharge immediately after a low battery event.

To connect the μSPEC to the cable, first ensure that neither end of the Configuration / Charge cable is connected to anything, as shown in Fig. 2.2. Inspect both connector ends for signs of grime or corrosion and clean with a rag and some isopropyl alcohol or contact cleaner if necessary.

Slide the connector sheath away from the cable end, align the pins of the cable end with the pins of the μSPEC sensor's bulkhead connector and press down firmly whilst holding the sides of the cable end in order to join the connector's flat face with the base of the bulkhead connector so there is no visible gap (see Fig. 2.5). If necessary, use a rapid pulse of silicone spray to lubricate the

Figure 2.1: The short benchtop Configuration / Charge cable provided with the logger variants.

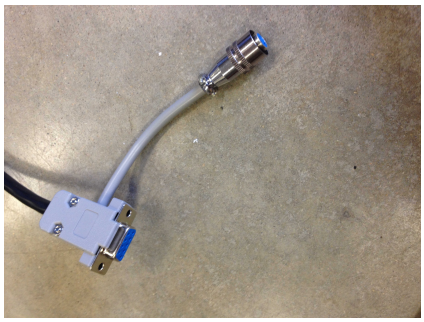

Figure 2.2: The Configuration / Charge cable end showing the RS232 and Turtle Charger connectors.

connectors so that the waterproof connector fits easily onto the μSPEC Sensor's bulkhead connector. Once the connection is made and is seated properly, screw on the protective sheath to finalise the connection.

Figure 2.3: The Configuration / Charge cable. Inspect for corrosion or grime prior to connecting.

Figure 2.4: Check pin alignment on both connectors before attempting connection.

Once the sensor end of the cable is connected and secured safely, other operations can proceed. For the internal battery versions, charging begins when the turtle charger is connected to the silver power supply end of the 'Y' cable and its 24V DC plugpack switched on. Refer to the Appendix for turtle charger status light descriptions. For non-battery versions, power must be applied to the unterminated MCIL-6F cable. Refer to figure 1.3 for pinouts.

Once the power is supplied to the μSPEC, via either the battery or external power, the μSPEC can be turned on using the Mode selector shown in Fig. 2.9. The unit is set to sample when the Mode Selector is in position 1, and completely off when position 0. The WiFi download mode is engaged when in position W.

Figure 2.5: Once correctly aligned, push down firmly whilst holding the sides of the cable end.

Figure 2.6: To finalise connection, screw the protective sheath onto the bulkhead connector thread.

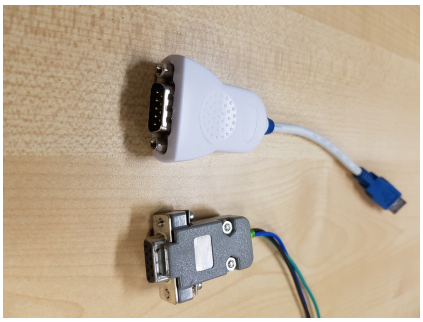

Figure 2.7: Identify the DB9 side of the Power/Comms 'Y' cable and the DB-9 side of the FTDI USB-serial adaptor.

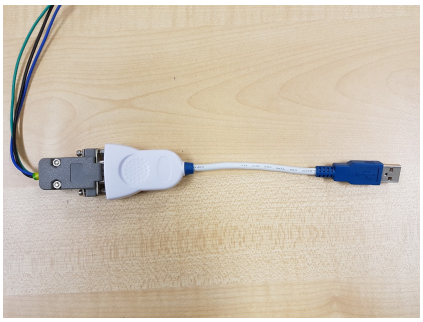

Figure 2.8: The completed serial communication connection. Plug the other end of the serial adapter into the USB port of the computer.

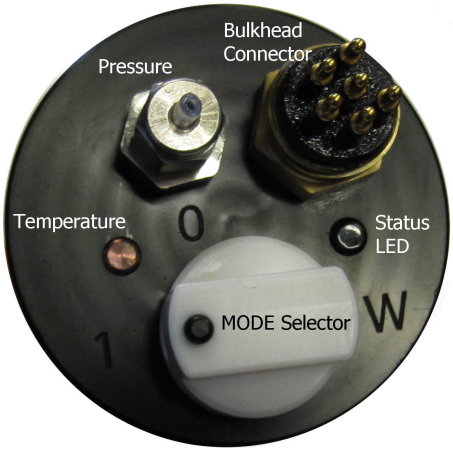

Figure 2.9: End cap of an μSPEC-LPT sensor. The unit is set to sample when the Mode Selector is in position 1, and completely off when position 0. The WiFi download mode is engaged when in position W.

2.2 Establishing Serial Communications

When the Configuration / Charge cable is connected (or a cable made up following Table 1.3) and the Mode Selector is in position 1, the μSPEC will begin streaming RS-232 serial data. For PCs that no longer have onboard serial ports, a high-quality USB to serial adapter must be used to emulate a serial (COM) port which can capture this data and issue configuration commands to the μSPEC. Programs such as Hyperterminal, Teraterm or Realterm are compatible with the μSPEC. Alternatively, the windows based Graphical User Interface (GUI) "uSPECview_VX.X.exe" can be used to provide a more user-friendly dashboard control panel with data display. The connection parameters are as follows:

- Connection Type: Serial / RS-232
- COM Port: This depends on the physical connection made to the PC
- Baud Rate: 115200
- Data Bits: 8
- Stop Bits: 1
- Parity: None
- Flow Control: None

2.3 ASCII - Serial Output Format

If supplied with 7 - 24V DC and upon switching the μSPEC to position 1 on the Mode Selector, the μSPEC will perform a wipe sequence, print a 5 line header and then stream data. Each line of serial data output after the header represents a new measurement, and is terminated with a new line. Variables are separated by commas.
For example:

```
In-situ Marine Optics - Copyright (c) 2019.
Hyperspectral Light Logger
uSpec-LPT (SN:0025)
SD CARD LOGGING = ON
LOGFILE: LOG_0083.TXT
Initialising uSpec...
uSpec-LPT,0025,11/11/2019,17:05:38.251,12.0,-0.35,14.0625,92.3,14.0625,10.004,67,11026,10998,...,17433
uSpec-LPT,0025,11/11/2019,17:05:39.097,12.0,-0.42,14.0625,92.1,14.0625,10.004,67,11080,10864,...,17483
uSpec-LPT,0025,11/11/2019,17:05:39.443,11.9,-0.44,14.0625,92.1,14.0625,10.000,67,11105,10823,...,17524
uSpec-LPT,0025,11/11/2019,17:05:40.000,12.0,-0.44,14.0625,92.1,14.0625,10.004,67,11162,10870,...,17472
uSpec-LPT,0025,11/11/2019,17:05:40.357,12.0,-0.42,14.0625,92.0,14.0625,10.004,67,11117,10913,...,17572
```

The 280 columns for the LPT product variants are as follows:

Sensor Type, Serial Number, Date (dd/mm/yyyy), Time (HH:MM:SS.sss), Input Voltage (V), Depth (m), Water Temperature (°C), Tilt (°), Detector temperature (°C), Integration Time (ms), % Saturation, Channel 1, ... , Channel 269.

The 278 columns for the non-LPT product variants are as follows:

Sensor Type, Serial Number, Date, Time, Input Voltage (V), Tilt (°), Detector temperature (°C), Integration Time (ms), % Saturation, Channel 1, ... , Channel 269.

For the LPT product variant, the output for the radiometer channel columns can be user-selected as either decimal **calibrated** irradiance (or radiance) or 16 bit integer (0-65535) **raw** count mode using the drop-down fields in the Configuration section of the GUI. For terminal program-based serial communications, the output format is selected by entering "RAW" or "ENG" then <ENTER> on the keyboard. The μSPEC should then echo the command as an acknowledgement and then wait for the user to press <space> to continue.
For **calibrated** output formats, the μSPEC sensor also has two GUI selectable output modes; either INAIR or INWATER. By setting the INWATER mode, the immersion factor is automatically applied to the output calibrated irradiance readings and is to be used for when the μSPEC is submersed in seawater.

Note: In order to make any configuration changes using uSPECview, the data stream must be in "PAUSE" mode (see top right of GUI window). If the logger is in low power sleep mode, first wake the sensor by pressing the "Wake" button followed by "Pause" to pause the data stream. Once paused, the "Configuration" and "SD Card" panels will become active ready for any changes or data downloading.

2.4 BINARY - Serial Output Format

For “sensor head” variants that require an external data logger such as the DL3, the data streaming can be user-selected as BINARY output. This special format significantly reduces the number of bytes of each spectral measurement which is sent to the logging device. Binary (BIN) output can be selected by using the drop-down fields in the Configuration section of the GUI. For terminal program-based serial communications, the output format is selected by entering "BIN" then <ENTER> on the keyboard. When data acquisition is resumed, binary data will be output (looks like garbled messages) and the GUI will no longer show spectral output. It will be up to the data logger to capture this data. The In-situ Marine Optics custom software “DL3_uSPEC_Extractor.exe” may be used to extract the uSPEC binary data from the DL3 and convert to human readable ASCII output. **Note:** Regardless whether or not BINARY or RAW data is selected as the RS323 output, a backup copy of the data is stored on the μSPEC’s internal SD Card as only RAW (ASCII) data.

2.5 Sampling Mode

The μSPEC has two different sampling modes and a few different options which should be well understood prior to deployment. The sampling mode can be set to either CONTINUOUS or BURSTMODE. CONTINUOUS mode is an ‘always on’ mode, where continuous sampling will occur and wiping will only occur once upon switching the white mode selector from 0 to 1. This is optimised for vertical profiling or other short-term deployments.
BURSTMODE on the other hand, will perform a wipe and take a number of samples (defined by **Burst Samples**) at a pre defined interval (**Burst Interval**, in minutes). Between these intervals, the wiper is parked in the closed position to protect the optical window and the μSPEC is placed into deep sleep mode to preserve battery life.
Further battery saving can be made by selecting between different **Burst Program** modes. STANDARD 24hr mode is simply running the burst sampling 24

hours a day, whereas SUNRISE / SUNSET time burst program is designed to only sample during daylight hours, based on the latitude, longitude and time zone of the sensor. Alternatively, a USER START / END TIME may be specified. For configuring these enhanced power saving features, the **More »** button should be clicked to reveal the additional parameters. The sunrise offset and sunset offset is used to capture data pre-dawn and post dusk. In this case, a sunrise offset of -1 would lead to burst sampling beginning 1 hour *before* sunrise. A sunset offset of 1 would lead to burst sampling finishing 1 hour *after* sunset.

2.6 Integration Time

The **integration time** is the duration (in milliseconds) that the spectrometer is allowed to capture photons for per sample. The longer the integration time a sample has, the more photons counts are collected for that sample. When collecting (integrating) photons whilst in motion, the longer integration time corresponds to a larger spatial (or depth weighted) average. The μSPEC incorporates a 16-bit Analog-to-Digital Converter (ADC) to convert photons into digital 'counts', so each spectrometer can theoretically collect no more than $2^{16} = 65,536$ counts per sample. It is often desirable to collect light for a long enough time in order to increase the number of photon counts relative to the number of noise counts which are always present in a spectrometer's measurement. It is important to not allow the integration time to be too high, otherwise the spectrometer will collect its maximum value of 65,536 counts during the integration time and will no longer resolve meaningful data. This is sometimes referred to as sensor 'saturation'. IMO recommends using integration times which will lead to a count no greater than approximately 80% of the full scale counts.
The integration time can be manually set by entering the integration time in milliseconds in the **Configuration** area, and then clicking the **Set** button. Alternatively, the **Auto integration time** checkbox can be selected, which automatically changes the integration time so that the number of digital counts collected per sample fall between pre-defined conservative **SPEC_UB** (Upper Bound) and **SPEC_LB** (Lower Bound) thresholds. These auto integration time threshold values can be changed via command line. Default configuration for LB and UB thresholds are:
SPEC_LB 20000
SPEC_UB 40000

Please be mindful that in certain situations, setting a lower and upper bound

too high can result in saturation events if the light field is fluctuating. In such situations, it is wiser to lower the bounds to accommodate the light fluctuations. The **Configuration** settings are automatically saved ("flashed") to the μSPEC's EEPROM so it remembers the configuration settings between deployments (i.e. between power-down cycles).

2.7 Wiper Interval

The μSPEC is designed to automatically wipe the optical window(s) on power-up. After that, the wiper will only operate during the beginning of BURSTMODE operations; when the unit comes out of deep sleep to begin a burst of samples. In order to save even more battery life, the Wiper Interval is a configurable parameter which allows users to skip "N" initial wiping events. For example, if the Wiper Interval is set to 4, then the wiper will work only prior to every fourth sampling burst. Significant battery life savings can be achieved using this feature.

2.8 Time Set

In the GUI, the sensor's internal clock can be synced to the PC clock by clicking on the "Set Time" link in the "Sensor Data" section in the middle of the GUI.
The μSPEC's internal clock can be set in the command line by issuing "TIMESET %Mmm dd YYYY HH:MM:SS%", where "Mmm" is the 3-letter month representation, "dd" is the day number and "YYYY" is the year. "HH:MM:SS" represents Hours, Minutes and Seconds (respectively). E.g. to set date/time to midday of the 1st of January, 2020 issue the command:

Jan 01 2020 12:00:00

Note: The 3 letter month abbreviation must be in english with the first letter as capital and remaining 2 letters as lower case.

2.9 Data Logging / Retrieval

The μSPEC features internal datalogging which can be engaged by the serial command “SD ON” or by turning on SD Logging by clicking the radio button in the Configuration **More »** section in the uSPECview GUI. With logging enabled, upon switching the Mode Selector from 0 to 1, the μSPEC will automatically create a new logfile named “LOG_XXXX”, where XXXX represents a number between 0001 and 9999. Within this file, the data from each burst is appended. The filename number (XXXX) is automatically incremented upon successive Mode Selector toggles between 0 and 1, so that data from different deployments can have a different filename. Alternatively, the μSPEC can be set to append all data to one master file, called ‘uSPECLOG.TXT’. This is achieved by turning **Master Append** on in the Configuration **More »** section.
To download logged data, it is recommended to use WiFi mode. WiFi can be enabled by placing the Mode Selector to W. For non-battery versions, power will need to be supplied using the Config/Test cable. This will enable the μSPEC to be an access point, that a remote device (the intended data destination) will need to connect to via WiFi, and then open up a browser window to http://192.168.1.1. Once this is done, a web page listing of the available files for download will be presented. These can be right-clicked and saved.
For laboratory or real-time continuous mode applications, data can be captured directly to PC by using the uSPECview GUI. This is initiated in the **PC Recording** section at the top right of the GUI window. Using this method, data is captured directly to the file specified. Note: Does not work in binary mode.

Chapter 3

Installation and Maintenance of the μSPEC Sensor

3.1 μSPEC Mounting Considerations

When considering mounting options for the μSPEC Irradiance (white diffuser) variant, choose a position that will allow an unobstructed view of the hemisphere; free from artificial shadows falling on the diffuser during the course of an experiment. Ensure that the diffuser window is as flat as possible with the horizon, in both axes. When the copper wiper is attached, try to mount the μSPEC with the motor shaft axis facing the south (in the southern hemisphere), to avoid shading. For the μSPEC Radiance variant, try to avoid obstructions within 20 degrees off normal incidence from the quartz window. Inside this angular range, artificially reflected light may contribute to the signal.

The μSPEC can be affixed to any upright pole (and/or sub-sea mounting frame) using In-situ Marine Optics' plastic clamps (sold separately), two or more large cable ties, hose clamps or even an adequate amount of cloth tape for shorter deployments. If hose clamps are to be used, ensure that these are hand-tightened to prevent the housing from cracking. Also be aware that the acetal housing can scratch, so measures can be taken such as wrapping the housing in layers of electrical tape, or thin rubber / neoprene if the device's cosmetic appearance is a concern. If mounting on a pole that extends past the copper faceplate of the μSPEC, align the μSPEC so the motor shaft axis is aligned with the pole so the wiper cannot come in contact with the power during its furthest travel extents during wiping. Also be aware that the measurement may be contaminated by the protruding pole, as the irradiance diffuser collects light

from the entire hemisphere, and the radiance detector may accept light from as far out as 20 degrees.

For long term deployment i.e. months, it is recommended that the black plastic tubular part of the housing is wrapped in copper tape to retard biofouling. In high light environments, the expense of the copper tape may be cheaper than the labour and ship time it takes to clean an unprotected housing during a servicing interval!

3.2 Routine Maintenance

If the μSPEC is being used in salt water, use fresh water to rinse the salt water or dissolve salts from the housing. If the sensor has had long periods of time underwater and is fouled, a domestic high pressure hose may be used; sprayed from an distance of no closer than approximately 50cm to assist the removal of biofouling. In this regard, prevention is better than the cure, so consider using copper tape on the sides of the housing prior to deploying. Some users find that applying a layer of black electrical tape onto the acetal prior to the copper tape layer assists with the subsequent removal of fouling and further protects the acetal surface. If the device is to be out of service for some time, soaking in fresh water for a few hours is also recommended. After removing, ensure the housing is wiped dry with a clean, dry cloth prior to storage. Also ensure that the batteries are not fully discharged during storage.

Throughout the deployment, the μSPEC optical windows may become dirty from biofouling even when the wiper is operating properly. The radiometric calibrations of the μSPEC are only valid for clean optical windows, so routine inspection and cleaning is an important part of using the μSPEC. The recommended procedure for cleaning optical windows includes:

- Rinse large particles off optical surfaces with water from a squirt or spray bottle,
- Inspect optical surfaces and if visibly clean, dry with lint-free delicate-task wipes (i.e. Kimwipes) by placing them over the lens and allowing them to draw up the moisture. Never wipe across the lens unless it is free from visible particulate contamination,
- If dirt or contamination remains, use isopropyl alcohol or ethanol to dissolve the contamination and used lint-free wipes in a gentle ‘dabbing’

motion to remove the contamination. Never wipe across the lens unless it is free from visible particulate contamination, and

- Once the contamination is removed, use isopropyl alcohol or ethanol and a fresh lint-free wipe to polish the lens to remove watermarks, excess alcohol etc. to achieve the final clean finish.

Throughout the lifetime of the μSPEC (i.e. through successive deployments), connectors of the μSPEC sensor or the Power/Comms cable connectors may become dirty or corroded. It is good practise to inspect all connector ends prior to and also after a deployment. Clean the contacts with a spray of isopropyl alcohol or contact cleaner. If necessary, gently scratch corrosion off the electrical contacts with some fine-grit sand paper. If the rubber appears dry, use a rapid pulse of silicone spray to lubricate the connectors so that the waterproof connector fits easily onto the bulkhead connectors without overly stressing the rubberised compound material. Corrosion of the pins may be a result of a poorly-seated underwater connection, exposure to salt water prior to making the connection, or simply from the rubber connectors wearing over time. In this situation, it may be advisable to use a product such as silicon grease over the female end of the MCIL6F connector. A small dab or smear of this product over the holes prior to seating the connection onto the bulkhead connector will lubricate and fill any voids which may fill with water. Upon seating the freshly-smeared connector, you will hear the satisfying pop or crackle which indicates that silicone is taking place of the air, and there should be a slight overflow of silicone compound out of the edges of the fully-seated connection. Wipe this excess off with a rag prior to attaching the retaining collar.

For μSPEC's with the Pressure option, it is worth occasionally inspecting the protruding tube. This tube is designed to be filled with an inert, transparent silicon oil (DC 200 XIAMETER PMX-200 20cs) which transfers the pressure of the water to the pressure sensor's membrane without the risk of corrosion. If there are air bubbles in this tube and the pressure readings are spurious, then the silicon may need to be refilled. In this situation, place the μSPEC with the pressure port facing upwards and remove the outer stainless steel nut which retains the tube. With the tube still in place inserted into the pressure port, use a primed syringe filled with silicon oil and slowly fill the inside of the tube until the entire tube and pressure port opening is filled with no air bubbles and meniscus is formed in the threaded area where the stainless steel nut was located. Once this has been filled, carefully replace the stainless steel nut and gently tighten it. After tightening, there may be a slight overflow on the tube and threaded area. Wipe excess with a cloth.

Being an electrical instrument exposed to sunlight, moisture, salt and extremes in temperature, the μSPEC may from time to time, need to be serviced by In-situ Marine Optics technicians. For μSPEC models with an internal wiper, we recommend returning the units yearly for an o-ring service and radiometric calibration. If any other symptoms are exhibited, please report any issues you have at support@insitumarineoptics.com and if necessary, organise the instrument's return to the factory for evaluation and service.

Appendix A

Bulkhead μSPEC LED status indicators

Event	Indicator	When?
SD Card Error	Red Flash x 3	On Startup and after wake
Low Battery	Red Flash x 5	On Startup and after wake
Very Low Battery	Solid Red	Then goes to sleep indefinately
Power On	Green Constant	On Startup
Logging	Green Flashing	During data sampling
Streaming (Only)	Green / Orange Alternating Flashing	During data sampling
Streaming with SD Card Error	Green / Red Alternating Flashing	During data sampling
Begin Sleep	Red, Orange, Green loop x 3	Just before sleep
Wifi Enabled	Solid Orange	Just after turning WiFi on
Wifi Access Point connected	Orange flashing	Just after turning WiFi on
Wifi Downloading	Orange/green Flashing	During data offload

Table A.1: Bulkhead LED status indicators.

Appendix B

Battery Charger LED status indicators

LED patterns	Description
Traffic light (red-orange-green)	System reset. Occurs at power on and battery connection
Slow orange blink	System waiting. Battery Disconnected or Battery completely discharged below safety threshold
Solid Orange	Constant current phase. (inc. pre-condition if programmed)
Orange with Green blink	Constant voltage phase
Solid Green	Charge Complete. Float Charge continues (if programmed)
Three Red Flashes	Charge suspended. Battery volts too low.
Two Red Flashes	Charge suspended. Battery volts too high.
Slow red blinking (1 flash every 5 sec.)	Charge suspended. Battery too hot. Or PCB too hot (PCB Self protected to $75^{\circ}C$)
Fast red blinking	Thermistor Error. (Needs Power Reset)
Orange blinking(1 flash every $\frac{1}{2}$ sec.)	Timeout. Time limit is customisable on request.
Solid red	Fault. (Needs Power Reset).

Table B.1: Battery Charger LED status indicators.

The μSPEC features a low battery shutoff mode which protects the battery from a critically deep discharge. However, if the battery is left for long periods of time in this state, the internal battery protection module may eventually disengage the battery so the turtle charger may not recognise that it is connected. In

this situation, the charger will exhibit a slow orange blink indefinitely, and no charging will take place. Please contact support@insitumarineoptics.com for further assistance in this event. It is recommended to never leave discharged batteries for long periods of time.

Appendix C

Specifications

C.1 Optical

Spectrometer	Hamamatsu C12880MA
Detectors	288 pixel Si photodiode array (269 used)
Wavelength Range:	340 - 850 nm
Spectral resolution	8.5 nm
Irradiance cosine response	< 3% (0 - 60°), <10% (60 - 87.5°)
Field-of-View	5 - 10° in-air. 4 - 8° in-water
Calibration	NIST traceable radiometric calibration

C.2 Electrical

Acquisition	16 bit ADC
Integration Time	0.125 - 2500.0 ms (user defined or automatic)
Sampling rate	configurable up to 5 Hz
Integrated sensors	Tilt, Int. Temp, Water Temp*, Depth*
Depth range	0 - 300 m (accuracy: ± 1.0 %)
Water temp range	-55 to 125 °C (accuracy: ± 1.0 °C)
Data storage	16 GB, micro SD card
Protocol	RS-232 @ 9,600 - 115,200 bps
WiFi	Data download
Input voltage	7 - 24 VDC
Power consumption	150 mA @ 12 VDC, 350 mA during wipe cycle
Internal Li-Ion battery:	11.1 V, 5.2 Ah (rechargeable)
Connector	Micro WET-CON MCBH6M

C.3 Physical

Length	μSPEC-L: 195 mm (connector + 36 mm) μSPEC-LB: 285 mm (connector + 36 mm)
Diameter	67 mm
Weight	μSPEC-L: 0.8 kg in-air, 200 g in-water μSPEC-LB: 1.4 kg in-air, 300 g in-water
Materials	Acetal housing, PTFE diffuser, Quartz, copper faceplate/wiper
Depth rating	300 m
Ambient operating temperature	-10 to +50 °C

Appendix D

Serial Command List

Table D.1: List of basic serial ASCII commands that can be issued to the μSPEC. To see a list of commands, enter "HELP" in the Console window. Where applicable, use a space between the command and the argument, followed by the carriage return or <ENTER> .

Command	Arguments	Details
HELP		Displays general commands that can be executed.
ADV		Displays advanced commands.
CONFIG		Displays logger configuration.
CALCONFIG		Displays calibration coefficients.
START		Starts data collection.
STOP		Stops data collection.
INTTIME	millis	Sets the integration time in milliseconds.
AUTOINTTIME	ON/OFF	Enables/disables auto integration time.
DPI	value	Sets dpi precision to cal output.
BAUD	value	Sets serial baudrate. Takes effect after power cycle.
GETWL		Lists detector wavelengths.
RAW		Sets raw data output. 24-bit integers (0-16777215).
ENG		Sets calibrated data output to Engineering units.
BIN		Sets binary data output.
INAIR		Applies in-air calibration.
INWATER		Applies in-water immersion factors.
BURSTMODE		Sets burst sampling mode.
CONTINUOUS		Sets continuous sampling mode.
BURST SAMPLES	n (integer)	Sets number of samples (n) to collect during burst.
BURST INTERVAL	mins (integer)	Sets time interval between burst starts.
BURST PROGRAM	n	Sets Burst Program, 0=24hr, 1=Sunrise/Sunset Time, 2=Start/End Time.
TIMEZONE	n (float)	Sets the TIMEZONE for Sunrise/Sunset calculation.
LAT	dd.dddd	Sets the latitude (-90 to 90) for Sunrise/Sunset calculation.
LON	ddd.dddd	Sets the longitude (-180 to 180) for Sunrise/Sunset calculation.
SUNRISE OFFSET	hr (integer)	Sets the sunrise time offset used with BURST PROGRAM=1. Negative offset is pre-sunrise.
SUNSET OFFSET	hr (integer)	Sets the sunset time offset used with BURST PROGRAM=1. Positive offset is post-sunset.
STARTTIME	HH:mm:ss	Sets the start time used with BURST PROGRAM=2.
ENDTIME	HH:mm:ss	Sets the end time used with BURST PROGRAM=2.
WIPE INTERVAL	n (integer)	Sets wipe rest period (i.e. a value of 5 wipes every 5th burst).
SD ON		Enables SD Card logging.
SD OFF		Disables SD Card logging.
APPENDON		Appends data to uSPECLOG.TXT log file on every power restart.
APPENDOFF		Creates new log file (LOG_XXXX.TXT) on every power restart.
LS		Displays SD Card filelist.
GET XXX_XXXX.TXT		Extracts logfile data off SD Card.
DEL XXX_XXXX.TXT		Deletes logfile from SD Card.
ERASEALL		Clears SD Card.
TIMESET	Mmm dd YYYY HH:mm:ss	Updates real-time-clock based on Unix datetime (En) format. E.g. Jan 01 2020 12:00:00
LOWBATT_TH	volts	Sets the Low Battery Threshold in Volts.
VLOWBATT_TH	volts	Sets the Very Low Battery Threshold in Volts.
TARE	volts	Tares depth sensor to 0m.
SAVE		Saves config to EEPROM.