**Pop-up Project Specifications**

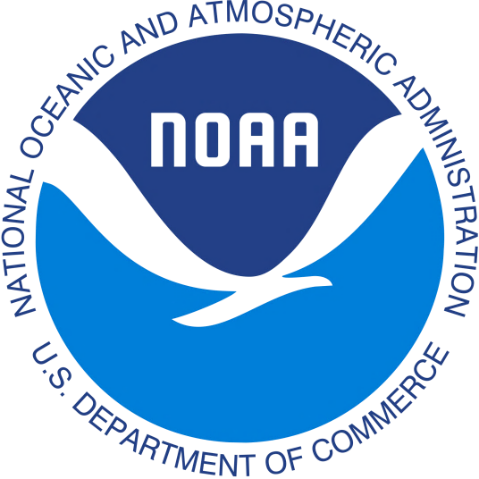
**(Low Cost Expendable Buoys for Under Ice Data Collection, Innovative Technology for Arctic Exploration (ITAE))**

**October 10, 2019**

**National Oceanic and Atmospheric Administration (NOAA)**

**Pacific Marine Environmental Lab (PMEL)**

**Ecosystem Fisheries-Oceanography Coordinated Investigations (EcoFOCI)**



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# Revision History

The table below identifies all changes that have been incorporated into this document.

| **Version** | **Draft Date** | **Summary of Changes** |
| --- | --- | --- |
| 1.0 | 10/10/2019 | Initial draft |

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# INTRODUCTION

## Purpose

This document is to identify goals for the pop-up project that cover: overall project direction, specific engineering requirements, data quality and sensor capability requirements and cost requirements.

## Scope

This document is intended for use as a developmental tool while the pop-up project is under the auspices and funding of the ITAE program [[1]](https://www.researchgate.net/publication/290392540_Innovative_technology_development_for_Arctic_Exploration). The pop-up project is a collaborative effort between EcoFOCI and the PMEL Engineering Development Division (EDD). Initial prototyping and development of the pop-up floats began under Lieutenant Daniel Langis, NOAA Corps in 2015 [[2]](https://www.researchgate.net/publication/330300648_Low-Cost_Expendable_Buoys_for_Under_Ice_Data_Collection).

# IMMEDIATE SCIENCE APPLICATIONS

## **Under Ice Production**

### Measure conditions and productivity levels under sea ice.

* + *The primary interest is in productivity at the water-ice boundary where productivity is very high in the spring before ice melt and ambient light levels are rapidly rising.*

## **Bering Cold Pool**

### Measure conditions in the Bering Sea to map the cold pool.

* + *Bottom temperatures below 2 °C characterize the Bering Sea cold pool, an important refuge for young pollock from predation. The primary interest is in measuring the extent, thickness and varying light levels of the cold pool through the winter months and how it changes over time.*

# LONG-TERM PROJECT VISION

*“Robust, inexpensive, and expendable, but sophisticated enough to acquire oceanographic-quality data.”*

The pop-up float was developed as a unique product designed to fill the gap in available technology between year-round deeper moorings and surface-based sampling in the summers. However, because of the harsh and unpredictable environment of shifting and breaking ice, actually acquiring measurements close to the ice during the winter and spring without losing instruments has been notoriously difficult. The pop-up project aims to develop a low-cost, expendable oceanographic instrument that can be easily deployed by hand from any vessel and that will reliably transmit data back via satellite.

Long-term goals for this project include:

* maintaining low-cost production and deployment (~$3,000 / pop-up)
* an environmentally friendly design with biodegradable materials (glass, cork, metals)
* up to 24 month at-sea endurance
* the ability to send commands with 2-way communication to the float (commands to resend data files, change sampling frequencies...etc.)
* a modular design that allows sensors to be added or removed easily depending on mission and budget requirements.

## Measurements of Interest

Measurements of interest vary for the two current science applications: Bering Cold Pool and Under Ice Production. The Bering Cold Pool application focuses on temperature measurements with highest interest in further development to include a dissolved oxygen sensor. The Under Ice Production application focuses on Fluorescence and PAR, with interest in improving current camera capabilities.The following bulleted lists for each science application show the core instrument package for all floats in blue and **additional sensors in order of priority**.

* + - GPS (only used during surface drifter mode)
    - Iridium SBD (only used during surface drifter mode)
    - Clock / Timer (RTC)
    - Profile (Primary) Temperature Probe (PTP)
    - Sea Surface (Secondary) Temperature (SST)
    - Pressure Sensor
    - Tilt
    - **Fluorometer**
    - **Photosynthetically active radiation (PAR) (light months only)**
    - **Camera**
    - **Oxygen [currently cost-prohibitive]**
    - **Salinity [currently cost-prohibitive]**

## Sampling Phases

The pop-up has a 5 phase sampling program: Anchored, Profile, Under Ice, Transmit and Surface Drifter. Each of these phases is run sequentially. Prior to the programmed unit start date, the pop-up is in sleep mode and is not sampling any sensors. The pop-up’s real time clock (RTC) functions as an alarm, which will wake up the unit and initiate the first sampling phase (Anchored) at the unit start date/time.

**--ANCHORED--**

This mode starts at the scheduled Start Time.

Unit will start sampling [Oct 01 2019 00:00:00] and take a sample every (1h,0m,0s)

**--PROFILE--**

This mode starts just before the scheduled Release Time.

Release Expected [Jun 01 2020 00:00:00] (<--Set Burn Wire Release for this exact time/date.)

Unit will wake up (2h,0m,0s) before scheduled release and wait for profile.

Start of profile will be triggered by a change in depth of (1 meters).

Profile will sample at 4 Hz for (0h,1m,30s) seconds before proceeding to phase 3.

If unit does not sense the release within (4h,0m,0s) of waking it will assume it missed the profile and proceed to the UNDER ICE phase.

**--UNDER ICE --**

This mode starts after profile has been collected (or missed).

Unit will take a sample every (1h,0m,0s) and take an image once a day.

Unit will search for GPS satellites for (0h,2m,0s) after every sample.

When unit acquires GPS fix, it will proceed to the TRANSMIT phase**.**

**--TRANSMIT--**

If unit does successfully find a GPS satellite, it will attempt to send all collected data back in the following order:

1-File Summary, 2-Profile Data, 3-Under Ice Data, 4-Bottom Data, 5-Daily Images

If any iridium messages send successfully, it will continue sending until one message fails and make the next attempt to send in (0h,20m,0s)

Otherwise, if no messages sent, the unit will take the next sample and attempt to send again in (1h,0m,0s)

**--SURFACE DRIFTER--**

This mode starts after all data has finished sending.

Unit will take a sample every (3h,0m,0s) and search for a GPS fix for (0h,2m,0s) after every sample.

Unit will attempt to send any new data regardless of whether a GPS fix was found

# ENGINEERING SPECIFICATIONS

## Basic Program Flow

A. Wake Up

B. Determine phase based on current date/time and programmed cutoff dates/times

0 = Initial programming (before start date)

If mode = 0, display parameters and shut down after user removes USB, don’t take any sample data

1 = Anchored

2 = Wait for Profile

3 = Under Ice

4 = Surface Drifter

C. Determine next sample time/date and set RTC alarm

D. Collect Sensor Data, Store to SD Card

E. If phase = 1 (Anchored)

Do nothing else, just go to sleep

F. If phase = 2 (Profile)

Take initial depth measurement

Continuously take depth readings and compare to initial measurement

Wait for depth to change by m meters

Start profile

Collect profile data at 4 Hz for p seconds

Go to sleep

G. If phase = 3 (Under Ice)

\*\*This mode is used primarily to preserve battery power. In this mode the unit will only attempt to search for GPS once a day, rather than every hour.\*\*

If hour = 23 UTC (1500 AKST, close to solar noon in most of Alaska)

Search for GPS for g seconds, n times, with delay in between

If GPS lock is found n times

Store GPS location and time on SD Card

Attempt to transmit iridium data

Else

Do nothing else, just go to sleep

H. If phase =4 (Surface Drifter)

Search for GPS for g seconds, n times, with delay in between

If GPS lock is found n times store GPS location and time on SD Card

Attempt to transmit iridium data

Else

Do nothing else, just go to sleep

## Mechanical Design Parameters

Trawl Housing Depth Rating: 200m, tested to max of 940psi (652m) at which point acrylic

camera housing cracked. Trawl float and delrin sensor housings withstood 940psi.

Buoyancy & GM:

The 12” trawl float provided ~28lb(?) net buoyancy. The net buoyancy should be tailored to produce the desired profile speed, while also providing adequate freeboard.

Profile speed: desired: ???? / actual: 1m/s

Freeboard: Generation 2 - 2.5” of freeboard

Generation 3 - 3.5” of freeboard

Generation 3.1 - 2.5” of freeboard

Total Dry Weight: Generation 2 - 13,305 g

Generation 3 - 11,263 g

Generation 3.1 - 13,305 g

Anchor Weight:

50lb Chain Link, 1m cable length

The anchor weight should be sufficient to keep the float from moving in high currents.

## Sensor Capability/Data Quality

Topside Temperature Probe (TTP) [Primary]\*[3-4m resolution, ±0.01°C @4Hz]

Sensor: TTI inc, USP19572 REVA

Absolute Accuracy: ±0.01°C or better

Range: -5°C to +70°C

Resolution: 0.0006°C @ -2°C

0.001°C @ 10°C

0.002°C @25°C

0.01°C @50°C

Sea Surface Temperature (SST) [Secondary]\*[3-4m resolution, ±0.01°C @4Hz]

Sensor: In-House (NTC Thermistor 50k Bead Epoxy,

Hex Head Plug 1/16”, Arctic Silver Alumina)

Absolute Accuracy: ±0.01°C or better

Range: -5°C to +70°C

Pressure Sensor \*[ 3-4m resolution, ±1m @4Hz ]

Sensors: [Keller PA-4LD OEM Pressure Transmitter](http://www.keller-druck.com/picts/pdf/engl/4ld_9ld_e.pdf)

Absolute Accuracy: ±70cm (10 bar) / ±0.7%FS

Range: 0 to 100m (10 bar) / 0 to 300m (30bar)

Resolution: 0.3cm (10 bar) /

GPS \*[Position Accuracy ~3meters 50% CEP]

Unit: [AMC-PA6H Alphamicro](http://www.alphamicrowireless.com/franchises/globaltop-technology/pa6h.aspx)

High Sensitivity: -165 dBm, TCXO Design

Position Accuracy: <3.0M 50% CEP

GPS Antenna: [Adafruit External Active 960](https://www.adafruit.com/product/960)

Iridium SBD \*[full two-way communication system, DoD Network Whitelisted]

Unit: [RockBLOCK 9603](http://www.rock7mobile.com/products-rockblock-9603)

Power Consumption: max 450 mA (100mA required)

Iridium Antenna: [Maxtena Helical 1621Mhz tuned patch antenna](https://www.maxtena.com/products/f-passive/m1621hct-ext/)

Clock

Unit: DS3234: RTC with Temperature Compensated Crystal Oscillator

Maximum Error: 1.05 minutes/year (0°C to 40°C)

1.84 minutes/year (-40°C to 85°C)

PAR \*[±3%-5% @4Hz]

Sensor: [Skye Instruments TAG-PARQ (Quantum)](https://www.skyeinstruments.com/applications/commercial-horticulture/light-sensors-systems-commercial-horticulture/par-quantum-sensors/)

Absolute Accuracy: ±3%-5% or better

Range: 0 to 1000 μmol/m2s

Sensitivity-current(I): 2μA/100μmol/m2s

Sensitivity-voltage(V): 1mV/100μmol/m2s

Response Time: 10ns

Tilt \*[±2.0° @4Hz]

Sensor: [ADXL345 3-Axis Digital Accelerometer](http://www.analog.com/media/en/technical-documentation/data-sheets/ADXL345.pdf)

Absolute Accuracy: Depends on Mounting/Calibration

Sensor is accurate for changes as little as 1.0°

Camera

Unit: [μCAM-III](https://www.4dsystems.com.au/product/uCAM_III/)

Resolution: (80X60 / 160X120 / 160X128 / 640X480)

Output: Raw or JPEG

Lens Angle: 116 degrees

Fluorometer\*[sample frequency @4Hz]

Sensor: [Turner Designs Cyclops-7F](http://docs.turnerdesigns.com/t2/doc/brochures/S-0209.pdf)

Linear Range: 0-500μg/L

Minimum Detection: 0.03μg/L

Depth Range: 600m

Power Requirement: 240mW @ 12V

\*\*[Oxygen](https://www.mouser.com/SST-Sensing/Sensors/Environmental-Sensors/_/N-axfl1?P=1y8dmrj)\*[±0.1% O2 saturation]

Sensor:

Oxygen range 0—25% O2

Oxygen pressure range 0—300mbar ppO2

Response time T90 < 10s (typical)

Accuracy

ppO2 < 2% FS

Temperature Indication only

Pressure ±5mbar

O2 Determined by ppO2 &

pressure accuracy

Resolution

ppO2 0.1mbar

Temperature 0.1°C

Pressure 1mbar

O2 0.01%

Lifetime > 5 years

\*\*Salinity\*[±0.1psu]

Sensor: [Starr DST CTD](https://www.star-oddi.com/products/data-loggers/salinity-logger-probe-CTD)

\*minimum requirement

\*\*Currently cost or design prohibitive

## Battery Life/Data Quantity

Total Systems Battery Life: 24 month at-sea endurance

Primary Battery: 9V, 42Ah Alkaline Battery Pack (18 Standard D Cells)

RTC Battery: 3V 12.5mm Lithium Coin Cell (Energizer CR1220=40mAh)

GPS Backup Battery: 3V 12.5mm Lithium Coin Cell (Energizer CR1220=40mAh)

Burnwire Release Battery: 18V, 56Ah Alkaline Battery Pack (2 Standard 9V batteries)

Release Board Battery: 4.5V, 7.7Ah Alkaline Battery Pack (3 standard C Cells)

Data Storage: microSD or microSDHC card: 1GB to 32GB (FAT16 or FAT32)

Sample Limit: Limited by battery power and sample intervals

# APPENDIX A: ACRONYMS AND ABBREVIATIONS

NOAA National Oceanic & Atmospheric Administration

PMEL Pacific Marine Environmental Lab

EcoFOCI Ecosystem Fisheries-Oceanography Coordinated Investigations

EDD Engineering Development Division

ITAE Innovative Technology for Arctic Exploration

# APPENDIX B: CITATIONS

[[1]](https://www.researchgate.net/publication/290392540_Innovative_technology_development_for_Arctic_Exploration) Cross, Jessica, C.W. Mordy, Heather Tabisola, Christian Meinig, E.D. Cokelet, and P.J.

Stabeno.“Innovative Technology Development for Arctic Exploration,” Vol. In publication,

2015.<https://doi.org/10.23919/OCEANS.2015.7404632>.

[[2]](https://www.researchgate.net/publication/330300648_Low-Cost_Expendable_Buoys_for_Under_Ice_Data_Collection) Langis, D., P. Stabeno, Christian Meinig, C. Mordy, Shaun Bell, and Heather Tabisola. *Low-Cost Expendable Buoys for Under Ice Data Collection*, 2018.<https://doi.org/10.1109/OCEANS.2018.8604752>.