SCOOP – NDBC's New Ocean Observing System

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Abstract- **The National Data Buoy Center (NDBC) is a world leader in providing high quality ocean observations. The first coastal weather buoy systems, developed over four decades ago, were enormous (10 and 12-meter discus type) due to large power systems and electronics racks. NDBC's data collection payloads have historically provided the standard measurements of wind speed and direction, barometric pressure, air temperature, relative humidity, sea surface temperature and directional waves. Data has typically been collected and reported using a centralized, single processor architecture and transmitted via the National Oceanic and Atmospheric Administration's (NOAA) Geostationary Orbiting Environmental Satellite (GOES) on an hourly basis using a non-standard message format. In more recent years, electronics and power systems have reduced in size allowing the use of smaller hulls (3-meter discus) and moorings. However, even these smaller observing systems remain complex, labor intensive, prone to human error, with require disassembly prior to shipment and service and support from vessels with large cranes for deployment and service required.**

The NDBC is currently developing a next generation system named the Self-Contained Ocean Observing Payload (SCOOP). SCOOP takes advantage of the latest in technology utilizing a modular approach that can be constructed, assembled and installed on a variety of moored and fixed platforms, including a new smaller moored buoy easily deployed and serviced by a less costly vessel. SCOOP is expected to provide the same high quality data but be significantly smaller, less expensive to produce and maintain, and more reliable. In addition, the system will provide ocean temperature profiles and camera images.

This paper describes the design of SCOOP, a design based on a distributed multi-processor architecture utilizing NDBC's Smart Module (SM) technology. Data messages are formatted using Extensible Markup Language (XML), an accepted industry standard, with processed data messages transmitted exclusively via Iridium allowing for more frequent transmissions; thus, decreasing the data latency, as well as the transmission retry capability. SCOOP modularity allows for additional auxiliary devices in the architecture for new or third-party sensors to be integrated easily into the system. This will provide additional expansion of ocean observation capability. The power system consists of a small lightweight Lithium-Ion Smart Battery/Charging system that allows for easier replacement, health monitoring, and remote power management. The overall system is lightweight and self-contained making it easier to replace in the field and eliminating the need for piecemeal repair. Buoy cameras (BuoyCAM) and Automatic Identification Systems (AIS) have been integrated into the design of SCOOP. The BuoyCAM not only provides critical situational awareness data for counter-vandalism, but may also lead to additional observational capability, such as fog, cloud cover, surface currents and sea state.

The presentation will also present performance data obtained during three prototype deployments in the Gulf of Mexico. The performance data will be used to determine if additional design modifications are necessary prior to designating it as an operational system. A total of twenty systems have been built, tested and are now being selectively deployed in NDBC's weather buoy program.

The 3-meter buoy has been NDBC's weather observing workhorse for the past three decades. During this period, technology improvements have been incremental. SCOOP is a revolutionary improvement in ocean observations and will dramatically affect all future areas of NDBC: production, testing, logistics, operations and shore-side processing of the data.

Keywords—Observations, Observing System, NDBC

I. SYSTEM DESCRIPTION

The vision for the system design included modules technicians would seal and test at the NDBC and would preclude reopening in the field. The intention was to have smaller, lighter, and more reliable observing systems that could be deployed by smaller vessels; thus, saving operations and maintenance costs. SCOOP could also be installed on a variety of existing NDBC platforms until a SCOOP-specific hull was designed, tested, and built.

The design requirements called for at least the same content and quality of observations that NDBC has provided throughout its history with only one deviation, i.e. a decrease in sensor height, acceptable. NDBC engineers, working through the requirements, have successfully developed a design that incorporated the latest in sensors and electronics.

The main building block for the design was NDBC's Smart Module (SM). It is a low power device that is easily programmed for different applications. Originally developed by the NDBC to convert analog sensors into smart digital sensors, the SM uses an MSP430 processor (very low power), a Salvo Real Time Operating System (RTOS), and has XBee (IEEE 802.15.4 standard) wireless communications.

II. MODULE DESCRIPTIONS

SCOOP is a complete ocean observation system with an Automatic Identification System (AIS) and imaging capabilities to support situational awareness for NDBC operations. SCOOP consists of three (3) modules:

- The CAMERA-METEROLOGICAL (CAM-MET) module for surface observations.
- THE POWER (PWR) module.
- The WAVE-OCEAN module for sub-surface observations.

Future plans include the potential for the addition of an auxiliary module, a fourth module, for interfacing third-party sensors or systems. Each sensor module, powered by the POWER module, communicates wirelessly with each other or to a user interface and, together, these three or four modules form a SCOOP payload. A SCOOP installed on a 2.4-meter foam hull is shown in Fig. 1.

All SCOOP buoy stations include the CAM-MET, POWER, and WAVE-OCEAN modules with a temperature sensor mounted in the bridle that is cabled to the WAVE-OCEAN module. Some stations are configured with either an Inductive Modem (IM) line with attached inductive sensors or a Thermistor array, which is attached to the same type of plastic-coated wire rope used in the IM system. A summary of SCOOP's measurements, or observations, is provided in Table I.

A. CAM-MET Module

The CAM-MET module includes an all-in-one meteorological sensor (wind speed and direction, air pressure and temperature, and relative humidity), anemometer, and an extended range barometer. Fig. 2 shows a CAM-MET tube. The all-in-one sensors were designed for terrestrial use and are under evaluation to determine how they perform in marine applications. In addition, these sensors do not have an integrated compass for wind direction. Therefore, the NDBC installed a separate compass in the module that must be orientated correctly in order to obtain accurate wind direction.

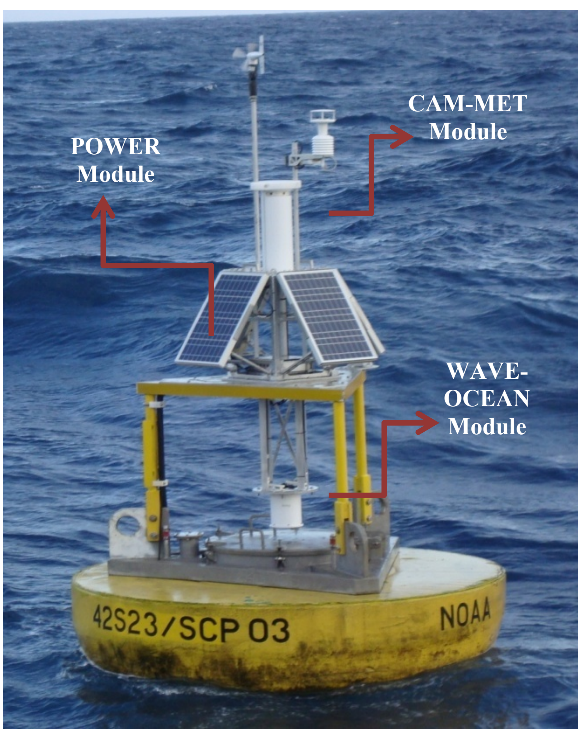

Fig. 1. SCOOP Mounted on a 2.4-meter Foam Hull

TABLE I. SUMMARY OF SCOOP MEASUREMENTS

Tube	Module	Measurement
CAM-MET	MET	Vaisala WXT-520 or Gill MetPak: Wind speed, Wind Direction, Compass (inside tube) Barometric Pressure, Air Temperature, Humidity
	X-MET	R.M. Young: Wind Speed, Wind Direction, Compass (inside tube) Barometric pressure (inside tube)
	AIS	*AIS Receiver*: AIS ship data
	CAM	***BuoyCAM*** - 360° 6 cameras 9622B Iridium RUDICS modem + antenna
	HUB	9602 Iridium SBD modem + antenna Wireless User Interface Radio
PWR	POWER	Power Health data Four (4) solar panels Lithium battery pack with smart controller
WAVE-OCEAN	WAVE	DDWM: Directional waves
	OCEAN	SST. NOTE: Serial Seabird sensor can be T or CT. Sub surface profile: IMM system - 9 positions of either T, TP, CT or CTD or Thermistor array

The cameras, AIS receiver, extended barometer, electronics and antennas are housed within an acrylic tube that has o-ring seals on both end caps. The tube and connectors located on the bottom end cap are watertight. A chassis facilitates mounting of the internal equipment and is fixed to the bottom end cap as well. A reflective film is applied to the tube to reduce thermal heating from the sun.

The CAM-MET module has a Smart Module (SM) that acts as the system hub. It communicates wirelessly with the eight other SCOOP Smart Modules to collect their data and then transfers this data to the Iridium modem. Communication with the HUB or any individual SM is also possible via a wireless technician interface.

Fig. 2. CAM-MET Module

B. *POWER Module*

The POWER module, shown in Fig. 3, includes four solar panels, a smart battery pack, and a frame. The battery pack was custom designed to NDBC specifications and includes a Lithium-Ion battery, a controller, and an NDBC SM circuit board for reporting battery system health information. The CAM-MET module attaches to the top section of the POWER module's aluminum frame, which consists of four foldable, solar panel mounts and lifting handles to facilitate handling.

C. *WAVE-OCEAN Module*

The Wave-Ocean module includes a short tube section, standard NDBC wave measurement and processing electronics, and ocean temperature and conductivity measurement and processing electronics. An extension mount, shown in Fig. 4, may be necessary for some existing NDBC hulls in order to place the wave measurement sensor NDBC hulls in

Fig. 3. POWER Module

order to place the wave measurement sensor as close as possible to the buoy hull's center of buoyancy. The module has connectors for power, a sea surface temperature sensor, and optional ocean temperature profile sensors via an inductive modem or a Thermistor string.

Fig. 4. WAVE-OCEAN Module

III. SCOOP ENHANCEMENTS

Table II presents the enhanced SCOOP observing system features as compared to legacy NDBC weather buoy systems.

TABLE II. SCOOP OBSERVING SYSTEM ENHANCEMENTS

Feature	***SCOOP***	***Legacy***
Meteorological Data Latency	*Every 10 minutes*	*Hourly*
Data Transmission Failure	*Multiple Retries*	*Only one try possible*
Message Format	*XML – human readable*	*Complex and prone to error*
Wind Speed Range	*0 to 100 m/s*	*0 to 60 m/s*
Sea Surface Temperature	*Direct measurement*	*Through hull (less accurate)*
Ocean Temperature Profile	*Up to 9 measurements*	*None*
Weight	*200 lbs. total system*	*800 lbs. of batteries*
Wireless Communications	*Fully wireless*	*Cables required*
Production Labor	*320 hours*	*600 hours*
Field Serving	*Modules easily replaced*	*Difficult and risky*
New Sensor Integration	*Simple*	*Major firmware modifications*

IV. SCOOP LIFE CYCLE

The chart shown in Fig. 5 depicts the SCOOP payload's lifecycle process.

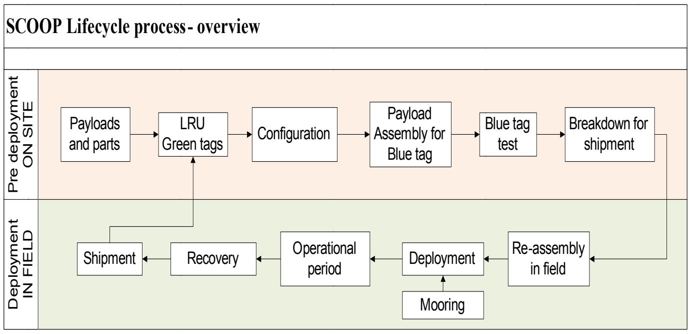

Fig. 5. Overview of the SCOOP Lifecycle Process

V. SCOOP PROTOTYPES

Six SCOOP systems were built and tested with three of those deployed in the Gulf of Mexico late in the fall of 2014. Fig. 6 shows the deployment locations. Two were placed in close proximity to NDBC operational buoy 42003 in order to evaluate their performance and to, in particular, evaluate differences between the IM and Thermistor strings. Unfortunately, the WAVE-OCEAN module and Thermistor line were damaged during deployment and no data were collected thereafter. The other prototype SCOOP was deployed close to NDBC operational buoy 42039. This last deployment was performed primarily to discover how quickly a SCOOP could be installed on a legacy, 3-meter buoy.

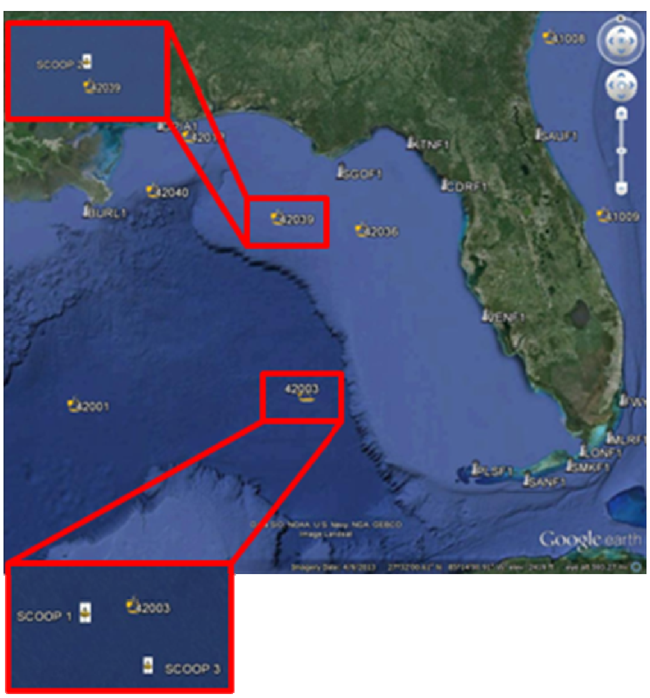

Fig. 6. SCOOP Prototype Deployment Locations

VI. SCOOP PERFORMANCE

Data availability is the best indicator of the overall performance of the observing system. It measures the total possible expected measurements against the actual number of measurements received shore side in real-time. The three SCOOP prototype payloads averaged 98% for the first three months that were evaluated. This is an exceptional performance.

Shown in Table III is a comparison of the Mean Difference and the Root Mean Squared (RMS) between the SCOOP all-in-one meteorological sensor measurements and the standard meteorological instruments on a 3-meter operational buoy in close proximity.

Table IV is a similar comparison between the SCOOP extended meteorological measurements and the standard instruments on a 3-meter buoy in close proximity.

Table V is a comparison between the SCOOP wave measurements and the standard wave measurements from a 3-meter buoy in close proximity.

TABLE III. SCOOP ALL-IN ONE METEOROLOGICAL SENSOR MEASUREMENTS COMPARISON

	SCOOP 1		**SCOOP 2**		**SCOOP 3**	
	Mean Diff	RMS	Mean Diff	RMS	Mean Diff	RMS
Air Temperature (°C)	0.17	0.24	0.19	0.23	0.20	0.26
Relative Humidity (%)	1.95	2.48	1.20	1.73	1.85	2.31
Dew Point Temp (°C)	0.50	0.62	0.29	0.41	0.50	0.61
Barometer (hPa)	0.21	0.25	0.13	0.17	0.26	0.32
Wind Direction (deg)	16.68	21.34	8.51	14.12	9.27	15.46
Wind Speed (m/s)	0.47	0.68	0.46	0.63	0.48	0.68
Wind Gust (m/s)	0.67	0.96	0.72	0.95	0.71	0.96

TABLE IV. SCOOP EXTENDED METEOROLOGICAL SENSOR MEASUREMENTS COMPARISON

	SCOOP 1		**SCOOP 2**		**SCOOP 3**	
	Mean Diff	RMS	Mean Diff	RMS	Mean Diff	RMS
Barometer (hPa)	0.18	0.23	0.15	0.18	0.29	0.32
Wind Direction (deg)	7.98	15.95	7.67	13.50	8.66	15.05
Wind Speed (m/s)	0.49	0.69	0.36	0.54	0.45	0.66
Wind Gust (m/s)	0.63	0.91	0.54	0.78	0.59	0.83

TABLE V. SCOOP WAVES MEASUREMENT COMPARISON

	SCOOP 1		SCOOP 2	
	Mean Diff	RMS	Mean Diff	RMS
Significant Wave Height (m)	<0.01	0.12	<0.01	0.10
Dominant Period (s)	<0.01	0.70	0.03	0.72
Average Period (s)	0.04	0.20	0.00	0.14
Mean Wave Direction (deg)	3.2	24.3	2.8	26.2

The image shown in Fig. 7 is a typical, hourly image provided by the SCOOP payload. Additional higher resolution images may be obtained by remotely dialing into the SCOOP Iridium modem.

Fig. 7. Typical SCOOP Camera Image

VII. CONCLUSIONS

As a prototype ocean observing system, SCOOP has performed extremely well. The meteorological measurements meet NDBC accuracy requirements and SCOOP provides additional measurement capabilities and situational awareness that was not possible before. The design of the system is expected to be more reliable and reduce costs. The SCOOP has a bright future for NDBC ocean observations and been deployed at several operational stations replacing older legacy equipment. The NDBC's weather buoy, hurricane, and Coastal-Marine Automated Network arrays will be tech refreshed with SCOOPs during the next phase of the project and with expected completion by 2020.