

Vertical Profiling Systems for Oceanic Observations

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Abstract -- With thousands of surface drifting buoys and deep-ocean profilers successfully deployed in recent years, the Global Ocean Observing System (GOOS) has become a reality. Over 1,000 drifters are now deployed and approximately 3,000 deep diving profilers will be deployed in the next few years. Since, these sensor systems provide very coarse time-series data (w/limited number of parameters) the next major thrust for the GOOS program is to collect data at much higher sampling rates. Two major efforts are underway in the oceanographic community to meet these requirements for more comprehensive and higher-rate, time-series data. One system uses bottom deployed "ocean observatories" linked to shore by fiber optic networks; the second uses integrated instrumentation packages that are autonomously powered, conducting vertical profiles many times daily, and regularly telemeter data during long-term deployments (one year or more).

InterOcean is developing a Vertical Profiling System (VPS) that satisfies GOOS program objectives and performance requirements. Two basic configurations are an Integral VPS, which interfaces with bottom-networked systems, and an Autonomous VPS (a self-contained system). Three major VPS components are: a bottom-mounted underwater winch; instrumentation for collecting data during profiling sessions (a twenty-minute profile every three hours); and a buoyancy package that raises the instrumentation package toward the surface. The major difference between the two systems is that the autonomous system surfaces to transmit data via satellite (Iridium, Argos, etc) and the other sends the data to the user via the bottom-mounted cable network. Centralized sensor, data, and system/telemetry control is handled using new S4VP-3 technology, which also performs all on-board data processing. Measured/profiled parameters include CTD, currents, directional wave, and expansion capabilities for eleven additional sensors; this greatly increases present profiling capabilities.

Overview

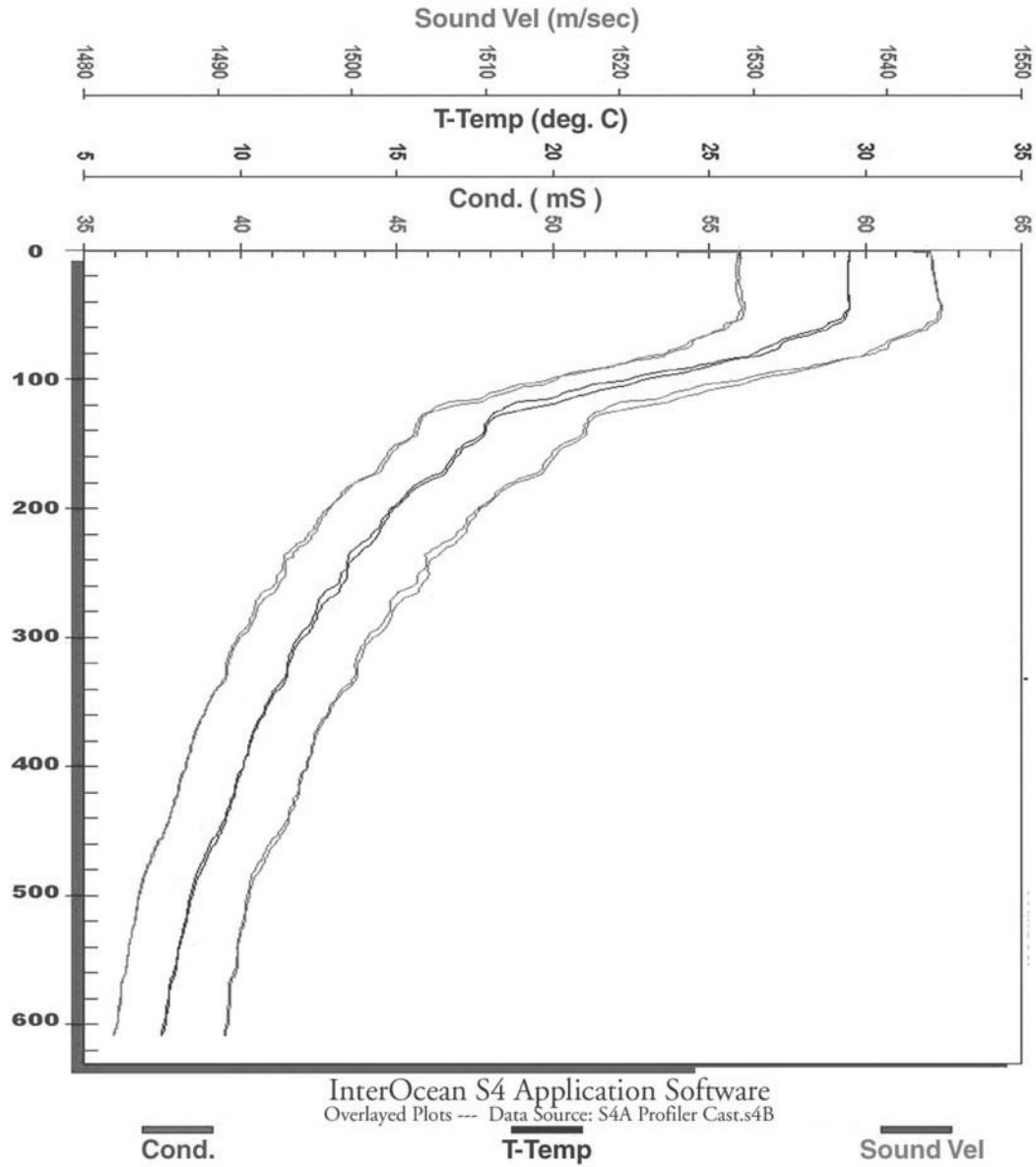
InterOcean development goal for VPS was to design a system that provided a cost-effective solution for real time water column data acquisition and processing

- *System attributes*
 - Unattended multi-parameter (physical, biological and optical) profiling with near real time data access
 - Stand alone autonomous system with enough power for one year operation
 - Fully integrated turnkey system with Internet capability
 - Long term time-series data without buoys, floats or survey ships
 - Greatly reduced sensor bio-fouling by remaining below the euphotic zone during idle periods
 - Compatibility with ocean observatory data telemetry and power
 - Modular design permits easy adaptation to each client's unique system requirements
- *Applications*
 - Coastal, deep ocean and under-ice polar regions
 - Ideal for monitoring areas where vandalism is a problem

InterOcean has designed and manufactured oceanographic sensor systems and marine handling equipment for more than 55 years

- *S4ADW is the ideal sensor platform to base VPS data acquisition and processing design*
 - Rugged design with high system reliability
 - Provides core measurement sensors, plus option to host 11 additional user-selected sensors
- *Extensive experience with winches for oceanographic applications and underwater operation*
- *Design and development of innovative and unique oceanographic data collection systems to meet client requirements*

S4 Profiling Results



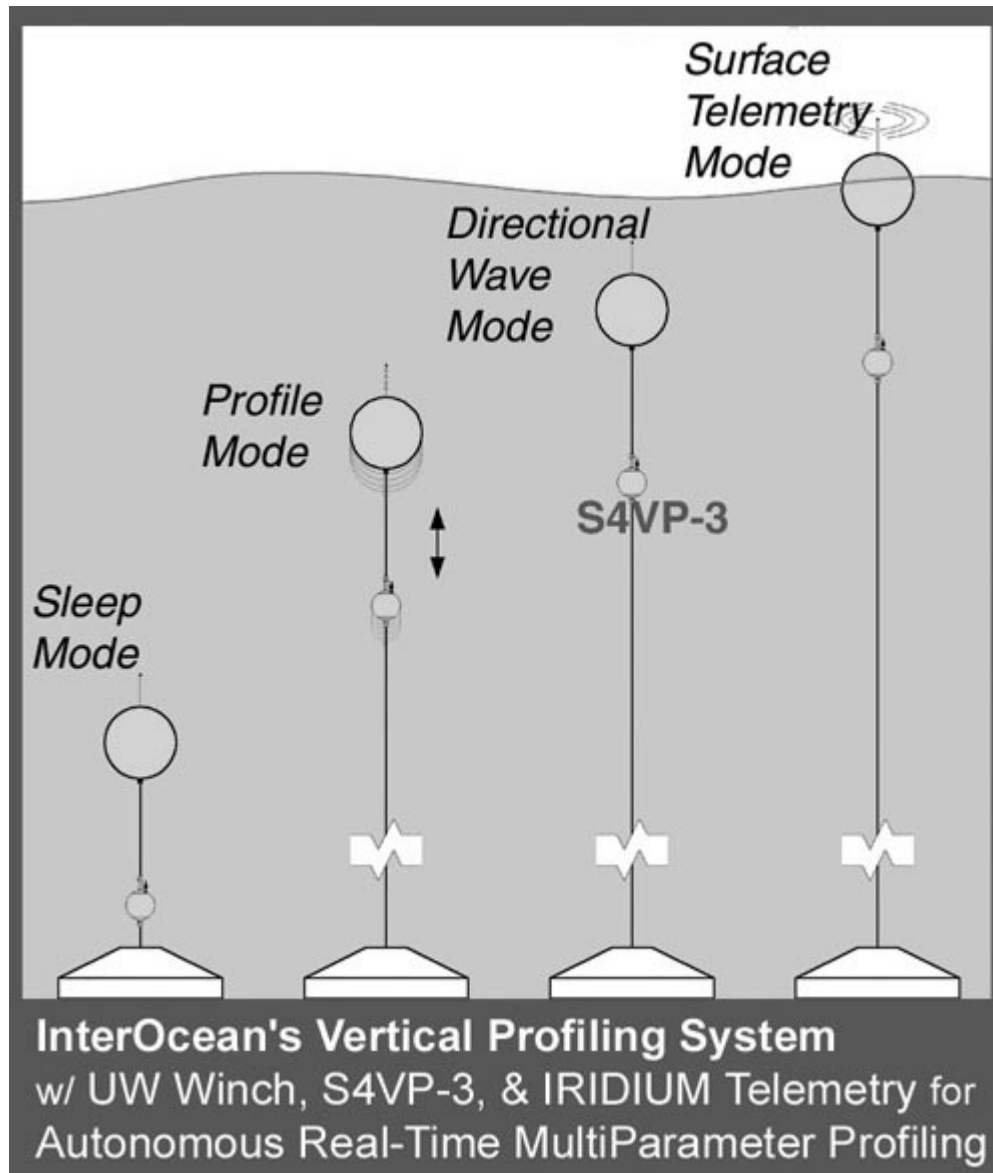
Performance Requirements

- *One-year operational life for autonomous system*
 - 8 profiles every 24 hours from 200 meters depth
 - 10 m/min profiling speed
 - Lifetime can be extended with additional battery packs or regenerative power source
 - In very shallow water applications, regular cleaning by divers will be required.
- *Design life of 5 years for systems with external power from observatory network*
 - System must be located below the euphotic zone
- *11 additional sensor ports available plus core sensors*
 - Core sensors -- CTD, current speed and direction and directional waves
 - 8 digital and 3 analog inputs
- *Internal memory for 1-year data set*
 - 512 Mbyte flash card (larger memory is optional)
 - All processed data stored
- *Data telemetry via satellite or observatory network*
 - Iridium or Argos
 - Interface to Internet protocols
 - All data reported in calibrated, engineering units
- *Environmental conditions*
 - 1 m average wave height for satellite telemetry
 - Max current of 1 m/s (or site dependent)
 - Operating depth of 200 m (or site dependent)
 - Custom design for higher currents or deeper depths

System Components

- *Subsea platform with underwater profiling winch*
 - Underwater profiling winch — 48 VDC, 500 watt, brushless DC motor
 - Stainless steel construction with level wind
 - Winch controller for *Autonomous AVPS* and system controller for *Integrated IVPS*
 - Designed for site conditions (typically 1 m/s currents)
 - EOM (electro-optical-mechanical) cable with breaking strength of approximately 2,000 lb (3/8 in)
 - Bottom deployed in coastal waters and on top of a subsurface platform in the deep ocean
 - Space available for other bottom mounted sensors such as cameras
- *Data acquisition system*
 - S4VP-3 Instrumentation package (3rd generation S4P)
 - Core sensors mounted on S4VP-3 and up to 11 customer-selected sensors mounted on cage just above S4VP-3
 - Data acquisition (2 or 5 Hz sampling), and real time signal and data processing
 - Adaptive sampling
 - Store processed data onboard (up to 30 days) until buoyancy package can rise to surface for satellite telemetry (in AVPS configuration)
 - Onboard data storage (512 MB at a minimum)
- *Buoyancy package*
 - Buoyancy force for raising sensor system from bottom towards the surface
 - Iridium or Argos satellite transmitters with antennae molded into buoyancy housing.
 - GPS receiver with antenna molded into buoyancy housing
 - S4VP-3 power supply for AVPS units
 - Telemetry controller for AVPS units
 - Under ice sonar system for polar applications

(Autonomous) VPS Operating Modes



VPS System Controller Functions

AVPS Controller

- *Primary controller on subsurface data buoy*
 - Overall system controller
 - Collects and stores all data acquired
 - Manages all data communications to shore via modem
 - Accepts and implements commands received via modem
 - Manages and collects data from sub-surface instrumentation
- *Secondary controller on subsea platform*
 - Controls winch
 - Manages system power use
 - Collects data from subsea sensors
 - Monitors power system status

IVPS Controller

- *Located on subsea platform*
 - Controls the entire IVPS system (overall system controller)
 - Controls winch
 - Manages system power use
 - Monitors power system status
 - Collects data from subsea sensors
 - Manages all data communications to shore station
 - Accepts and implements commands received from the shore station
 - Manages and collects data from the sub-surface instrumentation

VPS Sensor Configuration

Parameters	Range	Remarks
Core Sensors		
Depth	0 to 200 m	20 depths for each profile
Conductivity	5 to 70 mS	20 depths for each profile
Temperature	-4 to 45° C	20 depths for each profile
Current speed	0 to 100 cm/s	20 depths for each profile
Current direction	0 to 360 degrees	20 depths for each profile
Significant Wave Height	0 to 25 m	Estimated at 20 meters depth
Maximum Wave Height	0 to 25 m	Estimated at 20 meters depth
Height of Highest 10%	0 to 25 m	Estimated at 20 meters depth
Average Wave Height	0 to 25 m	Estimated at 20 meters depth
σ of Surface Elevation	0 to 10 m	Estimated at 20 meters depth
Peak Period	3 to 25 sec	Estimated at 20 meters depth
Significant Wave Period	3 to 25 sec	Estimated at 20 meters depth
Average Wave Period	3 to 25 sec	Estimated at 20 meters depth
Zero Crossing Period	3 to 25 sec	Estimated at 20 meters depth
Period of Max Wave Height	3 to 25 sec	Estimated at 20 meters depth
Crest Wave Period	3 to 25 sec	Estimated at 20 meters depth
Mean Direction of Max Energy	0 to 360 deg	Estimated at 20 meters depth
Spectral Band Width	0 to 1	Estimated at 20 meters depth
Spectral Density (0.033 to 0.33 Hz)	0 to 8 m ² /Hz	11 bins for Argos / 256 bins for Iridium
Wave Direction (0.033 to 0.33 Hz)	0 to 360 deg	11 bins for Argos / 256 bins for Iridium
Wave Spectral Density (2 to 30 sec)	0 to 8 m ² /Hz	15 wave period bands
Battery voltage at S4VP-3	5 to 15 V	End of profiling period
Battery voltage at S4VP-3 CPU	5 to 15 V	End of profiling period
Battery voltage at winch	15 to 30 V	End of profiling period
GPS Latitude	-90 to + 90 deg	End of profiling period
GPS Longitude	-180 to +180 deg	End of profiling period
Optional sensors		
Optical Back Scatter	.02 to 100 NTU	20 depths for each profile
Dissolved Oxygen	0 to 20 ppm	20 depths for each profile
Redox	-400 to +400 mV	20 depths for each profile
pH	0 to 14	20 depths for each profile
PAR	0 to 200 umoles/s/m ² /hr	20 depths for each profile
Chlorophyll-a Fluorometer	0.01 to 100 ug/l	20 depths for each profile
Downwelling Irradiance	0 to 200 uwatts/cm ² /nm	20 depths for each profile
Upwelling irradiance	0 to 200 uwatts/cm ² /nm	20 depths for each profile
UV-B	0-200 millijoules/cm ² hr	20 depths for each profile

VPS Applications

Environmental monitoring

- *Inlets and fjords*
 - Shallow water and requires regular cleaning by divers
 - Can either be autonomous or interfaced into an observatory
 - Example is the Bonne Bay, Newfoundland observatory
- *Coastal monitoring (on continental shelf)*
 - Monitoring to a depth of about 200 meters
 - Satellite telemetry for near real time reporting if not with a network
 - Can either be autonomous or interfaced into an observatory
 - Many examples including the VENUS and NEPTUNE projects

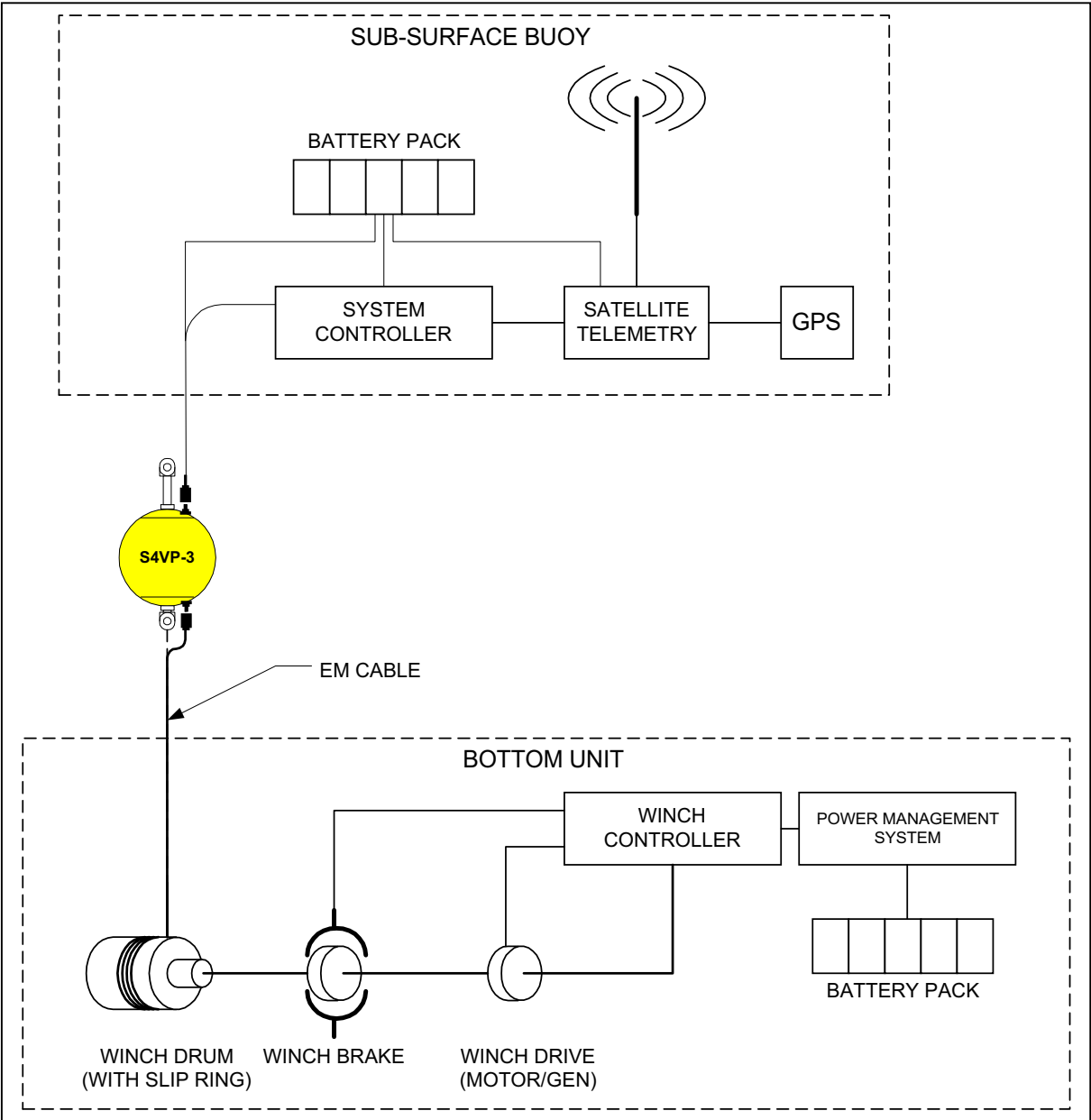
Open-ocean monitoring

- *Integrates into a cabled ocean observatory*
 - Mounted on a subsurface platform about 200 m below ocean surface
 - Profiles from subsurface platform depth to the surface
 - Data telemetry via bottom-mounted cable
 - Power from bottom cable
 - Example is the NEPTUNE project in deep water

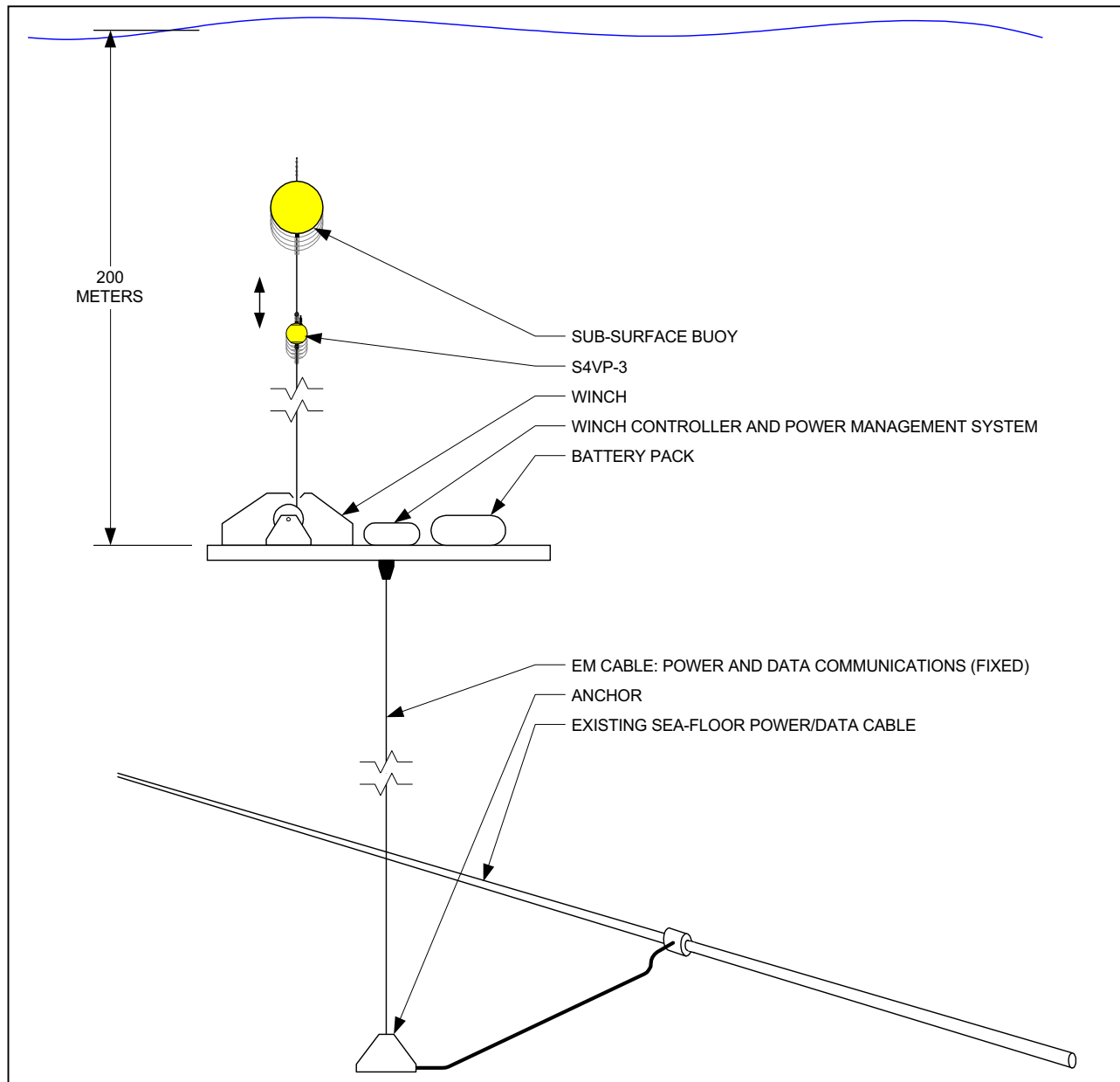
Polar region monitoring

- *Turnkey system for McMurdo Bay – NSF project*
 - Power from shore
 - Internet control for data telemetry and cameras

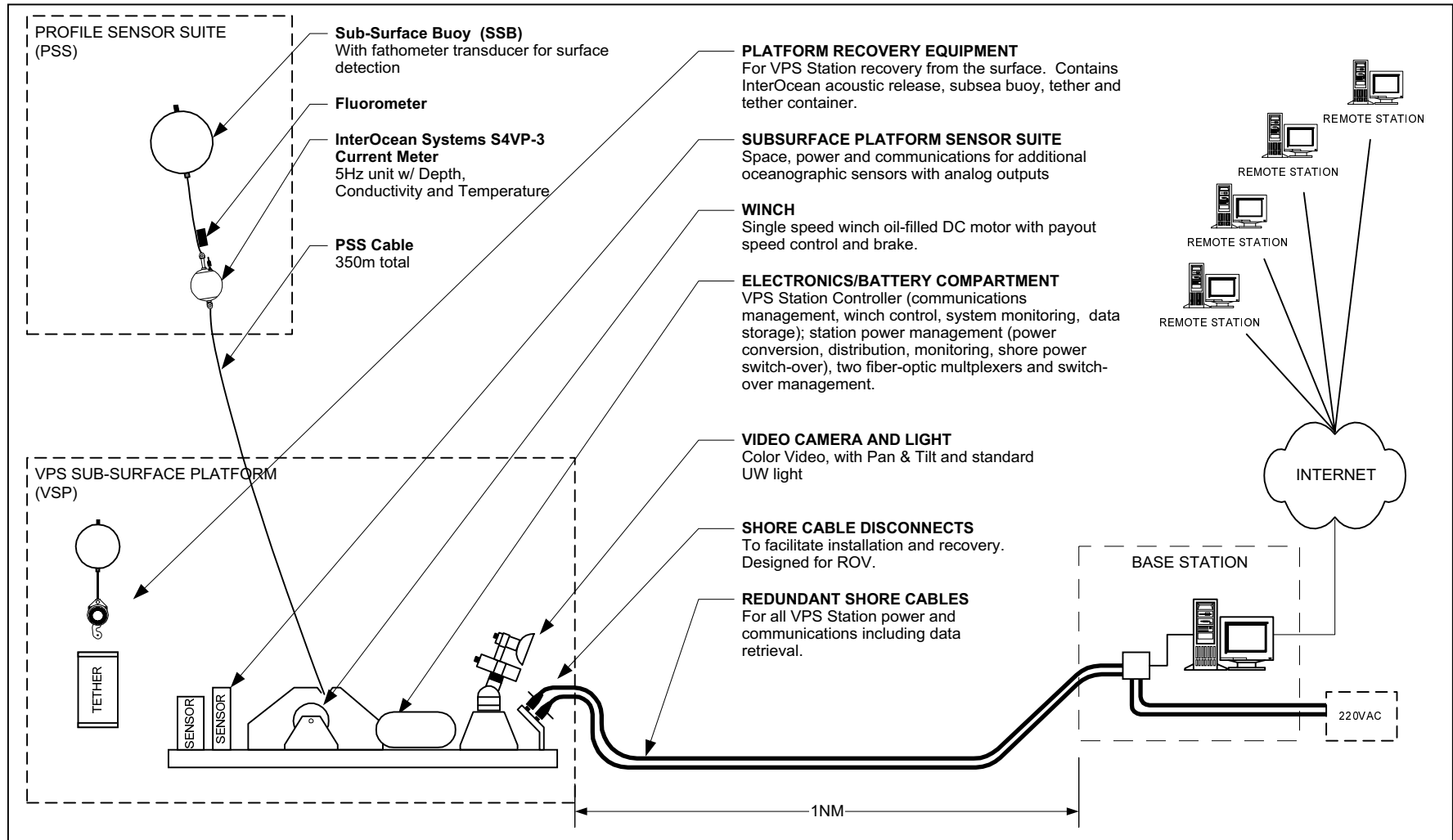
Autonomous Vertical Profiling System (AVPS) Block Diagram



Integral Vertical Profiling System (IVPS) System Diagram



Standalone Turnkey System (NSF/MRI Proposal)



VPS Developmental Efforts Accomplished to Date

S4VP-3 instrumentation package

- *S4ADWI*
 - All IOS developed proprietary SW (Waves for Windows) embedded into firmware and processed internally
 - Several tests conducted off the SIO pier – see tests results
- *S4ADWA – Development of a “virtual stationary S4 instrument”*
 - S4VP-3 will not be mounted on the bottom or on a rigid platform, therefore effects of sensor motion must be removed before wave and current estimates can be made
 - 3-axis accelerometer added to S4ADW and first experiment successfully conducted off the coast of San Diego in shallow water
 - 2nd experiment will have a 2-axis inclinometer with sign (S4 current meter does not need sign for current measurements) for correcting acceleration readings due to tilt. Experiment to be conducted in June 03 time period with a ground truth sensor
 - Future experiments will go into deeper water – about 100 meters

Underwater winch

- *Cable handling system for 1,000 ft designed and fabricated at InterOcean, and now in FAT testing*
- *New contract for two VPS winches designed to operate at 25 meters – delivery in July 03*

Buoyancy package

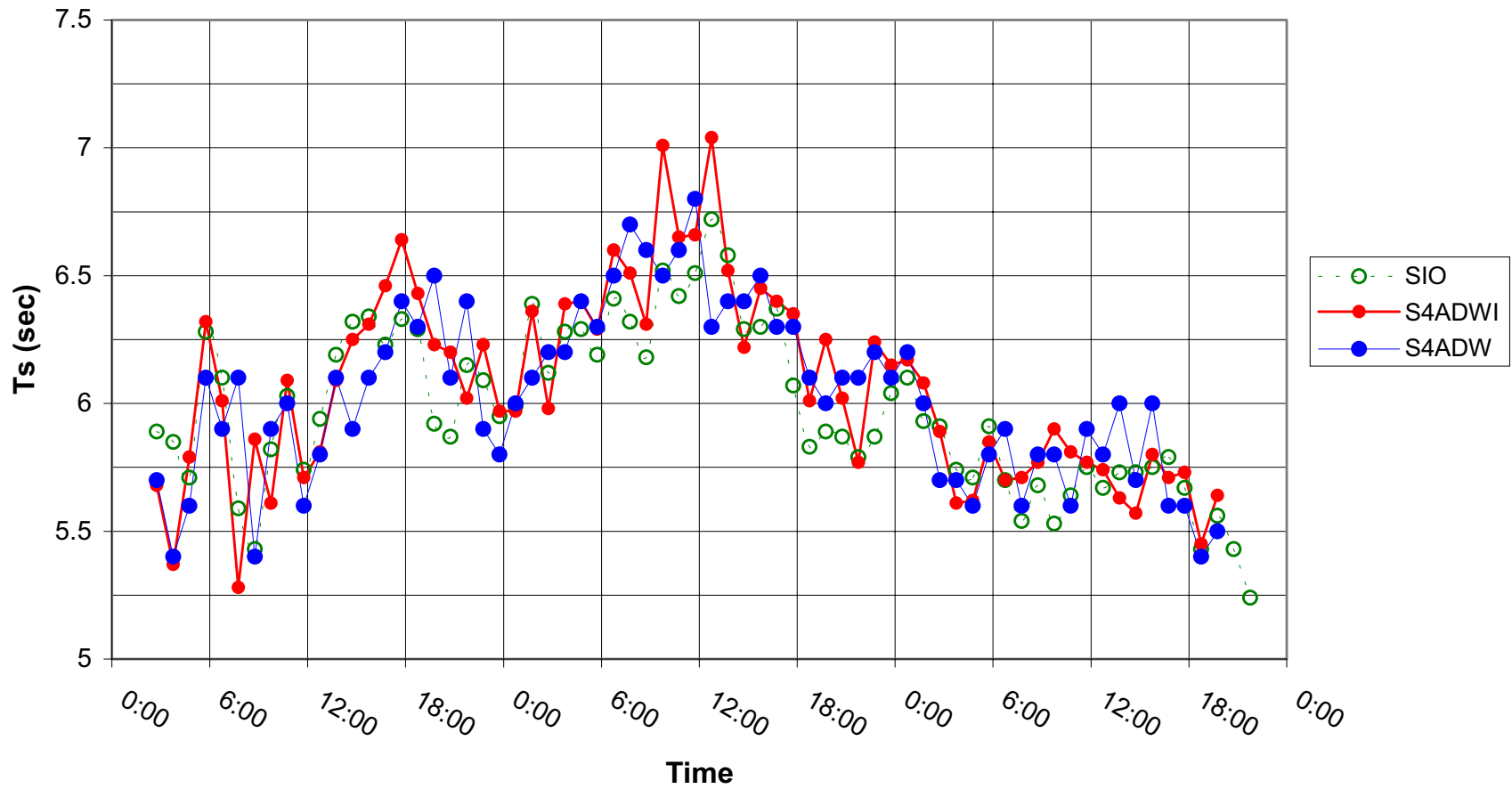
- *S4ADW with Iridium Telemetry – see tests results*

System integration and testing

- *First tests to be conducted near La Jolla canyon west of the SIO pier*

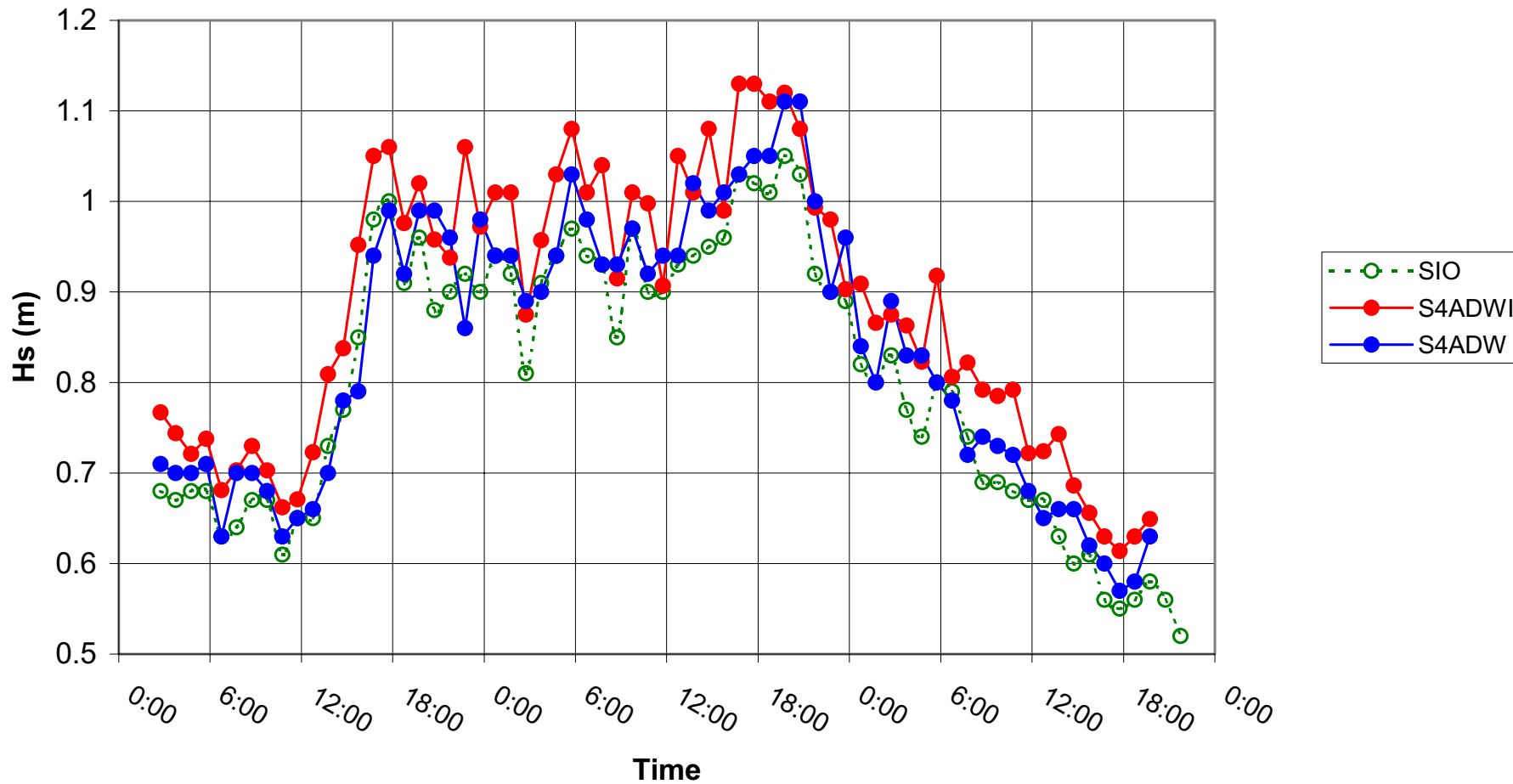
S4VP-3 Testing at SIO Pier

Comparison of Average Period Measurements Between S4 Internally Processed Wave Data and Two Standard Sensors
(SIO pier -- 26-28 April 2003)

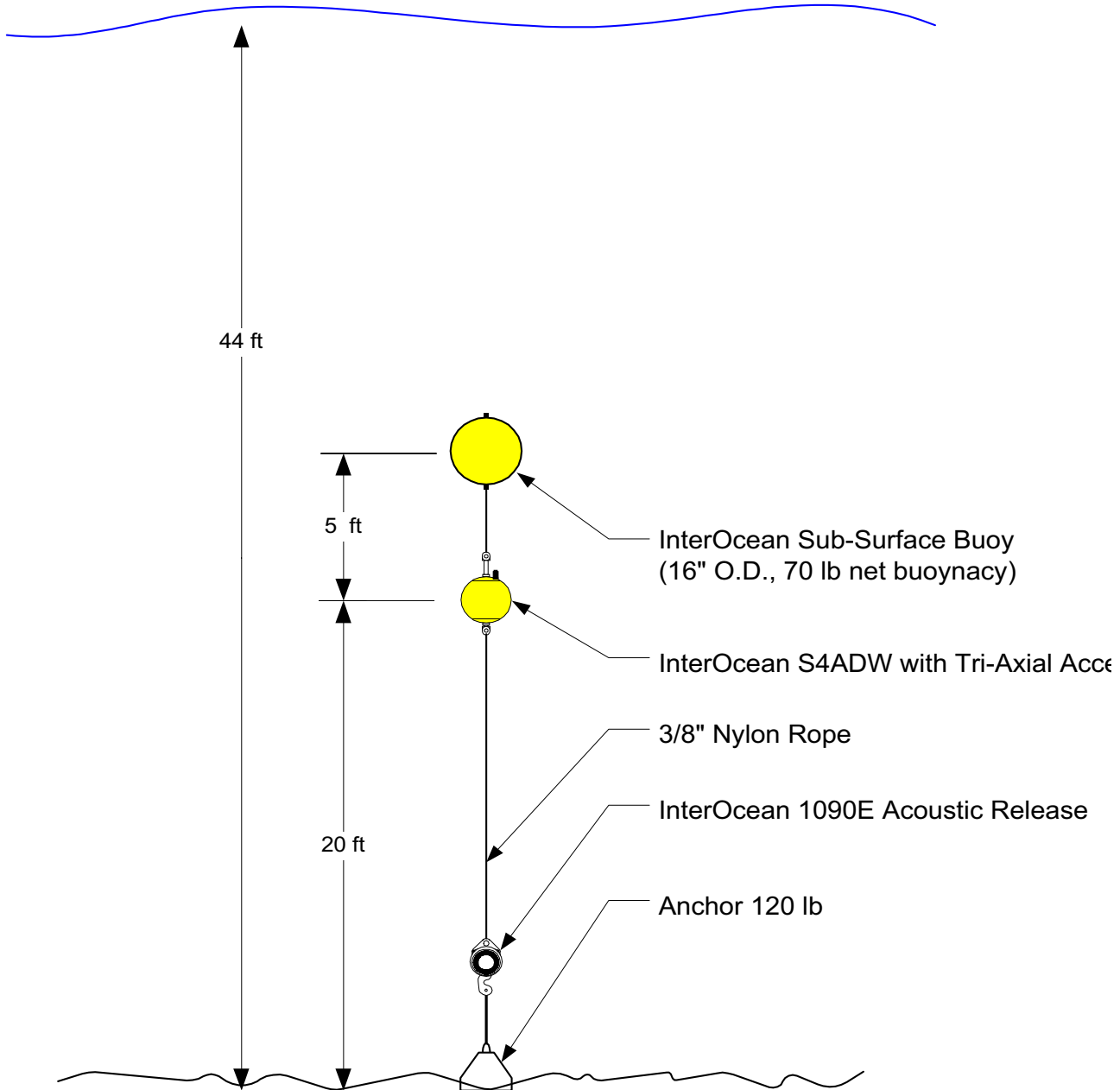


S4VP-3 Testing at SIO Pier

Comparison of Significant Wave Height Measurements Between a S4 Internally Processed Wave Data and Two Standard Sensors (SIO pier -- 26-28 April 2003)

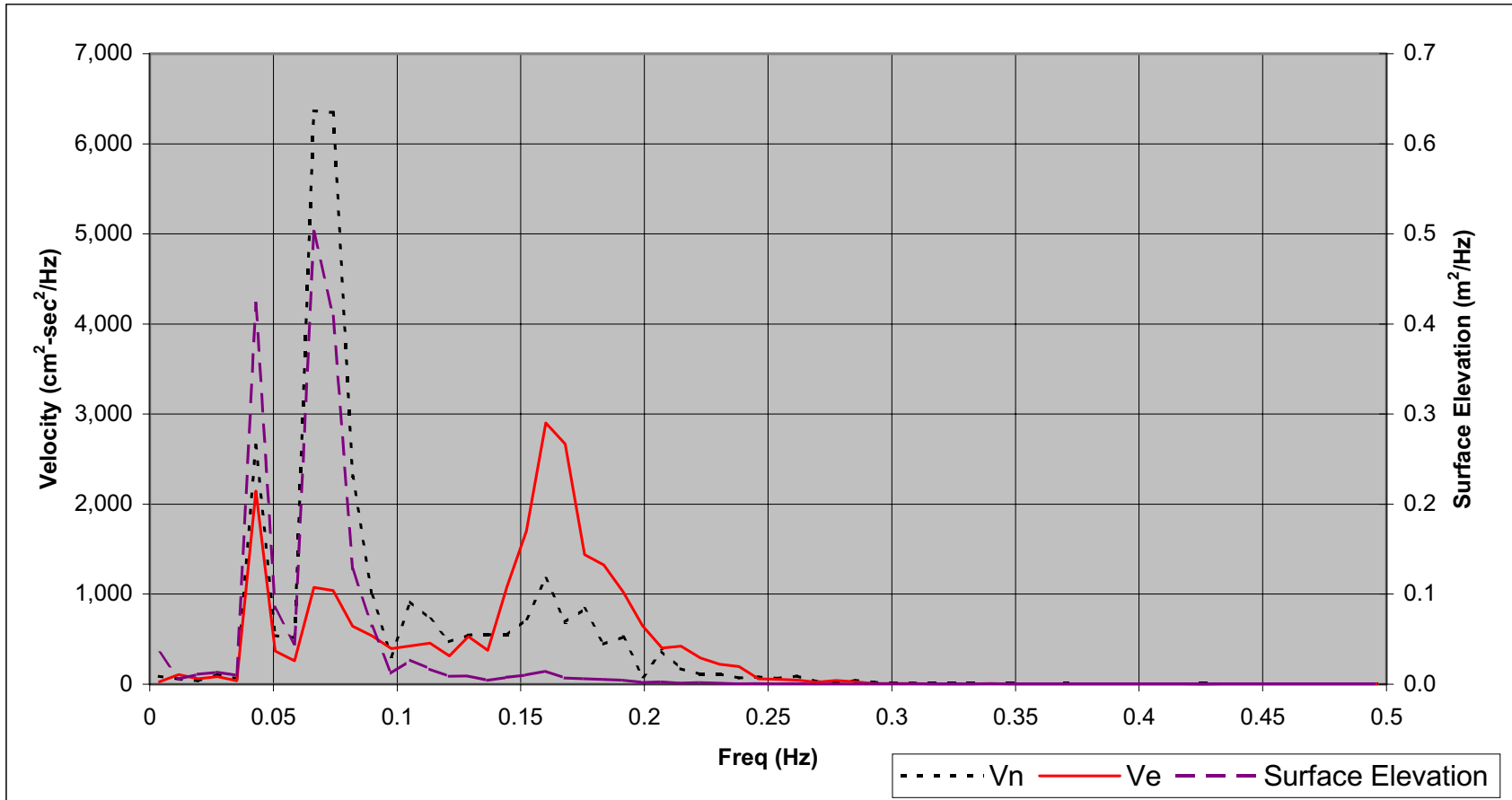


S4VP-3 Testing off the Coast of San Diego



S4VP-3 Testing off the Coast of San Diego

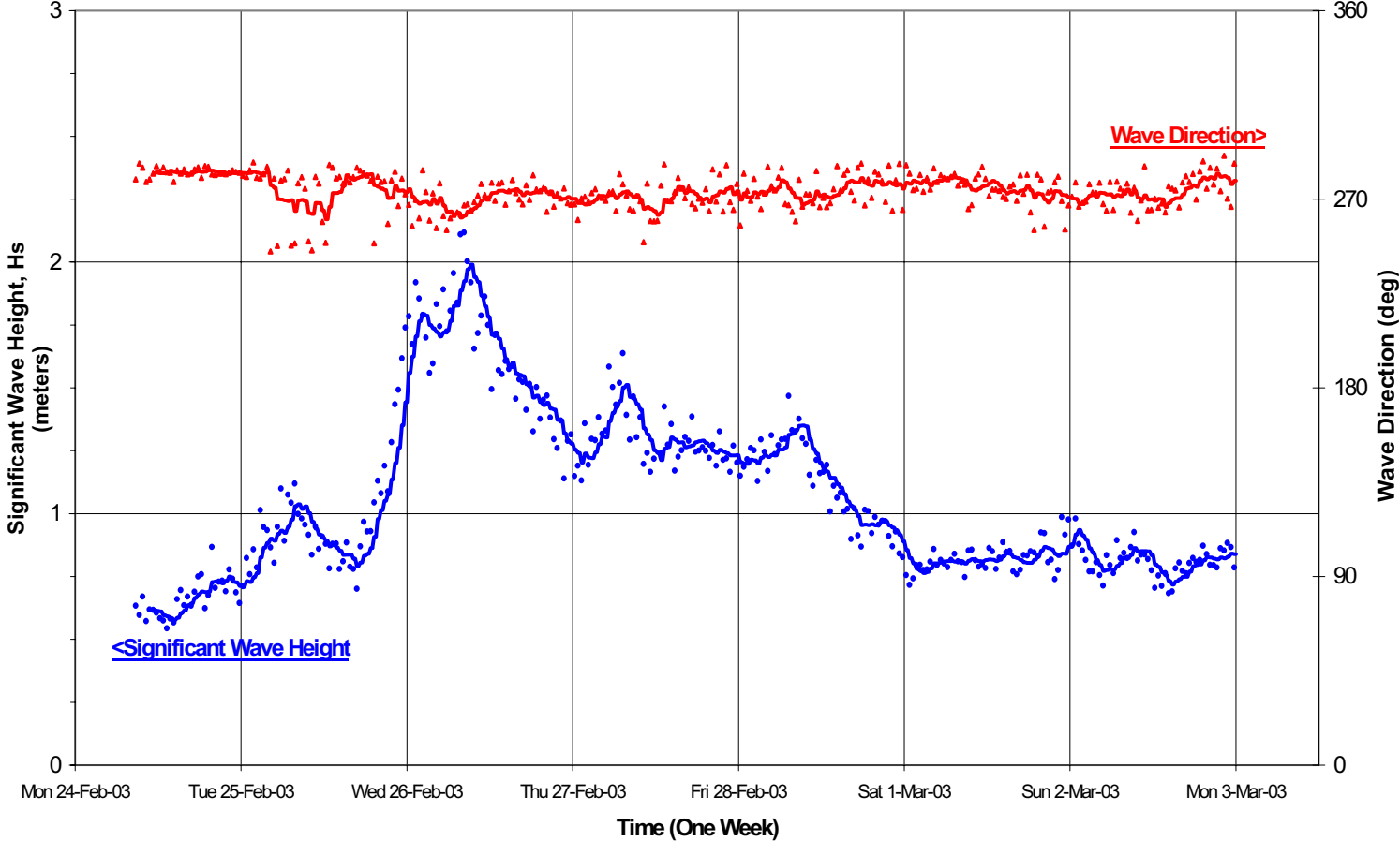
Velocity Spectra (East and West Components) vs. Surface Elevation for S4ADWA of the Coast of San Diego



S4ADW Iridium Testing at SIO Pier

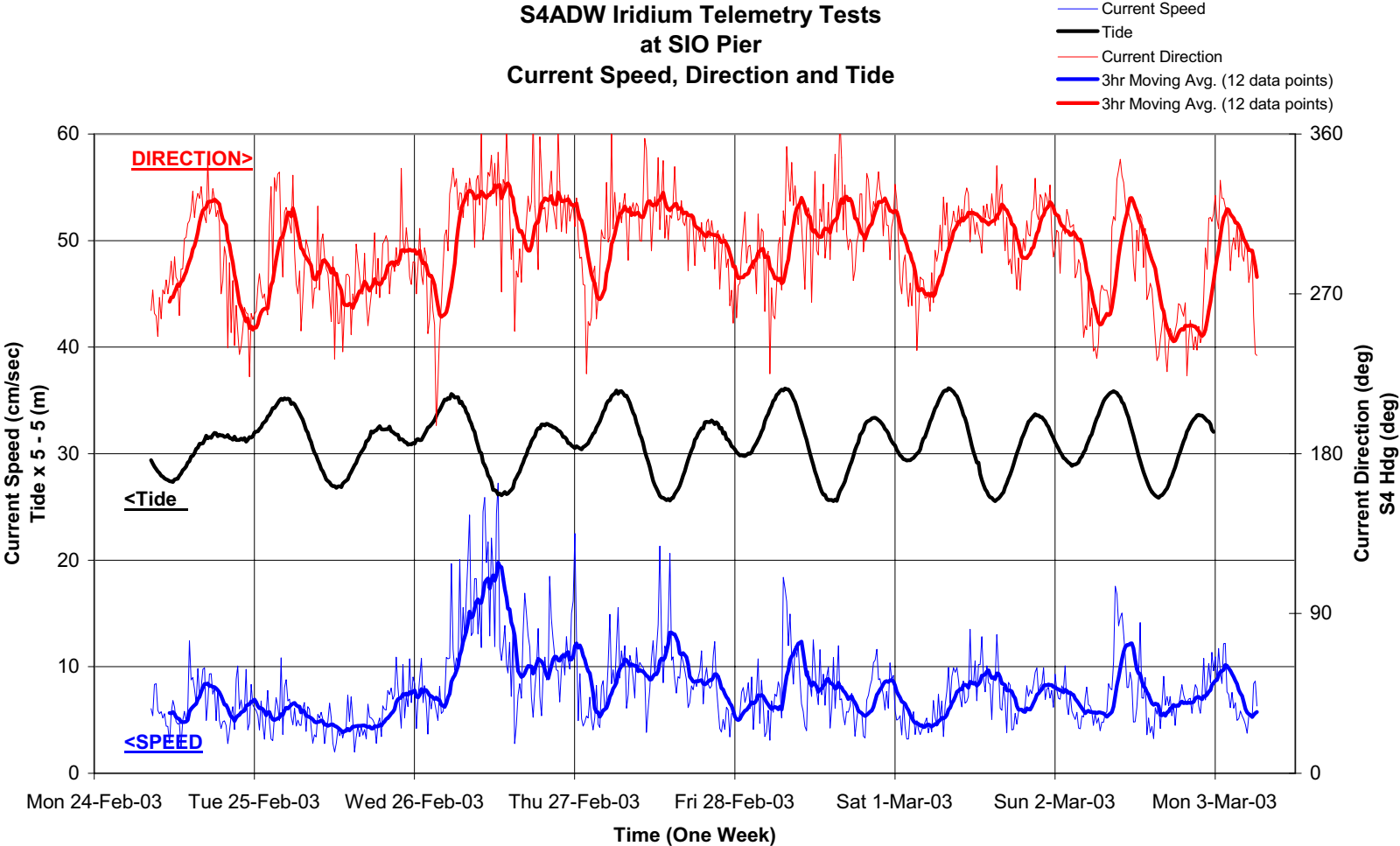
S4ADW Iridium Telemetry Tests
at SIO Pier
Wave Height and Wave Direction

- Significant Wave Height
- Wave Direction
- 3hr Moving Avg (12 points)
- 3hr Moving Avg (12 points)



S4ADW Iridium Testing at SIO Pier

S4ADW Iridium Telemetry Tests at SIO Pier Current Speed, Direction and Tide



Conclusions

Initial VPS system component developments have been very successful

- *S4VP-3 sensor platform*
 - Real time processing of wave and current parameters in S4VP-3 package
 - Application of 3-axis to create a virtual stationary S4 platform – initial tests look very promising
 - Use of 2-axis inclinometers with sign for gravity correction to accelerometer outputs
- *Subsurface buoy platform*
 - Iridium telemetry of S4 data
 - Base station software for S4 data
- *Underwater winch*
 - Winch system designed for 1,000 ft deployment is undergoing FAT – testing successful to date
 - All components tested to 700 psi

Deployment into high current regimes will require minor changes to underwater winch and cable supporting S4-VP3 instrumentation suite

- *Design of winch for deployments in 1.5 m/s currents with a larger buoyancy package is now in progress*

InterOcean VPS has applications in coastal, deep water and Polar regions

- *System can be easily upgraded to a complete turnkey system with an Internet capability*
- *VPS provides the perfect profiling platform for physical and biological measurements down to 200 meters*