Requirement for vicarious calibration of satellite ocean color data and plans for the next generation of the Marine Optical Buoy (MOBY)

Executive Summary

At the request of NOAA a meeting was held on July 18-19, 2006 at the National Institutes for Standards and Technology (NIST) to review the need for vicarious calibration for ocean color remote sensing and the plans for replacing the Marine Optical Buoy (MOBY) which has been used for this function but is aging and in need of replacement with a modern system. The committee reconfirmed the need for an optical mooring for vicarious calibration of ocean color sensors, particularly for VIIRS on NPOESS and a proposed Geostationary Ocean Color Imager (GOCI).

Based on current trends and on available parts for repairs it is estimated that MOBY can operate through the end of 2009. The MOBY team proposes replacing MOBY with the Advanced Hyper-spectral Autonomous Buoy (AHAB) at the same site. The MOBY site meets the requirements for a vicarious calibration site and has proven to be practical from a logistics point of view. It is recommended that AHAB be placed at the current MOBY site.

AHAB is designed to take advantage of new technologies and lessons learned from MOBY. The committee found the proposed AHAB design to be innovative and to meet the goals of meeting or exceeding MOBY data quality while reducing size and complexity and consequently the cost to maintain and deploy AHAB when compared to MOBY. The plans for developing and testing the critical component parts of AHAB and the schedule for deployment are well thought out and should allow deployment of the first AHAB in time to overlap at least 6 months with the last MOBY deployment planned for late 2009. The committee strongly recommends a six month or longer overlapping deployment for AHAB and MOBY to assure adequate cross calibration of the two systems. Like MOBY, AHAB will be thoroughly characterized and calibrated to NIST standards and thus will provide a continuous vicarious calibration site for all ocean color satellite sensors.

The committee strongly endorses the need for continued vicarious calibration for ocean color data and the goal of developing climate data records of ocean color including the current SeaWiFS and MODIS data cross calibrated with future VIIRS and GOCI data. We feel that AHAB as proposed will fulfill that need and we encourage NOAA and NASA to fund the development and deployment of AHAB. However, there are a number of technologies necessary for the AHAB design that need to be tested and refined to make AHAB a successful and reliable system. The current plans for testing those technologies are reasonable and should be adequate, however it is recommended that this committee, or another convened by NOAA and/or NASA review the progress and test results prior to the finalization of the design and development of the operational system. The exact schedule for that review is uncertain and will depend on funding and progress, but we recommend that NOAA and/or NASA schedule time and provide funding for that review as part of the AHAB development.
Requirement for Vicarious Calibration and the use of MOBY for SeaWiFS and MODIS Vicarious Calibration

The ocean color requirements for radiometric accuracy and precision have been established through various modeling studies and years of data analysis using the CZCS, SeaWiFS, MODIS, and other satellite ocean color data sets. The derived products such as water-leaving radiance, chlorophyll-a, and primary productivity are sensitive to calibration uncertainties at the level of 0.1%. This sensitivity is due to the relatively small ocean reflectances compared to those of the atmosphere, i.e., the combined Rayleigh and aerosol reflectances are ~ 90% of the total radiance over the open ocean (Evans and Gordon, 1994). Thus, small erroneous trends in sensor calibrations can be easily misinterpreted as real geophysical signals resulting from interannual oscillations or trends in the climate system. The system response can change over time as long as it is a slow trend and the combination of on-orbit and vicarious calibration can be used to correct the data to the required accuracy. This is consistent with the precision specification for the ocean color environmental data record and is absolutely essential if we are to construct a climate data record by combining SeaWiFS and MODIS data with future VIIRS data. Achieving this level of stability is challenging, but has been demonstrated with SeaWiFS using the lunar calibration and the Marine Optical Buoy (MOBY) (Barnes, et al., 2001; Eplee, et al., 2001, 2003). SeaWiFS responsivity has degraded in all bands with the most serious decay (15%) being in the 865 nm band (an atmospheric correction band). However, because the degradation has been accurately corrected independent of the earth-viewing data, there are no perceptible temporal trends in the global average water-leaving radiances or chlorophyll-a values.

To build an ocean color climate data record it will be necessary to merge data from SeaWiFS, MODIS, and future sensors like VIIRS together into a continuous record for studying decadal scale changes in marine ecosystems and primary productivity. This requires sensor stability and cross-calibration at the 0.3% level. Currently, MODIS and SeaWiFS cross calibration is continuing and consistency is improving, but is reliant on detailed pre-launch characterization data, e.g., Barnes et al. (1994) and Johnson et al. (1999) and robust solar and lunar calibrations on-orbit. The VIIRS specification for calibration accuracy is 2% and the specifications for open ocean chlorophyll a accuracy are 20% and 30% for concentrations less than 1 and 10 mg m-3, respectively. These specifications are inherently inconsistent, since an uncertainty of 2% in calibration can represent more than a 20% uncertainty in water-leaving radiance and on the order of 50% in chlorophyll-a. A 2% calibration accuracy obviates any hope of merging VIIRS data into the ocean color time series. Improvement of VIIRS calibration to acceptable levels will require on orbit calibration using the sun or moon imaging and vicarious calibration. In this workshop we only addressed vicarious calibration.

Vicarious Calibration Requirements

The fundamental objective of vicarious calibration is to isolate the effects of a satellite sensor’ systematic gain offset on the difference in a matched pair of normalized water-
leaving radiances derived from satellite and *in situ* measurements. This is accomplished by combining complete characterization of both sensors with constraints on the measurement conditions to minimize all other components of the combined uncertainty of the difference between the two measurements.

The *in situ* upwelled radiance measurements used to determine normalized water-leaving radiances for vicarious calibration must have the lowest possible radiometric uncertainty. Uncertainty associated with extrapolating in-water profile measurements of upwelled radiance to, and transmitting it through, the wind roughened air-sea interface is estimated to range between 3 % and 5 % under ideal circumstances (i.e. in clear Case I waters). If ocean bio-optical properties vary significantly within a few Km of the calibration site, then significant uncertainties that are difficult to quantify will arise in the comparison of a matched pair of satellite and in situ water-leaving radiances.

The radiometric and environmental requirements for Vicarious Calibration observations include:

- Hyperspectral (~1 nm) resolution to allow matching of radiances to the in-band and out-of-band radiance response functions of each individual satellite channel,
- Measurement of and if needed corrections for the in situ sensor’s out-of-band stray light functions, *e.g.* as determinable through laboratory characterization with the NIST SIRCUS facilities.
- Minimal platform and instrument shading, combined with validated corrections,
- Pre- and post-deployment radiometric responsivity calibrations, coupled with frequent validation of the direct traceability of the calibration sources to NIST scales of spectral irradiance and radiance,
- Tracking of the Observatory’s calibration sources using NIST-calibrated irradiance and radiance radiometers,
- A site location removed from land by >20 Km and characterized by low incidence of cloud cover in all seasons, and by aerosol optical depths that are typically small (<0.1 in the visible) and spatially homogeneous (i.e. no nearby localized sources of aerosol plumes). Using only matched water-leaving radiance pairs observed when aerosol optical thicknesses at visible wavelengths are <0.1 minimizes uncertainty associated with aerosol models in atmospheric corrections.
- Routine measurements of aerosol optical depth and sky radiance distributions, *e.g.* at a nearby AERONET site (Holben, *et al.*, 1997), or the equivalent are used to confirm aerosol optical thickness at time of individual comparison.
- A site that has easy access from port and is typically sheltered from high seas to facilitate the routine maintenance and if necessary emergency repairs on the observatory.
- A clear Case-I water mass, *e.g.* with chlorophyll *a* concentrations <0.25 mg m-3, and a range of horizontal variability over scales ~10 Km < 0.05 mg m-3, in all seasons. Vicarious calibrations should be done using only matched pairs observed in water masses where Chl < 0.25 mg/m³ and horizontal variability within ~20 Km in Chl is <0.05 mg/m³ which yields uncertainties significantly < 5 % in ocean BRDF adjustments to determine exact normalized water-leaving radiance at any viewing zenith angle.
• Frequent shipboard sampling of 3-dimensional radiometric and bio-optical variability near the site, as a basis for quantifying the resulting uncertainty when point observations at the buoy are matched with satellite radiance measurements integrated over 1 Km, or larger, scales.

MOBY was designed specifically for vicarious calibration for SeaWiFS and MODIS (Clark et al., 1997, Clark et al., 2002,a,b) and it has successfully met these requirements. The MOBY site has proven to be workable and to meet all of the requirements for uniform low chlorophyll waters and marine aerosols. The committee recommended not changing sites unless the new site meets all the above requirements for vicarious calibration and offers some major financial or logistic advantage. The committee also recognized the need for at least one supplemental, i.e. additional to the MOBY site, “blue-water” vicarious calibration site in the Atlantic Ocean to support a GOES-East Ocean Color Imager should NOAA deploy such a sensor.

The need to Replace MOBY Instrumentation

The current MOBY system was designed in the late 1980s and is aging resulting in more frequent loss of data and requiring more frequent repairs. Based on current trends and on available parts for repairs it is estimated that MOBY can operate through 2009. The MOBY team proposes replacing MOBY with the Advanced Hyper-spectral Autonomous Buoy (AHAB) at the same site. The MOBY site meets the requirements cited above for a vicarious calibration site and it has proven to be practical from a logistics point of view. AHAB is designed to take advantage of new technologies and lessons learned from MOBY.

AHAB Design Requirements

In designing the new system the overall goal was to build a smaller, simpler system that was modular, easier to deploy, took simultaneous data for all sensors and had equal or better data quality compared to MOBY. Table 1 summarizes these requirements.

AHAB Buoy System Design

The design goals of the new buoy system were to reduce the size, weight and complexity to reduce the size of the vessel required for deployment and thus construction and operational costs. Figure 1 shows the existing MOBY design with the watch buoy and tethered optical buoy, a well proven design that has been operational for the past 10 years. The most significant design change is the physical size of the AHAB buoy. To reduce AHAB optical buoy size, the primary power and communications system is moved to the watch buoy. This results in significant reduction in the optical buoy size (Figure 2) and thus reduces the requirements for the size of vessel needed for servicing, a significant operational cost improvement. To facilitate this change, power must be provided to the optical buoy from the watch buoy via an electromechanical tether (the current design uses a mechanical tether). The key to this design change is the use of an electromechanical swivel in the main mooring line (see Figure 3).
### TABLE 1. AHAB design requirements and goals.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MOBY</th>
<th>AHAB</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>System design</td>
<td>Integrated system with sequential acquisition of all ancillary parameters</td>
<td>Modular system with coincident, continuous measurement of relevant parameters</td>
<td>Increased knowledge of the physical state of the operational system during measurements. System easily configured for a variety of operational environments.</td>
</tr>
<tr>
<td>Optical design</td>
<td>Alignment sensitivity due to long path lengths, mechanical multiplexer</td>
<td>More robust, simpler optical configuration, no multiplexer</td>
<td>Component reduction, less sensitivity to optical alignment, better throughput, improved radiometric stability.</td>
</tr>
<tr>
<td>Spectrograph design</td>
<td>Convex reflective grating</td>
<td>Volume transmissive grating</td>
<td>Component reduction, improved imaging, reduced scattered (stray) light in the system</td>
</tr>
<tr>
<td>Mooring Design</td>
<td>12m spar, on board power, instrument bay in base</td>
<td>6m spar, power from mooring buoy, instrument bay in surface float</td>
<td>Reduction in size, complexity. Reduction in system cost, and operational costs</td>
</tr>
</tbody>
</table>

The swivel incorporates a slip ring that allows passing of 48VDC from the watch buoy to the optical buoy while allowing the optical buoy to swing around the watch buoy without fouling the tether. This is similar to tethers using in other industrial applications. This component is a critical element of the new design and as a risk mitigation strategy the swivel is currently being evaluated. A swivel has been installed in the currently deployed watch buoy since March of 2006 to evaluate endurance. Providing 48V at 3A for the proposed new optical buoy has also been tested through a 100m tether using the swivel for a 24 hour period. The tether was also tested at the maximum expected site current of 3 knots by towing a mock up AHAB behind the vessel. Continued testing of the electromechanical design is recommended to assure this approach is viable. Testing of a powered buoy mock up is recommended to assess the environmental effects on the swivel, tether, and optical buoy electromechanical connection ability to deliver reliable power.
Figure 1 - MOBY Mooring Configuration.

Figure 2 - Existing MOBY design (left), proposed AHAB design (right).
Figure 3 - Prototype AHAB electromechanical swivel.

The incorporation of a UV anti-biofouling system, reduced number of collectors (6 to 4) and a drop weight for easier recovery further reduces operational costs. The cost reduction is realized by increasing the service interval of the optical buoy (every 6 months for AHAB vs 3 months for MOBY) by improved anti-biofouling and the removal of Ed collectors which are problematic for biofouling. Recovery visit dive time is eliminated by using a drop weight system that allows for the recovery the buoy without divers. These design features will all make significant contributions to reducing operational costs. The anti-fouling system, however, will require some field evaluation to look at anti-fouling effectiveness, UV degradation of the input fibers, stray light, and the stability of the proposed reflective surfaces.

A larger, more robust watch buoy is planned to support a larger power system and improved real time communications system. This more robust platform will increase the time between servicing of the watch buoy from one year to two years, another significant operational cost reduction.

Design and modeling of the new watch buoy and optical buoy is being done by Mooring Systems Inc. Mooring Systems have significant experience with these designs and were responsible for the design of the current MOBY platforms.

AHAB Optical Design

The AHAB optical design reflects lessons learned from MOBY and takes advantage of new technologies. MOBY has a sensor for above water downwelling irradiance (E_d) and an E_d and upwelling radiance (L_u) sensor at 1.5, 6 and 11 meters depth. MOBY has solar
cells on the surface buoy and a large battery at depth. These features make MOBY large and difficult to put in and take out of the water requiring a large ship with two cranes. AHAB draws power from the watch buoy which allows a smaller surface buoy and less shadowing. Experience with MOBY showed that it was only necessary to have the surface $E_d$ and $L_u$ at two depths. AHAB has a smaller surface buoy with a surface $E_d$ sensor, two arms at each of two depths for a total of 4 $L_u$ sensors. Removing the in-water $E_d$ sensors and reducing the size of the buoy greatly reduces shadowing of the upwelling light field. The two arms at each depth are at approximately 35 deg angle to each other so that one will always be removed from the shadow of the buoy. Having two provides redundancy; experience when they are both collecting data will make it possible to effectively correct for the buoy shadow should only one be operating. Removal of the lower depth, elimination of the batteries and the size reduction of the buoy allow AHAB to be handled from a single crane on smaller ships. The instrument (spectrometer, fiber, collectors) can be removed from the buoy to allow servicing and calibration in more controlled conditions.

The transition from MOBY to AHAB places various requirements on the optical design. First, the spectral resolution should be equivalent to MOBY (or better) to allow adequate simulation of the optical bandpass of the bands of any current or planned satellite ocean color sensor. An analysis of MOBY data has shown that this resolution (full width half max of 1.03 nm with sampling at 0.6 nm) is adequate to simulate complex MODIS channel in-band and out-of-band responses to < 0.2%. The sensor should have lower uncertainty which depends on building a better instrument and on reducing various environmental effects. First, the instrument should be calibrated to a lower uncertainty. The instrument should have lower inherent stray light and a better correction for the remaining stray light. A new design that takes simultaneous data from the $E_d$ and in-water radiance sensors reduces the collection time for a single data set. The new design includes new biofouling prevention and a system level throughput monitor using fiber coupled LED sources to illuminate the full system.

**Additional Testing to be Completed**

The new design eliminating the dichroic beam splitter and associated input optics is an improvement over the existing sensor. The stray light performance of the new breadboard sensor using the Jobin Yvon spectrometer and Andor CCD is better which should allow for better system performance after correction (Figure 4). The JY spectrometer was less than optimal optical performance (smile and keystone) so alternative spectrometers and CCD cameras are being procured for testing. Samples of alternate systems will be evaluated in the next few months.

The dynamic range required for measurement at high SNR is large. The committee would like an analysis of the dynamic range required for a specified SNR at the worst case wavelength for clear and turbid water. This analysis should include any non-linearities or systematic errors in the proposed 16-bit digitizer and other electronics for the CCD camera. The necessary dynamic range has been demonstrated with the MOBY design and with the Andor in-water buoy tests. The proposed CCD camera and
electronics exceed the design requirements of the MOBY buoy. The camera will be completely characterized for linearity, dynamic range, binning characteristics, integration time, etc. before selection of final system.

One of the spectrometers being procured for evaluation is a Kaiser device using a volume scattering transmission grating. The committee has questions about the stability of the grating with UV exposure, the optical performance of the spectrometer over the entire field of the CCD (smile and distortion), the spectral performance, and the stray light performance. Blocking filters will be used to block ambient UV and the shutters will be closed when the UV anti-biofouling LEDs are on. Any changes that do occur will be accounted for in the pre and post calibrations. These instruments are widely used in precision biomedical and other science applications. The selected system will be thoroughly tested for stability.

One member of the committee has questions about possible interactions with the switching power supply system in the buoy with the low level analog and digitizing parts of the sensor. The high quality power supplies and good electrical design, which have been used for MOBY meets these requirements. The AHAB design utilizes similar high quality power supplies and electrical design and will be rigorously tested to assure it meets these requirements.

The committee would like to better understand the temperature responsivity of the system to understand the differences in response during calibration as compared to operation. AHAB will be fully characterized for temperature sensitivity.

The discussion of environmental influences was useful. The committee has questions about the design of the radiance collector head and the biofouling prevention and stray light. The biofouling design and the system level calibration shown was a preliminary conceptual design and have been replaced with several other concepts which will be completely evaluated before implementation.

There is a logical plan for the resolution of each of these issues. The committee recommends that the results of that analysis and testing be presented at a subsequent review prior to the finalization of the design and development of the operational system.

**Minimizing Environmental and Calibration Uncertainties**

A number of changes are planned to reduce uncertainty and provide calibration to NIST traceable standards. To minimize environmental sources of error the data is collected simultaneously on the same detector array reducing variations due to changing cloud shadows and ocean features that may affect MOBY data which is collected sequentially over 40 minutes. Fiber optic inputs will scramble any polarization. Dual L_u detector arms at each depth and a smaller surface buoy will minimize the shadow effects. UV Light Emitting Diodes (LEDs) will be used to periodically illuminate the sensor head to eliminate biofouling. Like MOBY, AHAB will be calibrated directly with NIST calibration sources to minimize uncertainties inherent in transfer standards. AHAB
Figure 4. Out of band stray light distributions. The blue lines represents the current MOBY performance, the green line shows the improved performance for the AHAB prototype system.

will be thoroughly characterized by NIST before deployment including stray light characterization (Brown et al., 2003a,b), thermal stability and wavelength stability. AHAB will be calibrated before and after each deployment. New blue rich LED illuminated calibration spheres which produce spectra similar to ocean spectra will be used to minimize errors caused by using the standard red rich lamp based calibration sources. When deployed wavelength stability is monitored using the solar lines. Each sensor head will have a blue LED source that will be used in situ to check calibration and stability during deployment.

Timeline for MOBY Replacement

The current MOBY system is aging, resulting in more frequent loss of data and requiring more frequent repairs. Based on current trends and on available parts for repairs, it is estimated that MOBY can operate through 2009. The proposed timeline is based on a careful analysis of the time required to develop and test AHAB and the desire to have a 6 month to one year overlap between MOBY and AHAB to assure the continuity of the data. Multi Input Fiber-optic Spectrograph (MIFS) is the spectrometer system that will be used in AHAB.

MIFS breadboard evaluation by 4/07
MIFS prototype final by 12/07
Reconfigurable AHAB

The AHAB design is much smaller than MOBY and it is designed so that the spectrometer system can be removed from the buoy structure for transportation and calibration. Like the current MOBY system, two AHAB systems are needed to support the vicarious calibration site, with a new one being installed when the old one is taken out for refurbishment and recalibration. It is proposed to build a third AHAB to address a variety of issues including the need to provide validation of coastal algorithms and to test sites and prototype a system for vicarious calibration on the east coast of the U.S. in anticipation of GOCI on GOES-East at some future time.

Avoiding Sun Glint at the VCS Hawaii Site

MOBY is located near 22°N and is susceptible to sun glint, especially for non-tilting sensors like MODIS, and VIIRS. As a result, there are few match-ups for the summer months and those that do pass the exclusion criteria (e.g. scan angle limit) are toward one limb of the scan (MODIS). Finding a higher latitude site would be preferable for this season, and also because higher latitudes get more frequent views, but other considerations become more problematic, e.g. clouds, optical variability, etc.). Alternatively, a blue water vicarious calibration site in the southern hemisphere would provide match-ups when the MOBY site is contaminated by sun-glint. Looking ahead to providing vicarious calibration for a GOES-East GOCI sensor, a separate normalized water-leaving radiance observatory will be needed in the Atlantic Ocean. High consideration should be given to an Atlantic Ocean site that is south of the equator in the field of view of GOES East.

Validation of Ocean Color Measurements and Products in Coastal Waters

VIIRS and GOCI both have an emphasis on coastal products to meet NOAA and navy needs. The coastal environment is complex and varies rapidly with tides and nearshore wind forcing making it unsuitable for vicarious calibration. However there is a need to make an appropriate suite of measurements in coastal waters to assure that the calibration and atmospheric correction algorithms apply to these waters and to validate coastal ocean color products. The third AHAB may be quite useful for validating coastal products. It is important to be able to cross calibrate sensors typically used in the coastal ocean with AHAB. It is common to use commercial hyperspectral radiometers, above-water measurements of remote sensing reflectance or measurements of inherent optical properties and radiative transfer models to calculate remote sensing reflectance in these waters. Using the reconfigurable AHAB to directly compare its measurements with the
results of these alternative methods will be essential for producing valid algorithms and products for the coastal ocean.

There is a growing recognition that experimental research is needed to address important issues of on-orbit characterization of ocean color sensor responses when viewing turbid coastal water masses through an atmosphere containing aerosols, especially absorbing ones, originating on land. An important research problem in this respect is to determine whether the spectrally integrated out-of-band responses of a satellite sensor viewing top-of-atmosphere radiances from green to brown water and atmospheres with terrestrial aerosols vary significantly from that viewing the blue-water and clear atmosphere (low optical depth of marine aerosols) during vicarious calibration. Deploying an AHAB in coastal waters could directly address this question.

**Calibration for GOCI on GOES-East**

It is proposed to have coastal water imaging capability on future Geostationary Environmental Satellites (GOES). There are typically two GOES satellites, GOES East (75 deg West at the Equator) over Brazil and GOES West off the West Coast (125 deg W at the Equator). GOES West will easily see the Vicarious Calibration Site (VCS) off Hawaii, but GOES East does not see west of California. A second VCS site on the East or Gulf Coast will be needed for GOES East. The third AHAB can be used to test the suitability of various Atlantic Ocean sites. One option would be to find a site south of the Equator in the GOES East filed-of-view that meets all of the vicarious calibration requirements. This would allow the collection of vicarious calibration data during the Northern Hemisphere summer when satellite data is often contaminated with sun glint at the MOBY site.

**Recommendations**

The committee strongly recommends the continuation of a mooring in a clear water site for vicarious calibration of future ocean color sensors; in particular VIIRS and GOCI. The Marine Optical Buoy (MOBY) has provided this service since 1991 and the committee recommends continuing to collect similar or better quality data for vicarious calibration purposes. The vicarious calibration site should be in uniform clear water with an oceanic atmosphere and minimal effects from land or human activities. The current MOBY site meets these requirements.

MOBY has demonstrated the ability to support numerous ocean color missions to maintain climate quality data records for the past 15 years. To avoid a potential gap and/or discrepancies in this record the committee recommends that the AHAB system overlap the MOBY deployment by at least 6 and preferably 12 months before MOBY is decommissioned in 2009.

MOBY is aging and new technologies facilitate the development of a smaller system with improved performance. Based on the MOBY experience the MOBY team has designed the Advanced Hyper-spectral Autonomous Buoy (AHAB). AHAB simultaneously
measures spectral upwelling radiance at two depths and surface downwelling irradiance. It is much smaller than MOBY and it is designed to operate for longer periods and to be installed and maintained without the need for divers.

The committee has reviewed the plans for AHAB as a replacement for MOBY and finds the overall plan timely and appropriate. The MOBY team has developed a prototype system and deployed it in Hawaii. They have outlined a plan for completing testing of the design and survivability at sea. The current plans for testing those technologies are reasonable and should be adequate, however it is recommended that this committee, or another convened by NOAA and/or NASA review the progress and test results prior to the finalization of the design and development of the operational system. The exact schedule for that review is uncertain and will depend on funding and progress, but we recommend that NOAA and/or NASA schedule time and provide funding for that review as part of the AHAB development.

**Disclaimer**

This review was conducted and report prepared at the request of NOAA. The views expressed in this report are the views of the review committee and should not be taken as official NOAA or NASA policies or views.

**References**


Eplee, R.E., Jr., R.A. Barnes, and F.S. Patt, 2003: Changes to the on-orbit calibration of SeaWiFS, Algorithm Updates for the Fourth SeaWiFS Data Reprocessing, NASA TM 2003-206892, 22.


Appendix 1. Meeting Agenda

Review of AHAB (Advanced Hyper-spectral Autonomous Buoy) Design and Plans for Implementation

July 18-19, 2006 at NIST, Gathersburg, MD

Tuesday July 18th

8:00 AM     Arrival at NIST and check-in at gate
8:30 AM     Welcome and meeting objectives   C. Davis and C. Johnson
8:45 AM     NOAA prospective and goals for meeting S. Wilson and K. Hughes
9:00 AM     MOBY background and need for replacement D. Clark
9:30 AM     RNO Concept: design and implementation D. Clark
10:00 AM    Coffee Break
10:30 AM    Description of AHAB design
            Physical Structure M. Yarbrough
            Optical Design S. Brown
12:00 PM    Lunch
1:00 PM     Plan for calibration and maintenance of AHAB
            Uncertainty budgets: Laboratory C. Johnson
            environmental K. Voss
2:00 PM     Plan to complete and test re-engineered system S. Brown
2:30 PM     Summary C. Johnson
3:00 PM     Afternoon Break
3:30 PM     Group Discussion of goals and presentation C. Davis and K. Hughes
            and development of and initial outline of report
4:00 PM     Review team and NOAA representatives meet in closed session
4:45 PM     Depart for Hotel
**Wednesday July 19th**

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Organizer(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00 AM</td>
<td>Arrival at NIST and check-in at gate</td>
<td></td>
</tr>
<tr>
<td>8:30 AM</td>
<td>Review team reports their initial findings and outline of the report</td>
<td>C. Davis</td>
</tr>
<tr>
<td>9:00 AM</td>
<td>Discussions with the MOBY team</td>
<td>C. Davis and D. Clark</td>
</tr>
<tr>
<td>10:00 AM</td>
<td>Coffee Break</td>
<td></td>
</tr>
<tr>
<td>10:30 AM</td>
<td>Review Team and NOAA meeting in closed session to update report outline</td>
<td>C. Davis</td>
</tr>
<tr>
<td>11:30 AM</td>
<td>Reconvene for discussion with the MOBY team and develop schedule for completion of the report</td>
<td>C. Davis and D. Clark</td>
</tr>
<tr>
<td>12:00 PM</td>
<td>Lunch</td>
<td></td>
</tr>
<tr>
<td>1:00 PM</td>
<td>Review team works on first draft of the report</td>
<td>C. Davis</td>
</tr>
<tr>
<td>3:00 PM</td>
<td>Coffee Break</td>
<td></td>
</tr>
<tr>
<td>4:00 PM</td>
<td>Adjourn</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 2. Meeting Participants and Roles.

Review Team Members

Curtiss O. Davis, Chairman of Review Team
College of Oceanic & Atmospheric Sciences
Oregon State University
104 COAS Admin Bldg.
Corvallis, OR 97331-5503
(541) 737-3571
(541) 737-2064 FAX
cdavis@coas.oregonstate.edu

Stuart Biggar
University of Arizona
Optical Sciences, Meinel Building
1630 East University Boulevard
Tucson, Arizona  85721
(520) 621-8168
stuart.biggar@opt-sci.arizona.edu

Bruce Guenther
Goddard Earth Sciences and Technology Center
Laboratory for Terrestrial Physics
NASA GSFC, Code 614.4
Building 33, Rm F321B
Greenbelt, MD 20771
(301) 614-6856
(301) 614-6856 FAX
guenther@ltpmail.gsfc.nasa.gov

Scott McLean
Satlantic
3481 North Marginal Rd
Richmond Terminal Pier 9
HALIFAX, Nova Scotia
B3K 5X8 CANADA
(902) 492-4780
(902) 492-4781 FAX
scott.mclean@satlantic.com

Jim Mueller
CHORS/San Diego State University
6505 Alvarado Rd. Suite 206
San Diego, CA 92120-5005
Tel: (619) 594-2230
Fax: (619) 594-8670
jim@chors.sdsu.edu

Michael Ondrusek
NOAA/NESDIS
E/RA3
5200 Auth Road
Camp Springs, MD  20746
(301) 763-8102 x161
michael.ondrusek@noaa.gov

Chuck Trees
CHORS/San Diego State University
6505 Alvarado Road, Suite 206
San Diego, CA 92120
Ph: (619) 594-2241
Fax (619) 594-8670
ctrees@chors.sdsu.edu

MOBY Team

Steve Brown
NIST
100 Bureau Drive Stop 8443
Gaithersburg, MD 20899-8443
(301) 975-5167
(301) 840-8551 FAX
steven.brown@nist.gov

Dennis Clark
NIST
100 Bureau Drive Stop 8442
Gaithersburg, MD 20899-8442
(443) 370-5747
clark.dk@gmail.com

Stephanie Flora
Moss Landing Marine Labs
8272 Moss Landing Road
Moss Landing, CA 95039
(831) 771-4456
flora@mlml.calstate.edu

Carol Johnson
NIST
100 Bureau Drive Stop 8442
Gaithersburg, MD 20899-8442
(301) 975-2322
carol.johnson@nist.gov

Kenneth Voss
University of Miami
Dept. of Physics
Coral Gables, FL 33124-0530
(305) 284-2323
voss@physics.miami.edu

Mark Yarbrough
Moss Landing Marine Laboratories MOBY project-Hawaii
1 Sand Island Access Road
Honolulu, Hawaii 96819
(808) 847-3449
yarbrough@mlml.calstate.edu

NOAA Observers

Kent Hughes
NOAA/NESDIS/ORA/ORAD
RA3 World Weather Building, Room 601
5200 Auth Rd. Camp Springs, MD 20746-4304
(301) 763-8102 x171
(301) 763-8572 ORAD FAX
kent.hughes@noaa.gov

Stan Wilson
Senior Scientist
NOAA/NESDIS
SSMC-I Room 8212
1335 East West Highway
Silver Spring, MD 20910
(301) 713-3389
stan.wilson@noaa.gov

Al Powell
NOAA/NESDIS/ORA/ORAD
RA3 World Weather Building, Room 601
5200 Auth Rd. Camp Springs, MD 20746-4304
(301) 763-8127
(301) 763-8572 ORAD FAX
al.powell@noaa.gov