TITLE PAGE (PROPOSAL COVER SHEET)

Proposal submitted to the Integrated Ocean Observing System Program, National Ocean Service (NOS), National Oceanic and Atmospheric Administration (NOAA), Department of Commerce

Pursuant to FY2010 Integrated Ocean Observing System Implementation

Developing the Hawai‘i Ocean Observing System (HiOOS)

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Focus Area 1: Regional Coastal Ocean Observing Systems by Geography

2. PROJECT SUMMARY

a. Project Name/Title

Developing the Hawai‘i Ocean Observing System (HiOOS)

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e. Brief Project Summary including objectives and intended benefits

The School of Ocean and Earth Science and Technology at the University of Hawai‘i at Manoa, with partners at local, state, and federal agencies, proposes to continue the development of the Hawai‘i Ocean Observing System (HiOOS). This demonstration project of the Pacific Islands Ocean Observing System (PacIOOS) Regional Association is the sole nascent system within the geographic area (Hawai‘i) defined in this funding opportunity. The goal of the proposed work is to develop an operational ocean monitoring and forecasting system that provides integrated, customized, and timely products that assist agencies charged with responsibility for the safe, clean, resilient, and productive capacity of Hawai‘i’s coastal ocean and shoreline. Initial development of HiOOS has focused on four thematic areas: *Coastal Ocean-State and Forecasting, Coastal Hazards and Resiliency, Water Quality Sensing, and Marine Ecosystem*

Monitoring. HiOOS currently serves data and products through a dynamic web interface to stakeholders though the region in each of these thematic areas (http://www.hioos.org) and proposes to maintain and expand those services. An iterative process of engagement, outreach, and extension of HiOOS data streams has clearly defined stakeholder needs for additional customized and integrated products. To that end, HiOOS will continue to develop an ocean observing network in the aforementioned thematic areas and within those foci tailor product development in the coming fourth year on: *(1) High Water Level and Coastal Inundation Forecasting, (2) Water Quality Indices for Coastal Waikiki, and (3) Predicting Conditions Approaching and in Harbors*. In addition, HiOOS will: 4) continue development of the Hawaii fish-tracking array—a regional component in a larger global network that monitors animal movements at different scales, as well as 5) update, integrate and serve information for marine spatial planning.

f. Partners

Federal: NOAA (Pacific Islands Fisheries Science Center—Coral Reef Ecosystem Division, IDEA Center, National Data Buoy Center, National Weather Service, Pacific Marine Environmental Lab, CO-OPS, Pacific Services Center, National Marine Sanctuary Program, Pacific Islands Benthic Habitat Mapping Center), United States Army Corps of Engineers, United States Coast Guard, United States Navy (Oceanographic Office, Joint Typhoon Warning Center, Naval Maritime Forecast Center), United States Geological Survey, Environmental Protection Agency 9th District, Department of Homeland Security (National Center for Island, Maritime, and Extreme Environment Security (CIMES), Federal Emergency Management Agency)

State: Department of Land and Natural Resources, State Office of Planning—Coastal Zone Management Program, Department of Health, Ocean Resources Management Plan, Department of Transportation – Harbors, University of Hawai‘i (Hawai‘i Institute of Marine Biology, Joint Institute for Marine and Atmospheric Research, Infrasound Laboratory, UH Sea Level Center, International Pacific Research Center (IPRC), EPSCoR, Hawaii Mapping Research Group (HMRG), Sea Grant College Program), Hawai‘i State Civil Defense, Pacific Disaster Center

Local: County of Hawai‘i (Office of Planning), County of Maui (Office of Planning, Office of the Mayor), City and County of Honolulu (Board of Water Supply, Department of Environmental Services, Ocean Safety Division), County of Kauai (Office of Planning, Ocean Safety Division)

Other: University of California at San Diego (Coastal Data Information Program)

3. PROJECT DESCRIPTION

a. Goals and Objectives

In accord with the geographic areas identified in the RFP, this proposal focuses on Hawaii and the development of its integrated ocean observing system (HiOOS). Hawaii encompasses almost one fifth of the US EEZ (Fig. 1A). As the whole of the population in Hawaii lives within a few miles of the shore, understanding and predicting the state of the ocean is fundamental to island life and wellbeing. Our vision is to enable an ocean-literate and well-informed population, industry and policy makers.

The goal of the proposed work is to develop an operational ocean monitoring and forecasting system that provides integrated, customized, and timely products that assist agencies charged with responsibility for the safe, clean, resilient, and productive capacity of Hawai‘i’s coastal ocean and shoreline. The initial three-year development of HiOOS is focused on four thematic areas: *Coastal Ocean-State and Forecasting, Coastal Hazards and Resiliency, Water Quality Sensing, and Marine Ecosystem Monitoring*. HiOOS currently serves data and products through a dynamic web interface to stakeholders thoughout the region in each of these thematic areas (http://www.hioos.org) and proposes to maintain and expand those services. An iterative process of engagement, outreach, and extension of HiOOS data streams has clearly defined stakeholder needs for additional customized and integrated products. To that end, HiOOS will continue to develop an ocean observing network in the aforementioned thematic areas and within those foci tailor product development in the coming fourth year on: *(1) High Water Level and Coastal Inundation Forecasting, (2) Water Quality Indices for Coastal Waikiki, and (3) Predicting Conditions Approaching and in Harbors*. In addition, HiOOS will: 4) continue development of the Hawaii fish-tracking array—a regional component in a larger global network that monitors animal movements at different scales, as well as 5) update, integrate and serve information for marine spatial planning.

Products: Specific examples of data products that will be developed given requested funding:

- daily maps of surface currents, winds and wave heights for each island domain (based on now-cast model runs), including archived maps of past days;
- similar maps providing daily forecasts out to three days;
- time-series plots of tide levels based on tide gauges (for past days) and numerical model (for forecasts) for various locations around the islands;
- time-series plots of temperature, salinity and turbidity from the near-shore sensor network with extreme levels shown (indicating days of potential poor water quality);
- near-real time vector plots of surface velocity from the HiOOS HF radios;
- plume dispersion maps based on daily model runs providing flow estimates for various outflow regions
- predictions of ocean conditions approaching and in harbors (including seiches and other extreme events);
- search and rescue advection probabilities;
- maps of coastline change and areas of vulnerability;
- forecasts of road over-topping events based on wave, tide and circulation models;
- layered marine spatial data to serve marine spatial planning.

b. Background

Hawai‘i’s distinctive beauty reflects the strong interaction between its coastal oceans, littoral margins, steep watersheds and biological diversity. Hawai‘i is uniquely an ocean state; 99% of its surface area is ocean (including EEZ). Half the land lies within 5 miles of the shoreline and the whole of the State is within the coastal zone. Its tourism, transportation, defense and food industries are marine dominated. Human activity, therefore, is tightly coupled to the marine ecosystem—we are the top predators, introduce nutrients and pollutants, redistribute sediments, alter environmental links between land and sea, impinge upon the natural biological order of the ecosystem and, in the process, increasingly expose ourselves, our visitors, and our endemic biota to natural and anthropogenic hazards, ecological depletion, and environmental stress.

Present Situation: The Hawai'i Ocean Observing System (HiOOS) was *initiated* in FY07 with a cooperative agreement between SOEST and NOAA awarded as a result of the IOOS RCOOS peer-reviewed competition. HiOOS was designed as a demonstration project within the larger Pacific Islands Ocean Observing System (PacIOOS) region that could be jump-started by leveraging substantial SOEST capacity and partner assets/funding. Its continued development is being undertaken as part of the national IOOS, with the down-stream intent of transferring technology, expertise, and best practices to other archipelagos in the PacIOOS region should adequate funding become available. The initial focus of the Hawaiian effort, similar to the current focus of the national IOOS program, has been the provision of operational products that assist agencies responsible for a safe, clean, productive ocean and resilient coastal zone. Early scoping meetings with multiple agency personnel, followed by sustained, iterative stakeholder engagement, led HiOOS to implement regional modeling, sensor deployment, and data integration in four key product areas: *Coastal Ocean-State and Forecasting, Coastal Hazards and Resiliency, Water Quality Sensing, and Marine Ecosystem Monitoring*. New sensors were deployed primarily along the south shore of Oahu, the center of population, commerce and tourism (Table 1). They leveraged significant existing (non-IOOS) ocean observing assets throughout the whole of the Hawai'i archipelago (Figure 1) including: the cabled Kilo Nalu Observatory (NSF/ONR), the CRIMP-CO2 system in Kaneohe Bay (NOAA-PMEL), the Hawai'i Ocean Time Series (NSF), Coral Reef Ecosystem Integrated Observing System — CREIOS (NOAA-PIFSC), NOAA CO-OPS, the UH Sea Level Center (NOAA-JIMAR), CDIP, NOAA-NWS, the Ocean Tracking Network, and various county and state agencies (especially for water quality and fish tag monitoring at aggregation devices).

c. Audience

Given the strong presence of the ocean in all aspects of life in Hawai'i, the need for a better understanding of the ocean environment is pervasive. For example, emergency responders identify drowning as the #1 preventable cause of death among visitors and residents. County planning departments cite coastal erosion, sea-level rise, and the lack of data to define appropriate setbacks as major management challenges. State and county water quality personnel and environmental groups recall the 2006 spill of 48 million gallons of raw sewage into Waikiki waters and ask for real-time monitoring of water quality and knowledge of the fate of such spills and their effects. Island communities and transportation officials point to the marine commerce industry as providing a lifeline of food and necessities between the mainland and Hawai'i and along the island chain. Harbormasters, recreational and commercial boat owners, and government maritime agencies desire accurate measurements and predictions of the state of the coastal and open ocean and of the seiche amplitudes in their harbors forced by winds, high swell, storm surge and tsunamis.

The users for ocean observing products are spread across all levels of government, the ocean recreation and commerce (fishing, transportation, offshore energy) communities, the hotel and tourism industry, the media, residents and visitors, and nongovernmental organizations. Despite their diversity and range of interests, this audience is asking for increasingly focused, innovative, and highly accurate products upon which to base decision-making, planning, user safety, and future cultural and community emphasis. In all cases, partners and investigators recognize that web-based, dynamic and frequently updated map-oriented products can provide ocean end users with an improved basis for decision-making and planning.

d. Approach

Development of initial data stream/products within the four catalyst projects during the current funding cycle of HiOOS and the distribution of same through an evolving web interface has facilitated an iterative process of user engagement to refine content structure and delivery. Through this engagement we have identified three main product suites within the region that our proposed ocean observing system enhancements will add in the coming year: 1) high water level and inundation forecasting; 2) water quality indices for coastal Waikiki; and 3) predicting conditions approaching and in harbors, for the commercial and recreational boating communities. In addition, HiOOS will: 4) continue its development of the Oahu fish-tracking array—a local component in a larger global network that monitors animal movements at different scales, as well as 5) update, serve and integrate information for marine spatial planning. These focus areas rely on data streams from several component groups of HiOOS. Plans for the continued maintenance, as well in some cases enhancement, of these focus areas and component groups are described as follows.

1. Water Quality

In order to accurately assess water quality in the densest use area we have deployed an observational network of cabled platforms, autonomous underwater vehicles, and moorings along the coastline and in the nearshore waters off Honolulu-Waikiki (Figure 1D). Our aim in the coming funding cycle is to merge data streams from those and leveraged sources (City and County of Honolulu, State Department of Health) with modeling output and HF Radio observations in order to generate a suite of real-time map-based visualizations showing water quality indices related to water clarity, salinity, temperature, and chlorophyll-a concentration. In order to make quantitative determinations for these indices, we propose to use existing instrumentation and targeted augmentation to portions of the existing array to measure light attenuation (turbidity), surface water salinity, temperature, and fluorescence (chlorophyll-a).

Water Quality Observational Network Components

The Kilo Nalu Observatory is a cabled ocean observatory situated within the focus area of the HiOOS water quality observing network (Figure 1D, E) that has been in operation since 2004.

Kilo Nalu serves as both a power and communications hub for some of the HiOOS platforms in the area as well provides information on wave state and currents, light attenuation, salinity, temperature and chlorophyll-a throughout the water column.

HiOOS currently operates an array of five nearshore sensors packages—three measure light attenuation, salinity, temperature and fluorescence, while two monitor only salinity and temperature. In addition to this nearshore sensor network HiOOS operates two CO_2 and water quality buoys in cooperation with NOAA's Pacific Marine Environmental Lab (Table 1, Figure 1D). These systems are core components of the *global* CO_2 monitoring network (Figure 2) and measure - in addition to light attenuation (turbidity), surface water salinity, temperature, and fluorescence (chlorophyll-a) - dissolved oxygen (DO) and CO_2 in both the atmosphere and water. These Eulerian water quality monitoring systems are augmented by routine autonomous underwater vehicle (AUV) surveys that examine light attenuation (turbidity), surface water salinity, temperature, fluorescence (chlorophyll-a), and current magnitude and direction throughout the water column.

Augmentation of the Water Quality Observational Network

In order to better understand the temporal dynamics of water quality, we request funding to upgrade two nearshore sensors packages to measure light attenuation (turbidity) and fluorescence (chlorophyll-a) (in addition to surface water salinity, temperature) and propose to maintain the remaining nearshore sensors and water quality buoys as they are currently configured.

In order to better understand the spatial dynamics of water properties in the study area we propose to expand the AUV surveys from 12 per year to 40 per year. This expansion will allow for greater frequency in regular surveys as well as provide for targeted event-driven surveys. Additionally, we propose expanding the survey area of the AUV to the whole of the Waikiki area (present area shown at http://www.soest.hawaii.edu/OE/KiloNalu/AUV/Remus.htm). The proposed work within this and other product suites depends on the continued use of the Kilo Nalu baseline array to provide data on water quality and properties, currents, waves and stratification. Kilo Nalu charges HiOOS monthly access charges based on estimated annual costs for technical support, management, administration and peripheral expense to maintain and operate the backbone cabled system, distributed among a target base of eight users. We request funding for an additional year of support for this system.

2. Coastal Hazards & Resiliency: High water level and coastal inundation

The coastal margins of the Hawaiian Islands are vulnerable to both long-term and episodic changes in coastal water levels. Observing systems are in place to assess sea-level rise and interannual to decadal sea level variations for the region; however, the immediate local need is for predictions of short-term, high water level events. The combination of spring tides with seasonal swell events lead to the over-topping of coastal roads, flooding of storm drains, and inundation of low-lying beaches and coastal margins. The addition of positive water level anomalies associated with mesoscale eddies and other ocean circulation features can exacerbate the impacts of these events, and the frequency and severity of inundation will increase with rising sea levels. Our intent is to show the efficacy of an inundation prediction product for Hawai‘i based on HiOOS model and observation resources, and then expand the capability to other territories/nations as appropriate in concert with PacIOOS and PI-GOOS.

The oceanic components that lead to inundation events can be predicted several days to a week in advance with acceptable skill. Wave buoys and regional models give nowcast conditions, and basin wave models provide predictions of near-term wave event arrivals. Tide gauges yield the long time series needed to predict the surface tide, and tide models provide a means to extrapolate the predicted tidal signal between tide gauge locations. Tide gauge and altimetry data can be used to assess mesoscale eddy events and low frequency variations in regional sea level. Kalman filtering has been used to extrapolate sea levels several days into the future. The largest uncertainty for coastal inundation estimation for Hawai‘i is the specification of swell and lower frequency (infragravity, setup) run-up energy at the shoreline. Run-up estimates are sensitive to the width and depth of offshore reefs as well as their roughness scales. SOEST high-resolution maps of nearshore topography are being used to parameterize the details of reef systems, and accurate and highly resolved digital elevation models (DEMs) are in place to map the inundation line along the coastal margin.

During the first two years of the HiOOS project, we have focused on developing the data streams needed to specify all components of high water level events. To develop a run-up forecasting capability, we have deployed an observational network of digital cameras and tripod scanning LIDAR (t-LIDAR) at two focus sites on Oahu (Waikiki, Waimea). The camera and t-LIDAR data are combined to map the elevation of the run-up line along the beach during a range of wave and water level conditions, which are specified using bottom-mounted sensors in the nearshore. Using these resources, we have developed an empirical model for run-up based on incident wave and water level conditions. During the third year, the observational and model data streams are being combined into a nowcast and up to 6 day forecast product of extreme swash/water level events at these two locations. The highest reach of the waves during these events will be mapped on the coastal DEMs.

We request funding to maintain the various components that go into the coastal inundation product. The present network of HiOOS near-shore sea-state instrumentation and wave buoys (in partnership with CDIP) requires ongoing maintenance to remain in operation. Personnel are needed to continue the camera and t-LIDAR datasets, which provide real-time run-up observations that are posted on the HiOOS website, as well as the time series needed to validate and improve the inundation nowcast/forecast product. In addition, we plan to extend the camera and t-LIDAR dataset to provide estimates of variable beach state (erosion/accretion phases) as a function of incident wave forcing and water level conditions. Funding is also sought for personnel to quality assess the components that go into the inundation product, and to quantify the empirical inundation model skill versus prediction time, which will be added to the on-line inundation product. Also, see numerical inundation modeling for storm surge and tsunamis, under wave modeling, below. Finally, the extremely successful Hawaii Beach Safety site is being maintained with other funding (http://oceansafety.soest.hawaii.edu/).

3. Coastal Ocean-State and Forecasting: Harbors and their Approaches

Commonly identified as a state with a small terrestrial area, Hawaiʻi is most accurately depicted as a large-ocean state. The ocean is the primary pathway for transport of food, fuel, manufactured goods and raw materials to, from, and between the islands and provides the backbone for the commercial and recreational maritime economy. The ocean is Hawaii's inter- and intra-state highway and railway, and *every shipping route to and between the islands uses one of the three principal ports on Oahu (Honolulu, Pearl Hbr., Barbers Pt*., Figure 1C). This is a primary driver for the focused observing and modeling domain on the south shore of Oahu.

Essential to the efficiency, safety, and timeliness of transit in the marine environment is reliable information on the present state of the ocean as well as timely and accurate forecasts on future ocean conditions. HiOOS presently operates the initial components of a planned observational network of high-frequency radios (HFR), ocean gliders, wave buoys, coastal ocean and harbor moorings, and numerical models in order to produce the most accurate information possible, especially for harbor conditions and their approaches. This information is served in real- and near real-time via the HiOOS website and is used to update the information provided in the Hawaiʻi Ocean Atlas (http://www.soest.hawaii.edu/hioos/oceanatlas/index.htm).

With the development and move towards an operational modeling system and, through the integration of existing data streams (HiOOS and leveraged assets), it is now possible to expand our ocean information services beyond real-time measurements and begin providing ocean state forecast products. To accomplish this new forecasting role we request support to maintain the existing observational network as well as expand our capability with the deployment of two HFR on the western coast of Oahu and a deep water multipurpose ocean mooring off the southern shore. This deep-water mooring, manufactured by Ocean Origo, will consist of fixed sensors and a profiling package that traverses the full water column (Figure 3). Measurements will include the full range of properties (T, S, DO, Turbidity, chlorophyll-a, PAR) as well as waves and currents. Not only a primary data source, it will become an essential node in the validation of HFR and model products.

In the present funding cycle we have begun to address the needs of the maritime industry through a focus on shipping activities related to Barbers Point Harbor, the second most active commercial harbor in Hawaii. After consultation with the State Department of Transportation and ship pilots, we identified three need areas: 1) water level and seiche motions in the harbor, 2) wave activity at the main fuel dock, and 3) currents that impact ship operations in the narrow entrance channel. We have installed a water level station at the fuel dock that reports real-time water level, as well as energy levels at swell and seiche periods. We are working with the U.S. Coast Guard to install a side-looking acoustic current meter to observe the entrance channel currents. We plan to install this system, with real-time data transmission, within the next several months. In addition, we will deploy a fourth Datawell Directional Waverider buoy off the Barbers Point area for direct information on the incident swell associated with southern swell and Kona storm events. In addition to Barbers Point, we are partnering with CDIP to provide real-time wave, seiche, and water level information at Kaumalapau Harbor on Lanai as part of HiOOS. For the 4th year of the project, we propose to maintain the two water level stations, the offshore Datawell buoy, and the entrance channel current meter. Quality assessment of all data streams and improvement of derived products in coordination with the identified user groups will be undertaken by a part-time analyst.

4. Marine Ecosystem Monitoring: Fish Telemetry

SOEST is a major partner in the Ocean Tracking Network (http://www.oceantrackingnetwork.org) and currently supports an array of automated acoustic receivers that stretches the whole of the Hawaiian archipelago, from Midway Atoll to the Island of Hawai'i. These receivers monitor the presence of fish tagged with acoustic transmitters that broadcast a unique identification code and other information (depth, water properties). This array monitors movements of ecologically important top predators, and the data collected from this system are used to estimate transfer rates between areas, describe patterns of residency and associative behavior of groups of fish, to improve estimates of the population size, and to better inform local agencies regarding public safety issues with respect to sharks. We request funds to maintain this novel acoustic array and to continue the integration and distribution of ecologically important data to stakeholders through the public and private sector.

Two HiOOS-funded Ecological Acoustic Recorders have been added (at Kilo Nalu and in the east Oahu humpback whale sanctuary) to the NOAA-CRED array (Figure 1), with that at Kilo Nalu being the only real time system. These will be maintained by other funding to Whit Au who, with a graduate student, is developing an automated whale detection system.

Modeling

Three modeling systems (atmospheric, waves and ocean circulation) produce a comprehensive package for ocean state prediction. The atmospheric Weather Research and Forecasting (WRF) model is used to generate daily nowcast and forecasts for the entire island chain as well as higher resolution runs for each island. These are provided directly to the local National Weather Service office and are used by the wave and ocean models for forcing. Using the Simulating WAves Nearshore (SWAN) model, daily nowcast and forecasts of ocean wave conditions are produced for each of the main Hawaiian Islands. These forecasts provide estimates of wave run-up and will allow estimates of inundation for use by state and federal agencies during storm mitigation efforts. The ocean circulation is produced using the Regional Ocean Modeling System (ROMS) model in a nested configuration. Each day, nowcast and forecasts of the ocean state are generated using advanced 4D-Var data assimilation to combine the observations and the models in a dynamically consistent way such that the result should be more accurate than either alone. The ocean circulation fields are currently used to generate a number of products for stakeholders including: circulation estimates and forecasts, plume dispersal, and search and rescue.

Atmospheric: We propose to expand our validation efforts and begin work on assimilation of non-traditional data in the WRF model to improve now-casts and (potentially) forecast skill. Because of the presence of steep terrain, the airflow over the island and coastal waters is strongly modulated by the land/sea thermal contrast during diurnal heating cycle. Large variations in the ground cover and surface properties, ranges from humid tropical rainforest on the windward slopes to lee-side semi-arid regions, are typical in Hawai‘i. Over Oahu, there are 13 surface stations and 69 hourly rainfall stations. Data collected from these stations will be used to verify the diurnal variations of the surface winds and weather simulated by the WRF model.

We propose to test the WRF data assimilation schemes. We have received funding to send someone to visit the Development Testbed Center/UCAR for one month (http://www.dtcenter.org/). Located in the mid-Pacific Ocean with limited conventional *in situ* observations, Hawaii is an excellent place to test the impact of remotely sensed data (e.g., satellite, radar, and etc.) in model initial conditions on high-resolution weather modeling.

Waves: Inundation estimates will be the 4th year focus of the wave group. The recently developed one-layer, non-hydrostatic numerical model for tsunami and storm inundation analysis will be used to cover the major Hawaiian Islands for water-level forecasting. This utilizes a two-way nested grid system to provide high-resolution inundation forecasts on Oahu's north and south shores. For example, we utilized a suite of five interoperable numerical models to describe the winds, surge, waves, surf-zone processes, and run-up to delineate coastal flood hazards from a series of Category IV hurricanes developed by the NWS Central Pacific Hurricane Center. This formed the environmental input to the Hawaii Catastrophic Hurricane Operations Plan recently developed by FEMA and Hawaii State Civil Defense. *This is the only catastrophic hurricane operations plan in the country that incorporates physics-based modeling of hurricane impacts*. It is imperative to our stakeholders to provide an event-based inundation forecast for emergency management. In addition, inundation forecasts for the coastline near Waimea Bay will be very helpful during the winter swell season. *Our inundation model won the 2009 Benchmark Challenge at the Inundation Science and Engineering Cooperative Workshop* in Oregon (http://isec.nacse.org/workshop/isec_workshop_2009/). It gave the best performance among more than 10 models examined, including models from NOAA-PMEL, USACE, and USGS as well as the commercial package Delft3D.

Ocean: The ocean group continues to develop assimilation techniques that are combined with forecasting efforts for the region. Using the assimilation procedure (observation-space, variational adjustment), we have the capability to generate the statistics of how each individual observation contributes to the forecast skill, as well as an estimate of the uncertainty in the nowcast. In year 4 we will begin generating estimates of the impact of each observation on the now-cast quality, as well as begin efforts towards coupling the atmosphere and ocean models by providing SST and surface forcing increments to the atmospheric model. We plan to provide circulation estimates to the inundation model in the wave group to assist with forecast estimates. We also intend to transition to a combined circulation/tidal model. We currently have developed a circulation model with tides in parallel to the present operational system, but it needs the validation and observational processing to be incorporated in year 4.

Data Management System and Product Development

Central to the HiOOS effort, and critical to its success, is the link between data (instruments) and information (data-synthesis products) in the Data Management System (DMS). The initial focus of the HiOOS DMS has been to provide the architecture through which data from the observing network could be archived, evaluated, integrated, and transmitted to users in the form of raw data and refined products. The main binary server is based on the Thematic Real-time Environmental Distributed Data Services (THREDDS). THREDDS is based on OPeNDAP, and allows for direct binary access to gridded data through URL calls. The THREDDS server also provides Web Coverage Services (WCS), and the HiOOS implementation includes a simple Web Map Service (WMS). These three servers (THREDDS, WCS and WMS) have all emerged as de facto standards within the IOOS data community. An additional server for in situ data, called Sensor Observation Service (SOS) will be configured through this proposed effort. The IOOS DIF is promoting SOS for all point-based measurements. In addition, HiOOS has started two different web-based browsing tools: a Live Access Server (LAS) and DChart. These two allow users to make time/space subsets, quick plots, downloads and more through a web interface. The data management group has successfully constructed a system for the management of raw and processed data and can, now that the stakeholder engagement process has articulated clear needs, expand its focus to include product development for distribution to the broader public.

A proposed additional task that will involve the HiOOS DM team is the construction of data products. Product generation will be facilitated through the creation of a product development team within the DMS. The team will consist of existing HiOOS members and, through this proposal, additional new hires. Three main groups will work together to draft, refine, and develop products that meet specified user needs in the product suites defined above. One group will have expertise in graphic design; the second group will have web development and programming skills; the third group will have the scientific knowledge to understand the data and how they would fit together to form a timely, accurate, and reliable product. These groups will work closely with stakeholder representatives to deliver relevant, useful timely information about our ocean systems to the community.

5. Marine Spatial Planning

One specific ongoing task for the DM team will be to update, integrate and serve existing marine spatial data. This will be built, literally, from the bottom up – starting with the SOEST-HMRG synthesis of Hawaiian multibeam bathymetry (http://www.soest.hawaii.edu/HMRG/Multibeam/index.php). It will link to and incorporate existing coastal/marine layers from the Hawaii Statewide GIS Program (http://hawaii.gov/dbedt/gis/download.htm#COASTAL/MARINELAYERS) as well as NOAA, USGS, etc, equivalents. For example, NOAA's benthic habitat maps for Oahu have already been added via a Google interface, and for the other islands will be added this year (http://www.soest.hawaii.edu/hioos/habitats/BioCoverTypes.php). Accommodating multiple, cumulative and potentially conflicting uses of marine areas is a growing issue for all coastal states, including Hawaii, which is home to the Hawaiian Islands Humpback Whale National Marine Sanctuary (Figure 1), the Papahanaumokuakea Marine National Monument, numerous bottom fish and other marine protected areas, restricted military marine areas (such as associated with the Pacific Missile Range Facility, Pearl Harbor and Kaneohe Marine Corps Air Station), commercial aquaculture sea cages, fish aggregation devices, inter-island IT cables, dump sites, offshore sewer lines, ocean recreation areas, etc. To this add proposed offshore energy (OTEC and wave power) sites and proposed inter-island electric power cables (that currently require 70 different Federal, State and County permits) and the need for better information products to support MSP is clear.

Educational Outreach

The educational outreach specialist will continue to work closely with principal investigators and technical staff to effectively interpret and communicate complex scientific information to natural resource managers, researchers, educators, and the public in a clear, understandable manner. She will focus on two major project areas: (1) working with the Data Management group to maintain and update an effective web presence and (2) increasing the impact of ongoing public outreach efforts.

The educational outreach specialist will liaise with users to ensure that the data products generated meet their respective needs. This feedback is a critical component that will allow researchers to modify their products in response to user input. As concerned residents of the State of Hawaiʻi, we are dedicated to the education of our public. Many efforts have been made to increase awareness for HiOOS activities among community members and students during the past 24 months. By showcasing HiOOS data on flat panel displays in high traffic areas (as proposed at the Waikiki Aquarium and collaborating yacht clubs), creating community user-specific data visualizations for use on the internet and other educational venues, and touring a mock glider we will ensure an expanded outreach effort with greater visibility. Effective web presence works synergistically with our public outreach goals. Specifically, the HiOOS website will benefit from the addition of data visualizations, activities, demonstrations specifically aimed at education and outreach applications, and, from these same efforts, collaborative projects with the Waikiki Aquarium, the NOAA-funded Navigating Change (curriculum) Program and others will benefit.

As educators in the University of Hawaiʻi system we are also dedicated to the education of our undergraduate and graduate students. This proposal will continue to provide the foundation for research experiences for both undergraduate students through the degree program in Global Environmental Science (GES), and graduate students through the MS and PhD degree programs.

The development of the Kaneohe Bay Information System (KBIS), a system envisioned to be a clearinghouse for information on ecological data and history from Kaneohe Bay, Oahu, is complementary to the HiOOS educational outreach goals. This proposal seeks collaboration between HiOOS and KBIS on 1) the compilation of available data and community stories, and 2) the creation of curriculum and data visualizations. Coordinating our efforts will enhance KBIS and expand the geographic scope of HiOOS outreach efforts.

Project Management Structure

The Hawai‘i Ocean Observing System is currently led by PI Brian Taylor and managed by co-PI Chris Ostrander, co-PI Alexander Shor, and a steering committee comprised of the remaining co-Investigators. This leadership team works to ensure the direct project goals are effectively achieved and that the system continues to generate data and products that are valuable and relevant to the user community. Additionally, Taylor and Ostrander serve on the Executive Council and Working Group, respectively, of the inter-agency Hawaii Ocean Resources Management Plan. It is recognized, however, that a transition of leadership to a governance structure focused on direct stakeholder engagement is essential for the long-term success of the system. The HiOOS leadership has drafted a vehicle for that transition and is currently refining the Memorandum of Agreement (MOA) prior to implementation in Year 3.

The MOA calls for a governing council comprised of representatives from stakeholder groups that benefit from and provide resources to ensure the success and viability of the system. The governing council provides strategic direction, oversight, and policy guidance to an Executive Director (currently HiOOS Coordinator Ostrander) who is tasked with the system management and administration, coordination between partner organizations and the broader PacIOOS regional association, and representation of HiOOS on a national level. Input to the governing council on product requirements, system design, and growth of the physical observing network will be provided by a stakeholder council comprised of interested users throughout the ocean community.

e. Benefits

The users of ocean observing information and products are spread across all levels of government, the ocean recreation and commerce communities, the hotel and tourism industry, the media, residents and visitors, and NGOs. Their continued engagement and feedback will guide our product development, refinement and distribution. HiOOS information and products feed up to national and global ocean monitoring programs. The OSTP draft of a National Ocean Policy clearly recognizes that national policy must be regionally coordinated and implemented.

Improving Community Resiliency to marine inundation will be achieved by developing products related to high waves/swell/tides, storm surge/tsunami, coastal geomorphology, and rising sea level. Our goal is to integrate numerical/empirical models and sea-state observations, coastal run-up, coastal GIS and DEM layers, to produce a line of web forecasts of marine inundation, highway overtopping, erosive wave events, beach safety conditions, and interpretive products that quantify community vulnerability under higher sea levels. Identified users include county ocean safety personnel and emergency responders, state and county public works offices, civil defense, land use managers, USACE-Navy-USCG-NOAA, media outlets, and the public at large.

Water Quality: The main goal of the water quality product suite is to enhance public health and safety in the coastal zone. The development of water quality indices, spatial maps of surface water properties, early warnings of potential water quality events, and the real time distribution of water properties to the stakeholder community will allow agency personnel to respond quickly to developing hazards, to accurately predict beach water quality conditions, and monitor potential for beach closures. Such products will also be tailored for ready integration into the daily decision-making of visitors and island residents alike. Key users include immediate responders from the Hawai'i State Department of Health (Clean Water Branch), the City and County of Honolulu (Department of Environmental Services), land use managers, NOAA officers, and the EPA.

Ocean-State Forecasting, especially for Harbors, their Approaches and Beaches: The ocean equivalent of the weather service is desired by all sectors. Hawai'i ocean hazards are highly variable in space and time and the requirements for real-time offshore hazard warnings and other information products are substantial. Moreover, when search and rescue missions are mounted these variable conditions must be taken into account to be most effective. We will continue working with the NWS Pacific Region and the USCG to develop warning and search & rescue products that meet federal requirements while better serving the cruise ship industry, commercial shipping, and recreational users.

Improved warnings of Hawai'i's nearshore hazards are needed for myriad recreational user groups. Dangerous wave conditions and associated currents are a perpetual reality along Hawai'i's beaches, reefs and rocky coasts, at harbor entrances and within harbors. Numerous successful lawsuits have claimed inadequate warnings of hazards, and improvements in this regard will find immediate application among emergency responders and ocean safety personnel. SOEST already provides daily updated (or more frequently, if needed) beach hazard ratings (www.hawaiibeachsafety.org). The success of this product reflects direct product engineering based on user-defined needs from state and county offices, the hotel and security industry, state health officers, lifeguards and emergency responders, tourism officials, and others.

Marine Ecosystem Monitoring - Fish Telemetry: Responsibilities for monitoring and protecting marine resources falls on the Hawai'i Department of Land and Natural Resources, Division of Aquatic Resources (DAR) for state waters and on NOAA Fisheries and the Western Pacific Regional Fishery Management Council (WPRFMC) for Federal waters. Per-capita fishing participation in Hawai'i is the highest of any state by an order of magnitude. Recreational and commercial fishers using small boats in Hawai'i make approximately $5x10^5$ fishing trips per year landing $5x10^6$ pounds of ahi (yellowfin tuna, *Thunnus albacares*). Charter fishing is one of Hawai'i's major tourist attractions and commercial pressure to expand this sector is increasing. Occasional shark attacks makes understanding shark movements of high interest to the public.

Marine Spatial Planning: Accommodating multiple, cumulative and potentially conflicting uses of marine areas is a growing issue for all coastal states. Updating, integrating and serving marine spatial data will help planners and policy makers manage overlapping use requests between the commercial, recreational, environmental, military, and other governmental, sectors.

Educational Outreach: The Hawaiian phrase which is the HiOOS by-line is "i ka nana no a ike" (by observing we learn). By engaging and educating "K through Gray" about the ocean, successive generations may make informed choices to better use and preserve this life-giving resource.

f. Milestone Schedule

A timeline for major tasks, target milestones for product development, and key project outcomes are graphed in Appendix 2. Lines in blue represent observations; lines in red represent products; and lines in black represent modeling efforts.

g. Project Budget

See Appendix 3 (Budget) and Appendix 4 (Detailed budget information).

4. APPENDICES

APPENDIX 1: Figures and Tables

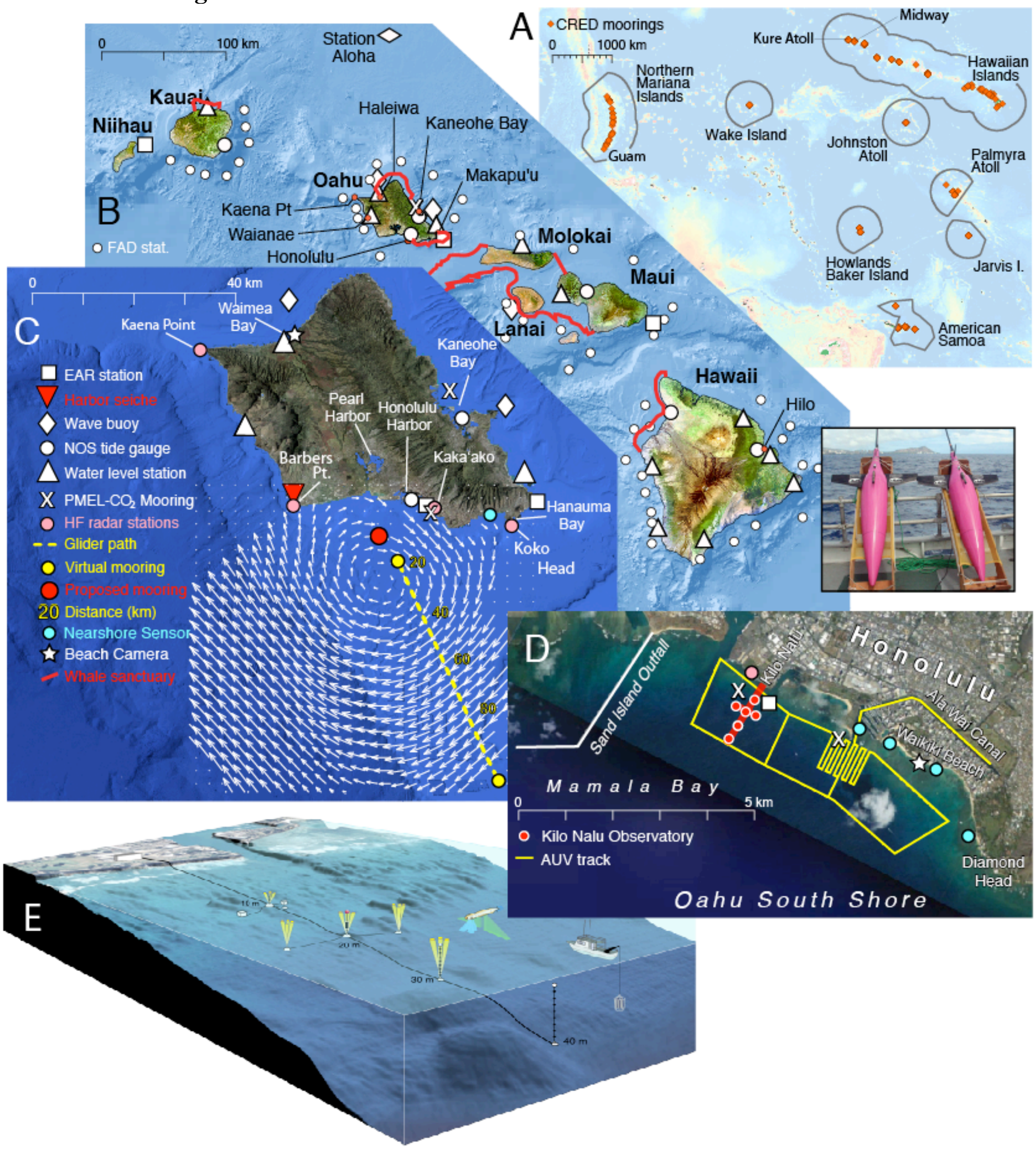

Figure 1: (A) The PacIOOS region including the locations of existing CRED monitoring stations. (B) The main Hawaiian Islands showing existing observing system components and the boundaries the Hawaii Islands Humpback Whale National Marine Sanctuary. (C) The island of Oahu with existing and proposed observing system components. (D) The Waikiki section of Mamala Bay showing existing observing system components including the expanded survey route of the AUV. (E) The Kilo Nalu Nearshore Observatory off of Kaka'ako, Oahu.

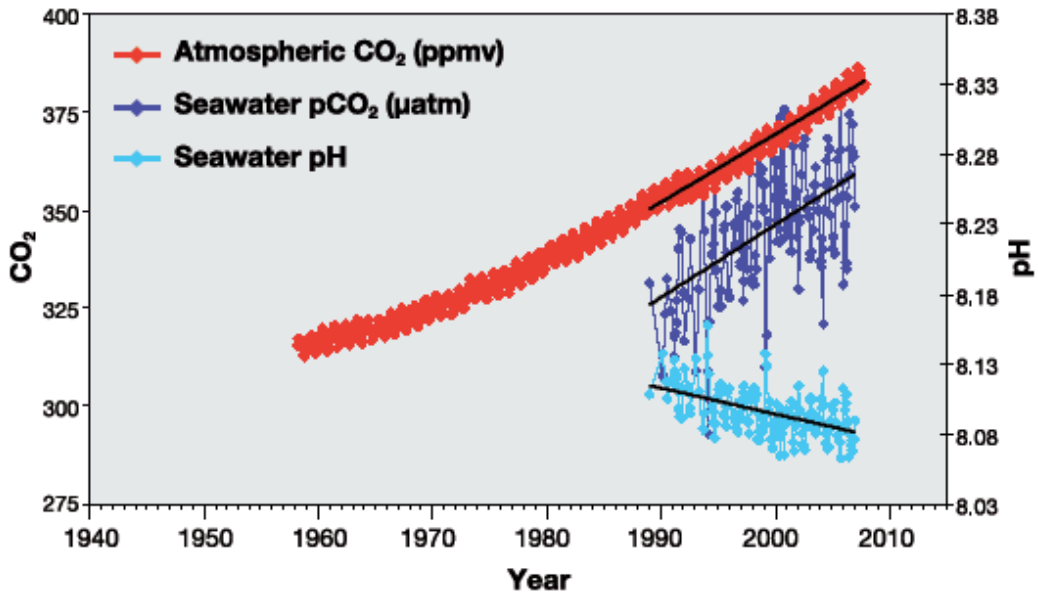

Figure 2: Observations in Hawaii provide the longest time series of global CO2 monitoring and ocean acidification, including the "Keeling curve" (red) from SIO-NOAA atmospheric measurements on Mauna Loa and the Hawaii Ocean Time series measurements, including pH (blue), at Station Aloha (adapted from Feely, 2008, Bull. Am. Meteorol. Soc. 89(7): S58). To these, in partnership with NOAA-PMEL and HiOOS, Eric DeCarlo has added over the last several years 3 CO_2 buoys, which monitor the coastal ocean pCO_2 and pH in Kaneohe Bay and off Honolulu (see Fig. 1)

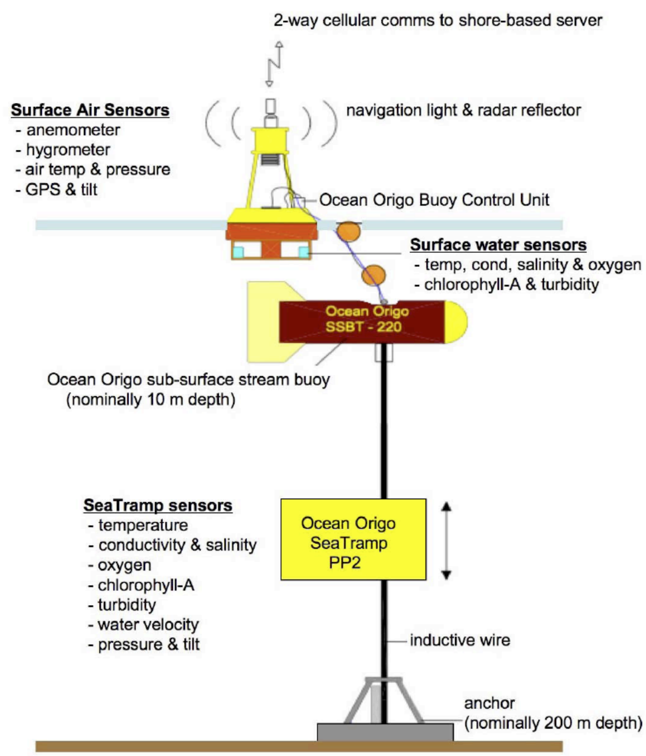

Figure 3: Diagram of the proposed deep water mooring for the southern shore of Oahu.

Table 1: IOOS-funded observing network assets currently operated by HiOOS. More information about system type, variables measured, and location can be found at http://www.soest.hawaii.edu/hioos/data_product/assets.php.

Component Group	Instrument Type	Variables Measured	Location(s)
Kilo Nalu	ADCP Thermistor Seahorse Profiler	currents (u,v,w)Ts,Dp,Tp T T,S,P,turbidity,DO, chlorophyll-a	Kaka'ako, Oahu Kaka'ako, Oahu Kaka'ako, Oahu
HF Radio	WERA	Surface currents (u,v),Ts, Dp, Tp	Kaka'ako, Oahu Koko Head, Oahu
Nearhshore Sensors	SBE 16+V2 ECO FLNTUS	T,S,P turbidity, chlorophyll-a	Ala Wai Harbor (x2) Waikiki Coast (x3) Ala Wai Harbor (x1) Waikiki Coast (x2)
Gliders	iRobot SeaGlider	T,S,P,DO, chlorophyll-a	Various
Waves and Water Level	Waverider Buoy Nortek Aquadopp Nortek AWAC	Ts,Dp,Tp,Ta,SST currents (u,v,w), P, T currents (u,v,w), P, T	Waimea Bay, Oahu Mokapu Point, Oahu Kamalapua, Lanai Kalaelao Harbor, Oahu Barbers Point, Oahu
Coastal Hazards	T-LiDAR Camera (PL-A741)	coastal imagery coastal imagery	Waimea Bay, Oahy Waikiki Beach, Oahu Waimea Bay, Oahu Waikiki Beach, Oahu
Water Quality	PMEL-CO2 Buoy	T,S,P, DO, CO2, turbidity, chlorophyll-a, nutrients	Kāne'ohe Bay, Oahu Ala Wai, Oahu Kaka'ako, Oahu
Remus AUV	Remus AUV	T,S,P,DO,turbidity, chlorophyll-a, currents (u,v,w), bathymetry	Various (Waikiki)
Fish Telemetry	VR3S modem Fish tags	data telemetry from tags T, P	Various (Hawai'i FADs) Various

APPENDIX 2: Milestones

Text in blue denotes equipment deployment, red denotes product/data development, and black denotes modeling development.

Q1	Q2	Q3	Q4
1-2 gliders deployed continuously			
Glider subsurface temp/salinity on-line			
	Ka'ena Barbers Point HF Radios deployed		
	Radio surface current maps on-line		
Bi-weekly AUV surveys			
AUV survey data on-line			
	2 Nearshore stations upgraded		
		Water quality indices on-line	
Sea level heights/trend products on-line			
		SeaTramp mooring deployed	
	High water level product on-line		
			Inundation model/product on-line
T-LIDAR surveys ongoing			
RSM/MSM atmospheric model in operation			
ROM circulation model in operation			
WRF atmospheric model in operation			
	WFR data assimilation		
Regional wave model in operation			
			Integrate tidal and circulation models
Model data and products on-line			
		Harbor approach and ocean condition products online	
Transmitting tags deployed on pelagics throughout year			
Service acoustic receivers throughout year			
	Collate and prepare biological results for integration/model forecasting		
Update, integrate, and serve marine information for marine spatial planning (ongoing)			
Kāne'ohe Bay Information System development ongoing			
	Educational displays installed		

APPENDIX 3: Project Budget

University of Hawaii
Developing the Hawaii Ocean Observing System

Proposal Budget		Revised :10/16/2009 2:51 PM
Executive Summary		
A	Total Salaries and Wages	969,772
B	Total Fringe Benefits	292,890
C	Total Travel	-
D	Total Equipment	476,220
E	Total Supplies	80,175
F	Total Contractual	12,480
G	Total Construction	-
H	Total Other	566,889
I	Total Direct Costs	2,398,426
J	Total Indirect Costs	601,574
K	Total	3,000,000