ARL/UHM TECHNICAL PROPOSAL SUMMARY

Previous fundamental research, funded through competitively awarded grants, has formed the basis for a strong underpinning of UHM’s support to the Navy. The focus of this research is on understanding the physical processes in the ocean environment with a particular emphasis on the Pacific region and applying core expertise in other designated areas. The ARL/UHM will enhance this focus and facilitate the continued close strategic partnering with Navy/DoD which is critical to solving system-related problems in the core areas of the ARL. UHM has demonstrated the ability to interpret and transition basic and applied research from academia to the Department of Defense (DoD). Over the past four decades UHM has performed scientific and engineering investigations in core disciplines for a diverse range of organizations including federal, state and local governments. Additionally, the Pacific region and Hawaii in particular are unique in their geographic strategic importance to DoD. The location and climate coupled with multiple unique facilities, like the Maui Space Surveillance facility, Pacific Missile Range Facility, and the Maui High Performance Computing Center, allow for an almost unlimited scope of investigative research activities. The School of Ocean and Earth Science and Technology (SOEST) on-going research programs include autonomous underwater vehicles development test and evaluation, biosonar and cetacean echolocation and the effects of manmade noise sources in the ocean, bathymetry, mapping and modeling and tropical atmospherics and oceanography. The Institute for Astronomy is a world renowned astronomical research center and includes the largest DoD telescope, the 3.67 meter Advanced electro Optical System. Ongoing astronomical investigations include a program for the discovery and characterization of Earth-approaching objects, detector programs and adaptive optic research and instrumentation. Hawaii’s College of Engineering continues to be a leader in the development of communication and computer networks and in development and testing of C4I systems, sensor hardware and signal processing algorithms. Additionally the college is renowned for its advanced research programs in LASER remote sensing and passive IR remote sensing.

ARL/UHM proposes to perform fundamental and applied research, engineering design and development, and technical support to the Navy in the areas listed below:
(1) We propose basic and applied research, and systems development, integration, test and evaluation, in the areas of ocean environmental effects and the interaction of natural and man made underwater noise sources on Littoral Anti-Submarine Warfare (ASW), marine life, mammals, and other Naval experiments. Other associated competencies have been developed in bathymetry, autonomous underwater vehicles, acoustic mapping and littoral topography, buried mine detection, advanced sonar and biosonar signal processing, and tropical atmospherics and oceanography.

(2) We propose astronomical research and applied engineering utilizing existing unique facilities and laboratories and development of world-class state of the art optics and sensors for defense applications. This research has been applied to advanced satellite tracking systems, development of adaptive optics, space observations coordination such as the Hubble Space Telescope and the Pan-STARRS program to detect and characterize Earth-approaching objects, asteroids and comets that may pose a danger to earth.

(3) We propose to develop, test and improve advanced electro optical systems, detectors, arrays and instrumentation. This competency had been applied to virtually all the astronomical research as well as other electro-optic devices including LIDAR, photonics, and other laser technologies.

(4) We propose research and applied engineering supporting improvements in the utilization of various regions of the electromagnetic spectrum, advancements in communications, networks and protocols, Command Control Communications Computer and Intelligence (C4I) systems hardware and signal processing. This capability has been applied to advanced radar technology, distributed processing, sensor network integration, design tradeoff studies especially in the areas of RF arrays, passive remote sensing, command and control integration and wave propagation.
Ocean Science and Technology (OST)

Broad Objectives:

A. Environmental Forecasting. The ARL ocean science and technology component will address the problems of developing, testing, evaluating, integrating and operating the full range of ocean prediction models from the deep ocean through the littoral zone to the shoreline, including ocean physics (dynamics, thermodynamics, acoustics and optics), biology, chemistry and geology. Development and implementation of forecast systems based on predictive models of oceanic variables is required to support Navy operations, including its various research and development activities in the field. The scope of these models must be expanded, and their performance improved. This requires a critical mass of multivariate ocean observations to strongly test model performance, to evaluate flaws, and to provide the basis for improvement and operational use. The ability to accurately forecast atmospheric forcing of the ocean with high spatial resolution is also essential. This hierarchy of nested and embedded models requires comprehensive systems integration to support improved environmental prediction for the Navy.

Excellent predictive models are necessary for successful ocean forecasting, but they are not sufficient; high quality initial conditions for the forecast cycle are also required. Data assimilation techniques must be further developed to consistently and uniformly meet this need. This requires sufficiently dense observations for testing assimilation techniques and their sensitivity to the type, quantity and distribution of observations. A particularly challenging objective is to ultimately configure predictive model systems to automatically identify sensitivity to errors in the initial conditions and to request specific observations needed to minimize forecast errors. Such adaptive sampling will be tested with fixed and relocatable measurement systems.

Enabling technologies must be developed to support the efficient acquisition of sufficiently accurate and dense ocean information over broad areas and diverse environments. Sensor capabilities and power capacities must be greatly enhanced to support expanded and extended mission requirements. Numerical ocean models will be used to guide sampling strategies. Observing systems must be accurately modeled to support development of field deployment planning, and to constrain adaptive sampling strategies. Transitioning these technologies into operational use is an essential element of the proposed ARL activities.
Building on the capabilities and facilities of the University of Hawaii, the ARL proposes synergistic activities that are essential for taking ocean forecast systems integration to the next level. The ARL will utilize a virtual testbed facility around the Hawaiian Islands that is characterized by its diverse environments and multivariate observational capabilities. These activities will play a crucial role in transitioning research applications into operational Navy capabilities, and they will support a spectrum of dual use applications.

B. Environmental Assessment. There is a general consensus that aquatic ecosystems worldwide have been adversely affected by human disturbances within the backdrop of a “shifting baseline”. For example, according to estimates provided by the Global Coral Reef Monitoring Network, 30% of the world’s coral reefs have already been substantially degraded while another 30% are forecast to be lost within the next several decades. Similarly, over 20 years ago it was known that of the 500,000 synthetic registered chemicals approximately 70,000 had found their way into aquatic ecosystems.

Researchers at the UH ARL propose utilizing and developing novel technologies for the assessment of ecosystem health to include evaluation of plant, animal, and microbe communities in conjunction with cutting-edge analytical assessment of water quality. Environmental stressors, such as those potentially stemming from activities of the military, do not usually directly affect changes in population density and community structure. Instead, these stressors directly affect molecular and cellular level processes, which in turn can affect higher-order processes (e.g., population density and community structure) in the biologic hierarchy. Hence, examination of molecular and cellular level behavior (i.e., biomarkers) is crucial in perceiving the relationship between causal factors and their biological effects.

Biomarkers are physical components or rates of reaction parameters) that indicate the condition or status of a biological property. Biomarkers are analogous to the concept of ‘parameter’ in mathematics; a single biomarker is a term or element in a functional process (i.e., a formula) that determines the specific form of the function, but not its general nature. For example, the rate of activity of an enzyme can provide information as to its working efficiency, but does not describe a physiological condition in of and by itself. To determine the condition of a physiological process, the behavior of other elements or parameters in that function must be known. One methodology that capitalizes on this concept is cellular diagnostics: a systematic approach to defining and
integrating biomarkers of exposure, effect, and susceptibility based on their functionality within a cell and how alterations in the behavior of a set of cellular parameters (biomarkers) may reflect overall cellular operation or performance. In terms of aquatic and terrestrial ecosystems, molecular and cellular biomarkers provide a means of assessing both qualitative and quantitative responses of organisms to a variety of stressors individually and collectively at sub-lethal levels.

This information, in turn, can then be used in the development of rational monitoring and remediation strategies.

Core Competencies and Background:

UHM has a broad range of ocean science and related engineering capabilities.

A. Physical Oceanography theory, observations and modeling
   • Water property distributions
   • Currents, from turbulence to general circulation
   • Sea level
   • Surface wave field
   • Internal waves

B. Biogeochemical Assessment

C. Marine Atmospheric Boundary Layer
   • Turbulent fluxes and air-sea interaction
   • Aerosol generation
   • Acoustic propagation

D. Remote Sensing
   • Microwave (Radars)
   • Acoustics
     o Currents
     o Bioacoustics of marine organisms
     o Echolocation in marine mammals
     o Infrasound Laboratory
   • Optics (see Sensors section)
     o Hyperspectral imaging
     o Raman spectroscopy
     o Fluorometry

E. AUVs - Autonomous Systems Laboratory
F. Survey Capabilities
   • Hawaii Mapping Research Group
   • Coastal Geology Group
   • HURL
   • Water mass properties

G. Numerical Models
   • Princeton Ocean Model
   • ROMS
   • MiCOM (IPRC)
   • Wave models (WaveWatchIII, SWAN)
   • Hawaii regional mesoscale meteorological model
   • AUV simulation model

Task Elements:

A. Ocean Science Basic and Applied Research:

   ARL/UHM proposes to conduct basic and applied research in the following areas:
   • Multiscale flow interaction with topography, including mesoscale eddy interaction with islands; large scale flow through channels; internal wave generation, reflection, and scattering; turbulence and mixing
   • Ocean surface wave transformation (by topography and currents) and littoral pumping
   • Sound and light propagation variability, including effects of benthic boundary layers, thin layers, sediment suspension, and spray and aerosols
   • Wave boundary layers, nearshore hydrodynamics and sediment transport
   • Ocean forcing (air-sea fluxes)
   • Adaptive ocean sampling
   • Seafloor characterization and hazards assessment
   • Buried mine and UXO detection
   • Marine mammal acoustics and ambient noise

B. Ocean Technology Research and Development

   ARL/UHM proposes to conduct R&D to enhance and extend the capabilities of in situ and remote sensing ocean observing technology,
and to improve use and application of numerical models. Activities to transition these improved capabilities to operational use will be supported.

In situ measurements will be conducted via autonomous and cabled ocean observatories, from autonomous undersea vehicles (AUVs), from drifting buoys, and from shipboard. Sensor development is required to expand the capabilities of these observational platforms. Acoustic and optical sensors will be integrated into observational systems. For example, multibeam bathymetry capability would be incorporated into a nearshore AUV system. Optical sensors for biogeochemical measurements are under development and will require integration into observatories and AUVs. Methods of undersea navigation will be improved. Sensors and observational systems will be modeled for deployment simulation, and for incorporation into command and control software. Adaptive sampling and multi-system interaction capabilities will be incorporated also. Providing greater power to observatories and AUVs is crucial for extending unattended duration, and for meeting increased power requirements of additional sensors, especially lidar and acoustics. New lithium batteries may provide an order of magnitude more power in the near term. Fuel cell technology will enable even greater increases over the proposed period. Methods for rapid recharging of batteries have been developed, but need to be engineered for applications including underwater docking stations for AUVs.

Remotely sensed measurements complement in situ ocean observations, and intersect with them in their undersea deployment. Space-based and airborne remote sensing systems being developed by the Sensors component of ARL/UHM will contribute to the observation of ocean variables, so there is a strong linkage with the Ocean Science and Technology component. Hyperspectral imagers and airborne lidars will provide bathymetric, seafloor and water column information. Ocean wave properties can be mapped, and sea spray generation can be quantified. Undersea application of Raman spectroscopy has the potential to supply detailed information about suspended materials. Active and passive acoustic measurements will be developed for such purposes as high-resolution bathymetric surveying, current measurement, bubble spectra, and fish and marine mammal location. Microwave remote sensing with HF and X-band radars will provide surface current and wave spectral information from coastal locations. Shipboard applications will be developed to extend this capability. The information contained in these observations needs to be extracted and integrated within the framework of nested, multivariate models.
Numerical model development and application will include addressing issues of model nesting, data assimilation and observing system simulation. Model nesting issues include both physical and numerical regime transitions, and development of appropriate parameterizations. Observing system simulations will guide deployment strategies, and are needed to model specific instrumental systems for purposes of command and control.

C. Test and Evaluation

The approach for developing a robust ocean model test and evaluation capability is to complement sustained, fixed-location ocean observatories with both broad scale and spatially focused surveys, and to occasionally conduct intensive observations around the observatories for limited periods, such as during the RIMPAC exercises. The intensive observations extend the spatial scale of the observatories, and they augment the variables measured and their spatial resolution. Surveying capability will be scaled up through AUV deployments. This nested observational strategy has been effectively applied, albeit on a limited basis, in Monterey Bay during August 2003.

Potential Sponsors:

NAVSEA, NAVAIR, SPAWAR, NUWC, NAWC, NSWC, NAVOCEANO, NOAA, ONR, DARPA, NRL, MDA, AFOSR, AFRL, ARO, ARL, NEODTC, SPECWARCOM, OST.
Astronomy (AST)

The Institute for Astronomy (IfA) is one of the world’s leading astronomical research centers. We propose fundamental and applied research in the studies of the sun, planets, and stars, as well as interstellar matter, galaxies, and cosmology. In addition to doing research, we propose to do design and build new instruments to measure and analyze the radiation collected by the telescopes. The Maui Space Surveillance System (MSSS) is a state-of-the-art electro-optical facility combining operational satellite tracking facilities with a research and development facility, the only one of its kind in the world. The MSSS houses the largest telescope in the Department of Defense, the 3.67-meter Advanced Electro Optical System (AEOS), as well as several other telescopes ranging from 0.4 to 1.6 meters.

Broad Objective:

We propose to undertake a range of fundamental and applied astronomical research objectives and to support these objectives by utilizing the unique staff, facilities and laboratories of the Institute for Astronomy to develop new, state of the art instrumentation and observational capabilities. This research is broadly focused on:

- Understanding the Sun and its many interactions with the Earth.
- Characterizing the atmosphere and its effects on optical signal propagation.
- Developing advanced adaptive optical elements
- Monitoring near-Earth objects
- Exploiting the Pan-STARRS data product for maximum scientific return
- Developing new instrument and focal plane architectures.
- Advancing the state of hyper-contrast, circumstellar imaging instruments.

Core Competencies:

The Institute for Astronomy (IfA) is the core astronomical research facility of the University of Hawaii. It is a university research institute with a staff of over 180 including more than 50 faculty and post-doctoral scholars. IfA operates facilities on the islands of Oahu, Hawaii, and Maui. IfA facilities include offices, shops, computer facilities, classrooms and libraries. The IfA is highly ranked as an international research entity in astronomy and has incubated many active research programs that have significantly improved astronomical and instrumental infrastructure. Many
have close ties to industrial partners and are generally supported by NSF, NASA and DOD. Supporting IfA are significant companion capabilities including:

- Design, development and fabrication of instruments of all types from spectrographs to coronagraphic cameras.
- Modeling and characterizing the atmosphere and atmospheric propagation.
- Soft and hardware support for the manipulation and analysis of large data sets.
- Shops, test facilities and a strong technical support staff.
- Design and operation of wide-field survey telescopes.
- Massive mosaic focal planes and novel detectors and detector arrays.
- Design and fabrication of state-of-the-art, high speed array controllers.
- Curvature adaptive optics systems.
- High dynamic range imaging systems.
- Polarimetric instruments.
- Signal processing software and user interfaces.

Task Elements:

A. Solar Research: The Sun is important to us for many reasons. It is the closest example of a star we can study and its radiation is the source of almost all life on Earth. It already affects crops, communications and weather on Earth but the full range of Solar-Terrestrial interactions are just beginning to be understood. Specific research objective with respect to the Sun include:

- High precision imaging Stokes polarimetry of the solar corona at 1-4 microns.
- High spectral resolution dual beam echelle polarimetry of the solar corona.
- Development of atmospheric remote sensing technology using astronomical scintillation sources.

B. Atmospheric Characterization: All optical/infrared observations from ground-based telescopes are fundamentally limited by critical atmospheric parameters: atmospheric transparency, sky brightness and turbulence arising from variations in the index of refraction along the line of sight. The success of techniques to overcome atmospheric effects is strongly determined by our own understanding of the distribution of the
optical turbulence along the line of sight, and the speed of at which that turbulence changes. Specifically we need to understand:

(1) The mechanical mixing of the atmosphere above the site. The physics of turbulence in the free atmosphere is fairly well understood and with the advent of high-speed computing facilities, we are now beginning to model and predict the strength and location of optical turbulence in the free atmosphere and boundary layer. These models however are in their infancy and need a dataset of optical turbulence measurements for calibration.

(2) The effects of locally induced temperature variations (e.g. telescope/dome eddies). Although this has been recognized for some time as a major source of image degradation it has been only recently that modeling of flows in and around telescope enclosures and monitoring of the temperature variations within the observatory have been done. Again, the models are qualitatively correct but more homogeneously taken data to quantify the results.

(3) Surface layer turbulence arising from ground winds and a warm/cold ground layer and boundary layer turbulence arising from local topographic features at the site. This is the least understood regime of optical turbulence. This layer typically accounts for 60-80% of the total optical turbulence at a site but what gives rise to this turbulence and its evolution are just now being studied. The local topography is important but on scales from meters to kilometers. For example, there is evidence of stability waves oscillating between mountain peaks giving rise to waves of optical turbulence above a site. These waves can extend from 100's of meters to many kilometers into the free atmosphere.

While instrumental campaigns have addresses each of these issues interpreting the data within the context of a complete turbulence profile is often very difficult because only part of the profile is being observed or only integrated quantities are being measured. We propose to characterize atmospheric turbulence with an complete facility that can simultaneously address the entire profile. Such a facility would include:

- an integrated optical turbulence monitor (Seeing Monitor)
- an optical turbulence low-res monitor (MASS)
- a high-resolution optical turbulence instrument (G-SCIDAR)
- an optical turbulence wave front outer-scale monitor (G-GSM)
- a set of 2-3 high-resolution low-altitude turbulence monitor (e.g. Scanning scintillometer (SPM), Lunar SHABAR, or SLODAR)
- an all-sky/wide field photometric camera with measuring in multiple wavelengths.
- a set of basic weather stations for distributed around the site
C. Adaptive Optical Elements. Over the last decade the IfA has been developing a new type of adaptive wavefront corrector based on a wave front sensor invented at the IfA by Francois Roddier. This system measures and corrects wave front curvature and is now in use in many facilities around the world. Curvature-based adaptive optics (AO) systems are very efficient compared to traditional approaches and require far fewer elements to achieve a high level of correction. IfA is currently commissioning the largest curvature system built to date which allows an eight meter diameter telescope to be corrected to 80% of ideal at a wavelength of 2 microns with just 85 correcting elements. The system can work with guide stars as faint as 16-17 mag. Curvature adaptive systems hold great promise for the future but have not yet been anywhere near fully exploited because there is very little active research on component development and on gaining a theoretical understanding how curvature systems work. IfA will undertake significant efforts in both areas and research will focus on:

- Characterizing and using new piezoelectric materials like single crystal materials and their application to curvature AO systems.
- Development of high order curvature components and systems with more than 500 correction channels.
- Development of large lightweight deformable elements for wave front control.
- Development of powered adaptive elements.
- Evaluation of low noise detectors and detector arrays for wave front sensing.
- Development of low-cost, modest performance curvature adaptive systems for general improvement to the national observational infrastructure.

D. Monitoring near-Earth objects and exploiting the Pan-STARRS data product. Earth has been hit many times by asteroids and comets whose orbits bring them into the inner solar system. These objects, collectively known as Near Earth Objects or NEOs, still pose a danger to Earth today. Depending on the size of the impacting object, such a collision can cause massive damage on local to global scales. There is little doubt that sometime in the future Earth could suffer another cosmic impact. That such cosmic collisions can still occur today was demonstrated graphically in 1994 when Comet Shoemaker-Levy 9 broke apart and 21 fragments, some as large as 2 km in diameter, crashed into the atmosphere of Jupiter. If these fragments had impacted on Earth instead, we would have
suffered global catastrophes of the kind that inspire science fiction movies.

In 1994 the House Committee on Science and Technology directed NASA, in coordination with the DOD, to work with the space agencies of other countries to identify & catalogue within 10 years the orbital characteristics of all comets and asteroids larger than 1 km in orbits that cross the orbit of the Earth. Several programs have been undertaken to map the orbits of large NEOs that might pose a danger to Earth. Pan-STARRS is designed to complete the survey of all 1-km diameter objects, and to detect most of the dangerous objects down to 300 meters in diameter -- objects that can cause major regional catastrophes should they hit the Earth.

Pan-STARRS uses four comparatively inexpensive 1.8-meter-diameter telescopes each designed to have a 3.5-degree field of view to make a nightly survey of the sky to very faint magnitudes. Each telescope is fitted with a massive 109-pixel CCD array being developed. The survey will have 3-16 times the collecting power of the current NEO survey telescopes that will reach objects 100 times fainter than those currently observed by the NEO surveys. Further, Pan-STARRS' large field of view, 7 deg² per exposure) is larger than that of any of the current NEO survey programs. This allows observing the sky faster and more frequently. Finally, Pan-STARRS will have higher spatial resolution than existing survey systems, allowing observation where the ecliptic plane overlaps with the Milky Way, often too crowded with stars for the current surveys to observe effectively.

Backing up the observational component will be a powerful computing environment that will process the observations, calibrate the astrometric and photometric (position and brightness) properties of individual observations, and detect the "moving" objects such as asteroids, comets, and Trans-neptunian objects (TNOs). The system will also track all objects already known (or discovered by itself), so that on future nights when an object is re-observed it can be rapidly identified and its orbit updated to include the new data. There are currently about 100,000 known moving objects in our solar system that are tracked by professional astronomers. With Pan-STARRS, we estimate that we will catalog up to 10 million main-belt asteroids and tens of thousands of NEOs and TNOs. The problem of processing the 3,000 Gigabytes of data that will be collected every night will is being addressed in collaboration with the Maui High Performance Computing Center.
The massive Pan-STARRS data stream can be used for much more than the project primary goals and it is essential that efficient and maximal use are made of the data. Secondary data products include:

- **Solar System Science.** Discovery and characterization of outer solar system objects, asteroid and Kuiper belt objects.
- **Stars and the Galaxy:** Massive stellar catalog of the Northern sky with the discovery of many variable stars and microlensing events.
- **Discovery of massive extrasolar planets by occultation.**
- **Discovery of many transient events such as those associated with both young and old stars as well as phenomena like gamma ray bursts and active galactic nuclei.**
- **Understanding the large scale structure of the universe by looking at galaxy distributions and gravitational lensing events.**

In addition to the astronomical data product, Pan-STARRS will also produce significant atmospheric data including large angle tilt correlations, transparency distribution and integrated turbulence distribution.

**E. Instrument and Focal Plane Technologies.** The Pan-STARRS effort is just part of IfA’s ongoing detector development program. Chips are produced in collaboration with several electro-optical companies but the IfA is specialized in adapting detectors to special applications like a new, high speed 2Kx2K 1-2.5 micron array, an 8K, visible Mosaic camera, infrared arrays for the JWST, and “orthogonal transfer” CCDs that allow images to be shifted rapidly on the array while being exposed. This allows image motion compensation that can be done much more rapidly than with a traditional tip-tilt mirror.

We propose to continue these efforts as well as extending our detector research into new areas like photon counting arrays for wavefront sensing and a high dynamic range infrared demodulating imaging detector.

IfA designs and builds a wide array of instruments in addition to those built specifically for adaptive optics. Projects include a spectrograph being built for the 3.67-meter AEOS telescope operated by the Air Force on Haleakala, Maui, the UH-Wide Field Imager will use the UH 8K CCD camera, Infrared Camera and Spectrograph (IRCS) for the Subaru eight-meter telescope, Solar-C – a half-meter, off-axis, low scatter reflecting telescope designed to allow unprecedented Solar coronal observations and Near Infrared Imager (NIRI) - an imaging instrument for the 8-meter Gemini Telescope. In addition, all NASA Infrared
Telescope Facility instruments are built at the IfA, which also staffs and hosts the facility.

We recognize that progress in instrumentation goes hand in hand with progress in science and we propose to develop a suite of new generation instruments keyed to many of the scientific objectives discussed above. Many of these instruments like those for solar observing and atmospheric characterization have already been discussed but we are also developing new approaches to other problems. One of the most demanding of these problems is that of hyper-contrast imaging; detecting faint objects in the immediate neighborhood of bright ones. While this is strictly speaking an instrumental problem it is also intimately coupled to the optical system, the adaptive corrector and many other factors. Efficiency and the control of scattered light are critical to this problem and we are working to develop both high order adaptive systems and a new approach to generating image cubes to support this effort. Because the high dynamic range imaging problem is so intimately related to the gross optical system we are proposing to upgrade the IRTF to become a test bed both for adaptive optics and new hyper-contrast instruments.

Potential Sponsors:

NAVSEA, NAVAIR, ONR, DARPA, NRL, MDA, AFOSR, AFRL, ARO, ARL, NASA.
Advanced Electro-Optics and Sensing (AEOS)

We propose to develop optical systems and technologies that support surface, undersea and amphibious research. The ultimate goal is a coupled understanding of the physical and optical environment of the littoral zone with an emphasis on validation of models with precise and timely remote and in situ optical instrumentation. Development will include systems to characterize the marine boundary layer, in water optical properties, bathymetry, hazards, oil slicks, submarine object detection, and dry land littoral zone properties. Technologies include novel sensor concepts, systems miniaturization, space sensor calibration and detector array characterization for maritime applications.

Broad Objective:

The objective of the work is to understand and characterize the optical properties of the maritime environment from subsurface to space. The focus will be on the development of prototype and single use optical instrumentation and data sets supporting Naval objectives, including supporting other UARC areas of core expertise.

Core Competencies and Background:

The University of Hawaii has extensive experience in development of optical instrumentation for civil and DoD applications. This experience includes development and long term use of atmospheric LIDAR, space sensor calibration, passive and active hyperspectral sensing, and in-water optical properties characterization. These instrumentation projects are developed in support of specific scientific goals and led by specialists in the fields to ensure the scientific fidelity of the technology development, while maintaining close collaboration with innovative technologists to maximize the science return from technology.

Task Elements:

A. Develop instruments and systems for characterizing the marine boundary layer: These include airborne, ship- and shorebased scattering LIDAR’s, nephelometers and infrared profilers. The intent is to increase both spatial and temporal resolution of measurements to promote understanding of atmospheric microphysics and processes that affect surface and underwater visibility, sea state and weather. This element
also supports the characterizing of the effectiveness of space-borne systems to provide information on denied regions.

**B. Measurement and phenomenology of in water optical properties:** The bio-optical properties of the water column dictate the effectiveness of passive remote sensing techniques in characterizing water properties including visibility, detectability of submerged objects, and bathymetric mapping. The emphasis is on using these measurements in an integrated way with active and passive remote sensing from air and space, and in situ physical measurements to accurately gauge the ability to determine key parameters in denied areas. This task will also include development of AUV optics sensors to support real time validation of passive space or airborne spectral imaging.

**C. Bathymetric mapping and detection of submerged objects:** The dynamics of the littoral zone require frequent remapping of bottom topography to contribute to success of amphibious warfare and special operations. Passive spectral imagery from air or space has the potential to provide bathymetry in the range of 1-30 meters, but the robustness of the current algorithms against water properties and data quality is not known. We will combine active (LIDAR) and passive airborne hyperspectral imaging to make these assessments and develop new sensor and operations concepts to maximize the quality of the retrieved information. Detection of submerged objects shares much of the challenges of bathymetric measurements using spectral imagery and this will be an area of emphasis.

**D. Development and testing of advanced hyperspectral systems:** Both the maritime and dry land aspects of littoral warfare can strikingly benefit from hyperspectral systems, and such systems should be optimized for Naval requirements. In maritime applications, passive hyperspectral systems must be optimized for blue wavelength performance, but must also include sufficient infrared coverage to characterize the atmosphere. Current systems are not optimized for maritime use, and both space and UAV sensors are presently not available with sufficiently high performance. The dry land aspect of littoral warfare requirements are strikingly different than maritime scenarios as systems must be responsive in a tactical environment and can take advantage of more spectral range than ocean systems. Current day/night hyperspectral sensors are confined to R&D efforts and their size and power consumption are incompatible with all but the largest UAV applications. We will emphasize the miniaturization of hyperspectral systems aimed at UAV and soldier-carried sensors aimed at counter-camouflage, chemical weapons release and detection of
precursors, buried land mine detection and detection of clandestine facilities.

**E. Development and testing of detectors for naval requirements:** Optics sensors for naval use often have special requirements not shared by commercial or other DoD entities. We will both develop and test sensors optimized for Naval use, including large format blue sensitive arrays, low irradiance infrared arrays, and LIDAR detection systems.

**F. Calibration of space sensors:** Space-based observing is a key aspect of naval warfare including nowcasting for ship operations, measurement of currents and bathymetry, and measurement of boundary layer and in-water optical properties. Space systems require calibration and validation to ensure their effectiveness. We will continue, and extend, our long-term program of calibration of maritime space sensors. Extension will include adding detailed boundary layer optical properties measurements to our existing MOBI buoy, and adding a near-shore equivalent in Kaneohe Bay, and establishment of a bathymetry/submerged object validation range.

Potential Sponsors:

NAVSEA, NAVAIR, SPAWAR, NUWC, NAWC, NSWC, NAVOCEANO, ONR, DARPA, NRL, MDA, AFOSR, AFRL, ARO, ARL, NEODTC, SPECWARCOM, OST.
Sensors, Communication, and Information Technology (SENCIT)

Broad Objective:

We propose fundamental research and applied engineering supporting improvements in the utilization of various regions of the electromagnetic spectrum, advancements in communications, networks and protocols, command, control, communications, computers and intelligence (C4I) systems hardware and signal processing. This capability has been applied to advanced radar technology, distributed processing, sensor network integration, design tradeoff studies especially in the areas of RF arrays, passive remote sensing, command and control integration and wave propagation.

Core Competencies and Background:

A. Sensors and Electromagnetic Development

The Sensors and Electromagnetic Development Division offers expertise in radar system analysis, prediction, signal processing and performance evaluation; antenna development, measurements and technology; and photonic applications.

Research Areas

- Characterization of the sensitivity and resolution of radar methods,
- Design modeling and simulation of antennas,
- Detailed electromagnetic propagation studies,
- Experimental studies to validate simulation observations and guide development of full scale systems,
- Signal processing and adaptive processing of radar signals for interference and clutter rejection.

B. Communication, Networks and Protocols

The Communication, Networks and Protocols Division provides experience in the fast-growing telecommunications industry including wireless, hybrid fiber-coaxial systems, satellite and optical
communications. Additionally, it conducts research in network applications for a variety of domains.

Research Areas

- **Command and Control Networks**,  
  - Knowledge based decision support systems;  
  - Models of behavior for agent-based systems, e.g., search and rescue;  
  - Intelligent agents with varying levels of autonomy;  
- **Imagery Collection, Analysis and Dissemination**,  
  - Algorithms for object segmentation with applications in target tracking, identification, surveillance and medical diagnosis, e.g., tumor detection;  
  - Modeling human motion perception and motion analysis;  
  - Algorithms for image, video and volumetric data compression;  
  - Signal and image based decision support systems;  
- **Wideband Wireless Communications**,  
  - High performance, low cost phased array antenna design and characterization;  
  - Broadband RF component design;  
  - Programmable waveform software development;  
  - EMI/EMC analysis and assessments.

C. Advanced Systems Development

The Advanced Systems Development Division offers expertise in a wide variety of engineering development domains including autonomous technology development of air, ground and underwater platforms; advanced signal and data processing; and command, control, communications, computers and intelligence (C4I) systems engineering.

Research Areas

- Autonomous navigation technologies including Simultaneous Localization and Mapping,  
- Swarming technologies,  
- Self-aware adaptive systems,  
- Prognostics and Health Management,  
- Advanced pattern recognition techniques,  
- Knowledge based decision support systems,
• Models of behavior for agent-based systems, eg. search and rescue,
• Intelligent agents with varying levels of autonomy,

D. Information Technology

The Information Technology Division offers solutions to complex problems involving information processing, storage, representation and exchange.

Research Areas

• Integration of computing, networking, human-computer interfaces, and information management to support reliable complex, distributed systems,
• Innovative approaches to the integration of data, models, communications, analysis and/or control systems, including dynamic, data-driven applications for use in prediction, risk-assessment and decision-making,
• Interactions and complex interdependencies of information systems and social systems,
• Innovation in computational modeling or simulation in research or education.

Task Elements:

ARL-UH proposes related work such as:

• Design and engineering of communication antennas and data distribution components to reduce size and weight for airborne platforms.
• Design and engineering of high power amplifier systems and sub-systems for installation in the surveillance radar test bed systems that investigate potential improvements to Airborne Early Warning radars.
• Investigation of potential system architectures and sub-system designs to determine technology readiness and associated costs, risks, reliability and maintainability of alternative concepts for next generation surveillance radars.
• Perform fundamental research on sensor network integration with particular emphasis on integration of optical sensors for Ballistic Missile Defense. Results could have broad applicability to sensor networking of platforms such as the Littoral Combat Ship.
- Prototype C4I system that collects, correlates and disseminates information from undersea warfare sensors, platforms and intelligence sources and provides Theater Commanders with coherent data for strategic planning and tactical employment of forces.
- Develop gateways among sensors, and Command and Control elements to permit remote participation in tests and experiments conducted at PMRF and other range facilities. The goal is to maximize the return on investment when conducting costly tests and experiments by networking on range sensors with remote military units and laboratories.
- New diagnostic approaches for highly reliable, fault-tolerant systems that can immediately and reliably detect and isolate the sensors, actuators or system component failures. These methods are used to compensate for failures as they happen, to predict system failure and move from unscheduled maintenance to scheduled maintenance.
- Development of intelligent platforms with simultaneous pointing and jitter control with micron and sub-micron accuracy employing sensors, actuators, control systems, smart composite structures, and nanotechnology with applications in adaptive optics, telescopes, precision laser pointing, as well as satellite and marine structures.
- Corrosion testing and development of sensors for corrosion in diverse atmospheric environments. Research will focus on a number of areas, including corrosion mapping, metal matrix composites, compatibility of materials, ceramics films, microelectromechanical systems, buried munitions, and corrosion protection compounds.
- Develop an integrated system to defend fleet and associated support ships in forward and home ports against threats. We propose a networked set of organic sensors that create a layered barrier above and below the water that enables a minimal set of watch standers to identify and quickly react to threats.
- Perform research on exploiting available sensing technologies to develop advanced sensor approaches and a data analysis system to detect, characterize, and neutralize underwater mines. Ultimately, the results from this work will provide a cost-efficient way to protect a variety of survey, relocation, and inspection/intervention operations in the littoral zone.
- The development of a low-light underwater spectral imager and image-processing system, in support of the DoD need for clandestine reconnaissance via unmanned underwater vehicles (UUVs) deployed from submarines. This will allow submarines to use just one torpedo tube for launch & recovery.
• The rapid design, development, test and demonstration of a UUV equipped with a modular mission sensor package, which communicates to the Navy vessel via a fiber optic tether, to actively navigate, search, detect, classify and localize potential targets.

• Prototype detection system platform for unexploded ordnance (UXO) for the shallow water and very shallow water environments. The current research priorities will focus on exploiting available technologies to develop a near-term capability to verify the scope of the underwater problem and to begin to collect some real-world data.

• The development of a land based UXO detection system. The proposed work in this project consists of two major but strongly interrelated components. This includes Ground Penetrated Radar technology with its associated antennas, electromagnetic modeling and simulation, and propagation studies; and the SAR technology with its associated matched-filter techniques for data processing and image.

• Image processing and signaling, converting raw data from electro-optical sensors, seismic instruments, radars, and satellites into meaningful information. Rapid advances in collecting, processing, and storing spectral, Synthetic Aperture Radar, and seismic data are helping astronomers explore the solar system, military groups observe space objects, petroleum engineers develop new oil fields, and environmentalists track natural disasters.

• Modeling and simulation uses mathematical emulators and prototypes to create logical representations that facilitate decision-making. Parallel computation, storage, and communications capabilities can facilitate high-resolution terrain representations for use in combat situations and for disaster mitigation, digital animations for education, training and entertainment, and 3-D imagery for scientific and medical use.

• Data mining helps predict future trends and behaviors through the evaluation of existing data. Advancements in data retrieval, analysis, storage, and parallel database technologies enable defense, health, and retail organizations to use this technique to make proactive, knowledge-driven decisions.

Potential Sponsors:

NAVSEA, NAVAIR, SPAWAR, NUWC, NAWC, NSWC, NAVOCEANO, ONR, DARPA, NRL, MDA, AFOSR, AFRL, ARO, ARL, NEODTC, SPECWARCOM, OST.