

center for microbial oceanography: research and education  
**C·more** *linking genomes to homes*

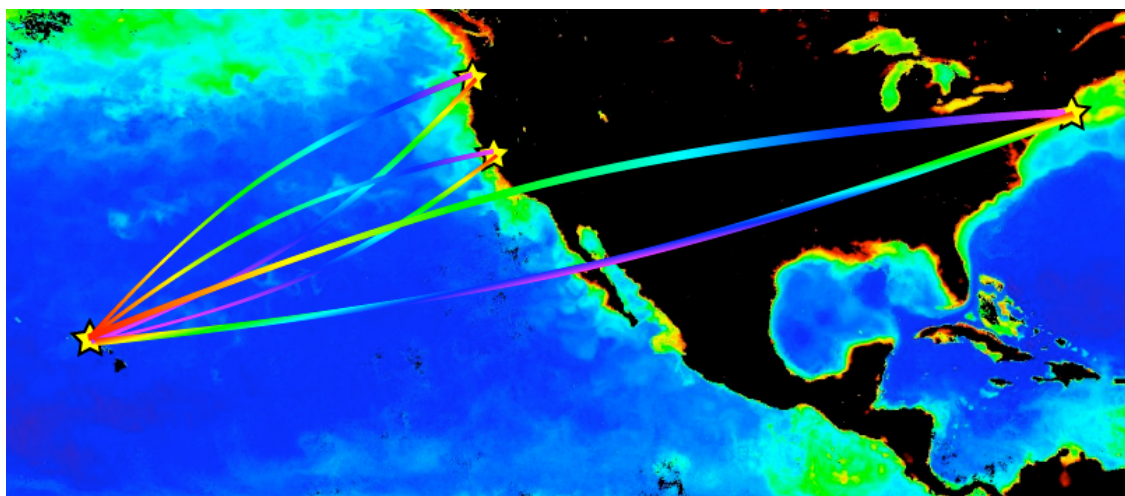
# Strategic and Implementation Plan

Center for Microbial Oceanography:  
Research and Education  
(C-MORE)

2006–2007

**Lead Institution** University of Hawaii

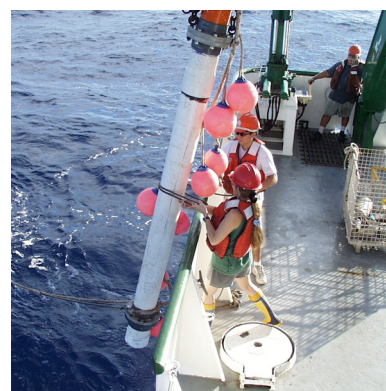
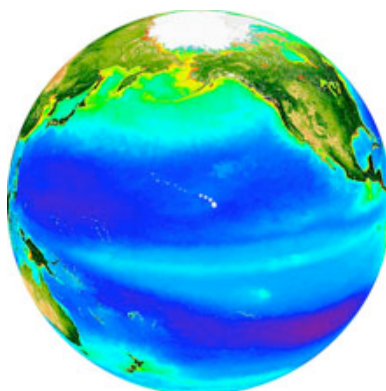
**Partner Institutions** Monterey Bay Aquarium Research Institute  
Massachusetts Institute of Technology  
Oregon State University  
University of California-Santa Cruz  
Woods Hole Oceanographic Institution



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## 1. Executive Summary

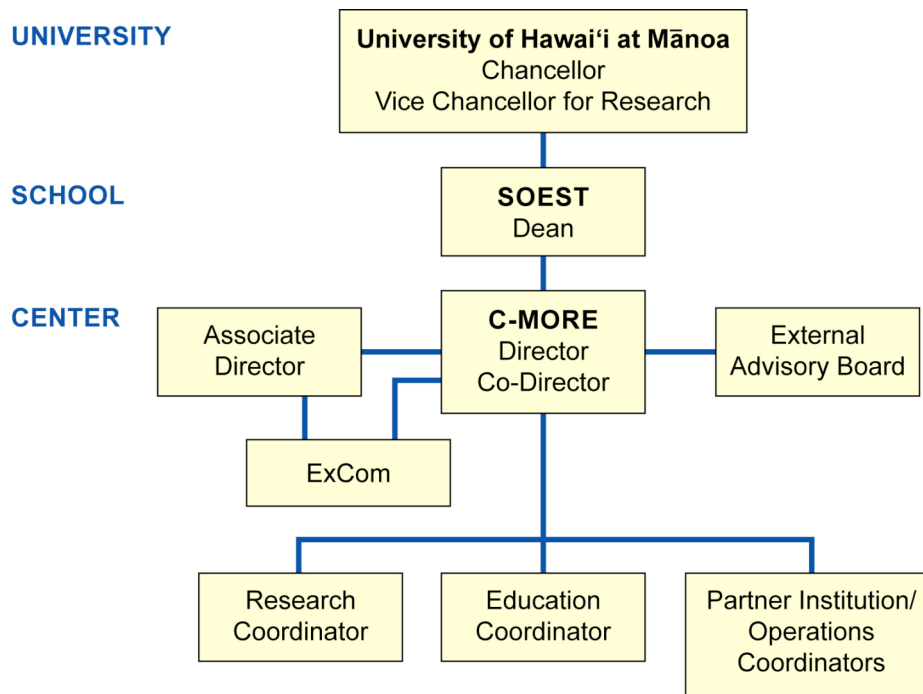
Life on Earth most likely originated as microbes in the sea. Over the past 3.5–4 billion years, microorganisms have shaped and defined Earth’s biosphere, and created conditions that allowed the evolution of macroorganisms and complex biological communities. Today microbes inhabit and sustain all of Earth’s biotopes, including those found in marine environments; they are truly the “unseen majority.” They catalyze key biogeochemical transformations of nutrients and trace elements that maintain productivity of the oceans, produce and consume greenhouse gases, and are a critical component of the food web linking dissolved organic matter to higher trophic levels. Until recently, very little was known about the biology of the microorganisms *in situ*, their metabolic and genomic properties, or their temporal and spatial dynamics. Recent advances have highlighted the vast unknown genetic information contained in marine microbes. Now there is an opportunity, using recent advances in molecular ecology, genomics, remote sensing and ecological modeling, to make great strides in the understanding of the biology, ecology and biogeochemical roles of the unseen majority in the world’s largest biome: the global ocean. The Center for Microbial Oceanography: Research and Education (C-MORE), is a physical and intellectual space where a synergy between these otherwise separate disciplines will be fostered in the study of marine microbial ecology. The primary goal will be to increase our understanding of how biological diversity at the genomic level expresses itself at the ecosystem functional level — i.e. the biogeochemistry of the oceans — and to transfer this knowledge to policymakers and to the public at large.

C-MORE will facilitate broad based research on marine microorganisms across geographical, disciplinary, and cultural boundaries. The Center will establish, monitor and manage research; broker partnerships; increase diversity of human resources; implement novel education and outreach programs; and obtain and utilize comprehensive

information about microbial life in the sea. The Center will bring together teams of scientists, educators and community members who otherwise do not have the opportunity to communicate, collaborate, and design creative solutions to long-term ecosystem scale problems, and whose collective expertise will advance microbial oceanography in new and exciting ways. The Center will conduct a range of activities, from genomic surveys, to instrument/sensor development for remote sensing, to mesocosm experimentation, to ecosystem modeling and, most importantly, integration of results from these diverse approaches using a single marine ecosystem — The Hawaii Ocean Time-series (HOT) station ALOHA — as a focal point.

This Strategic and Implementation Plan (SIP) for C-MORE 2006–2007 outlines the vision, mission and planned implementation of various research, education and outreach activities for the new Center. This document grew out of discussions at a C-MORE planning workshop that was held at the University of Hawaii in May 2006. This event brought together, for the first time, the National Science Foundation’s (NSF) C-MORE management team (led by Drs. Matt Kane and Margaret Tolbert), NSF’s consultants Dr. Walter Collier and Robert Mortis of C&A Technologies, Inc. and most of the C-MORE Team. We acknowledge the patience, advice, and support of the NSF management team members as we embark on this new voyage of ocean discovery. This working document presents our prospectus for the first year of C-MORE operations: 2006–2007. It will be updated annually to reflect our progress towards the stated goals, as well as the incorporation of new and exciting opportunities that will undoubtedly arise. In these three months since the opening of the Center on 1 August 2006, the two key leadership positions have been filled (Associate Director Paul Kemp and Education Coordinator Barbara Bruno), the research thrust teams have been assembled, and interdisciplinary field research at Station ALOHA has begun. It should be a very exciting decade.

## 1.1.Center Management



The Center will become a new administrative unit within the School of Ocean and Earth Science and Technology (SOEST) at the University of Hawaii at Manoa (UH). The C-MORE Director (David Karl) will report to Brian Taylor, the newly appointed Dean of SOEST. Within UHM, the SOEST Dean reports to the Vice Chancellor for Research and Graduate Education, Gary Ostrander, who in turn reports to the UHM Chancellor Denise Konan. The Center's co-Director, Edward DeLong (MIT) will assume Center Directorship in case of the inability of Center Director David Karl to perform those duties (see Section 1.2).

The management structure of the Center is designed for maximum efficiency and minimal administrative burden for the C-MORE team members. The Center's Associate Director (Paul Kemp) will oversee and direct the administrative staff and will be responsible for the day-to-day operations of the Center. The Center began operations without an Associate Director on board. In order to facilitate operations during the start-up phase (Aug–Dec 2006), a senior administrator was assigned by the SOEST Dean to work with the Center Director in addressing all matters of Center management and operations. This interim

solution is programmed to change as the Center's Associate Director arrives in Honolulu (early November) and begins to take charge.

All C-MORE activities will initially be coordinated by a management team, the Executive Committee (ExCom). Membership includes the C-MORE P.I.s (J. Zehr and S. Chisholm), the Education Coordinator (B. Bruno), the Research Coordinator (E. DeLong), and the Research Theme Leaders (J. Waterbury, C. Scholin and S. Doney). C-MORE Associate Director (P. Kemp) will serve as Chair of the ExCom, and the C-MORE Director (D. Karl) will serve as an *ex officio* member (NOTE: E. DeLong is also a C-MORE P.I. and Co-Director so wears three hats; J. Zehr is also a Research Theme Leader). The final two members will be elected from the remainder of the C-MORE Team and will serve non-renewable 1 year terms. This will provide an opportunity for the younger members of C-MORE to participate in the management of the Center. The ExCom will advise the Director on issues pertaining to all missions in the Center. The ExCom will have regularly scheduled monthly meetings by teleconference, and will circulate minutes of each meeting to the C-MORE Team. An External Advisory Board,

comprised of distinguished senior scientists and educators, will provide additional guidance to the Director.

## 1.2. Succession Plan

If the Center Director resigns, becomes incapacitated or is unable to provide effective leadership as judged by an annual performance evaluation conducted by the ExCom, he/she will be replaced. Under this circumstance, the Center's co-Director will immediately assume the role of Director until a permanent replacement can be made. The new Center Director will be recruited by the Dean of SOEST with advice and consent of the ExCom. The co-Director, Associate Director and senior members of the C-MORE team would all be eligible to serve as the new permanent Director. Should the co-Director resign, become incapacitated or have a performance deemed unacceptable to the Director and the ExCom, the Director will appoint a replacement subject to the approval of the ExCom. The effectiveness of the Research Theme Leaders will be reviewed annually by the ExCom, and new individuals will be appointed if past performance is deemed ineffective. The Associate Director, Education Coordinator and Research Coordinator all serve at the discretion of the Director.

## 2. Research – Science and Technology

### 2.1. Vision Statement for Research

C-MORE will be a transdisciplinary, global research information center for comprehensive, integrative understanding of the living ocean, with a special emphasis on microbial plankton diversity and dynamics. The connectivity between different hierarchical levels of biological complexity (including gene and organism diversity, physiological function and regulation, and community structure and function), and biogeochemical and physical dynamics will be measured and modeled. These data, and the predictive, biologically-informed ecosystem models they enable, will be essential in predicting the effects of global change in the marine environment, and

managing marine biomes in the face of ongoing global environmental perturbations.

### 2.2. Mission Statement for Research

The mission of the Center is to support interdisciplinary research on four interconnected themes (microbial diversity; microbial metabolism and biogeochemistry; remote and continuous sensing of microbial processes and their links to climate variability; and ecosystem modeling, computer simulation and prediction), and to integrate these studies at multiple time and space scales.

### 2.3. Situational Analysis: Strengths, Opportunities and Challenges

#### Strengths and Opportunities

- A An intellectual and human-resource base of talented, experienced and enthusiastic leaders in microbial oceanographic education and research; and an oceanographic and microbiological infrastructure and experience base.
- B Direct access to one of the largest marine biomes on Earth, the North Pacific Ocean.
- C A focus on a single habitat, targeted microorganisms and associated biogeochemical cycles.
- D Integration of four complementary areas of research through the interactions of researchers associated with the Center.

#### Challenges

- A Establishing priorities for an ambitious and comprehensive research program.
- B Integrating the diverse themes across multiple time and space scales.
- C Integrating research activities with educational and knowledge transfer activities.
- D Ensuring that we succeed in conducting highly collaborative and complementary research rather than individual, independent programs.
- E Ensuring communication among geographically dispersed collaborators and institutions.

- F Ensuring that development, testing and application of novel tools and sensors is in service to the research needs of the scientists who will use them.

## 2.4. Goals and Objectives

### Goals

- A To understand how the information encoded in marine microbial genomes manifests itself at the ecosystem functional level.
- B To understand the interlinked roles of microorganisms in energy capture and transfer, and in carbon, nutrient and trace metal cycling.
- C To develop models for the prediction of microbial distributions, dynamics (growth and mortality), and response to environmental changes in the sea.

### Objectives

- A Characterize, interpret and understand genomic diversity as the genetic basis of marine microbial biogeochemistry and its emergent ecological properties (Goals A-B).
- B Cultivate model microorganisms to represent the key biogeochemical cycles and key microbial populations, including their phages, and understand their “cellular machinery” (Goals A-B).
- C Determine the links between energy source and energy flux within and between biogeochemical cycles (Goal B).
- D Determine how N, P and trace metal and organic micronutrient cycles regulate carbon and nitrogen fixation in the oligotrophic gyres (Goal B).
- E Examine the sources and fates of dissolved organic matter, and how dissolved organic matter interacts with trace elements (Goal B).
- F Develop biological sensors for detecting major microbial components (organisms or genes), and biophysical sensors for continuous *in situ* measurements of critical microbial processes (Goals B-C).

- G Examine the role of meso- and large scale physical forcing on marine microbial diversity (Goal C).
- H Design, build, test and deploy large mesocosms for use in open ocean nutrient perturbation experiments to test specific C-MORE hypotheses (Goals A-C).
- I Build more credible, mechanism-based models for predicting current and potential future dynamics of ocean microbes and their role in marine ecosystems (Goal C).

## 2.5. Strategies

- A Create highly collaborative, transdisciplinary research and engineering groups, and facilitate numerous and practical opportunities for their interaction (Objectives A-H).
- B Emphasize high throughput and other novel approaches to obtain pure cultures and enrichments of key microbial representatives for use in model genomic and physiology studies (Objectives A-B).
- C Employ multiple genomic approaches to identify metabolic properties of microbial populations (e.g. whole genome sequencing of model organisms, single cell genome sequencing, large insert libraries, shotgun cloning, microarrays, transcriptome and proteome approaches) (Objectives A-B).
- D Develop biological sensors based on the Environmental Sample Processor design for detecting key microorganisms and genes at Station ALOHA, using alternate test sites as appropriate (e.g. Monterey Bay and contiguous waters) (Objectives B, C, F).
- E Incorporate spatial and temporal statistical studies of remote and *in situ* data to explore environmental controls of marine microbial diversity and activity (Objectives D-G).
- F Integrate multiple data products of C-MORE process studies, manipulation experiments, and environmental time-series studies into the development and evaluation of marine ecological-biogeochemical models (Objective H).
- G Combine *in situ* observations with spatial and temporal analyses of satellite-based remote

sensed observations to assess physical forcing on marine microbial diversity (Objectives G-H).

## 2.6. Implementation Plan

| Objective                                                                                                                                                                        | Goals | Actions Required                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Responsible Person(s) *                                                                                                                                    | Location(s)                                                            |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|
| All objectives                                                                                                                                                                   | A-C   | <ul style="list-style-type: none"> <li>Create transdisciplinary, collaborative working groups (Years 1-5)</li> <li>Identify new opportunities for productive partnerships and proactively encourage new collaborations among investigators (Years 2-5)</li> </ul>                                                                                                                                                                                                                                                                                                   | Chisholm, DeLong, Karl, Kemp, Zehr                                                                                                                         | All                                                                    |
| A. Characterize, interpret and understand genomic diversity as the genetic basis of marine microbial biogeochemistry and its emergent ecological properties                      | A-B   | <ul style="list-style-type: none"> <li>Begin HOT-site specific analyses of pre-existing metagenomic datasets (Years 1-2)</li> <li>Create new metagenomic data, and link to oceanographic data and metadata (Years 1-3)</li> <li>Develop and implement new molecular probes and quantitative techniques to track microbes and microbial processes (Years 1-5)</li> </ul>                                                                                                                                                                                             | Bidigare, Chisholm, Church, DeLong, Kemp, Rappé, Repeta, Saito, Steward, Zehr                                                                              | UH, MIT, UCSC, WHOI                                                    |
| B. Cultivate model microorganisms to represent the key biogeochemical cycles and key microbial populations, including their phages, and to understand their “cellular machinery” | A-B   | <ul style="list-style-type: none"> <li>Employ traditional and dilution culture techniques with high-throughput screening targeting selected prokaryote groups (Years 1-3)</li> <li>Characterize the major reservoirs of dissolved organic nitrogen and phosphorous in model microorganisms (Years 2-4)</li> <li>Isolate and characterize new key players in biogeochemical cycles (nitrifying Archaea, photoheterotrophs, other “uncultureds”) (Years 1-3)</li> <li>Characterize hosts, phages and basic properties of the phage-host system (Years 1-3)</li> </ul> | Chisholm, DeLong, Rappé, Waterbury<br><br>Chisholm, DeLong, Karl Rappé,<br><br>Church, DeLong, Rappé, Waterbury<br><br>Chisholm, Rappé, Steward, Waterbury | UH, MIT, WHOI<br><br>MIT, UH<br><br>UH, MIT, WHOI<br><br>UH, MIT, WHOI |
| C. Determine the links between energy source and energy flux within and between biogeochemical cycles                                                                            | B     | <ul style="list-style-type: none"> <li>Identify biophysical markers for photosynthetic and respiratory electron fluxes and investigate photoadaptive strategies of microbes (Years 1-5)</li> </ul>                                                                                                                                                                                                                                                                                                                                                                  | Church, DeLong, Dyhrman, Karl, Kolber                                                                                                                      | UH, MBARI, WHOI, MIT                                                   |

| Objective                                                                                                                                                                                | Goals | Actions Required                                                                                                                                                                                                                                                                                                                                                                                                            | Responsible Person(s) *               | Location(s)          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------|----------------------|
| D. Determine how N, P and trace metal and organic micronutrient cycles regulate carbon and nitrogen fixation in the oligotrophic gyres                                                   | B     | <ul style="list-style-type: none"> <li>Measure the trace metal and organic micronutrient cell quotas for key microorganisms in laboratory cultures; compare the chemical diversity and forms of bioavailable trace metals and micronutrients in laboratory and field (Years 1-3)</li> </ul>                                                                                                                                 | Boyle, Chisholm, Dyhrman, Saito, Zehr | MIT, OSU, UCSC, WHOI |
| E. Examine the sources and fates of dissolved organic matter, and how dissolved organic matter interacts with trace elements                                                             | B     | <ul style="list-style-type: none"> <li>Engineer and deploy new systems for the isolation of dissolved organic matter (Years 2-4)</li> <li>Characterize the diversity and metabolic capacity of dissolved organic matter degrading microbial consortia in laboratory cultures (Years 2-4)</li> </ul>                                                                                                                         | Church, Karl, Repeta                  | UH, WHOI             |
| F. Develop biological sensors for detecting major microbial components (organisms or genes), and biophysical sensors for continuous in situ measurements of critical microbial processes | B-C   | <ul style="list-style-type: none"> <li>Document functional requirements and conduct instrumentation design reviews for new sensors and samplers (Years 1-2)</li> <li>Development, testing, refinement and operation of biological and biophysical sensor instruments within C-MORE program and beyond (Years 1-5)</li> <li>Deploy autonomous SeaGliders for remote surveillance of open ocean blooms (Years 1-5)</li> </ul> | Kemp, Kolber, Scholin, Taylor         | UH, MBARI, WHOI      |
| G. Examine the role of meso- and large scale physical forcing on marine microbial diversity                                                                                              | C     | <ul style="list-style-type: none"> <li>Generate remote sensing databases for the regions studied (Years 1-2)</li> <li>Develop/implement spatial and temporal statistical analyses (Years 2-3)</li> <li>Combine remote sensing analyses with <i>in situ</i> data and models development (Years 2-5)</li> </ul>                                                                                                               | Bidigare, Doney, Karl, Letelier       | UH, OSU, WHOI        |
| H. Design, build, test and deploy large mesocosms for use in open ocean nutrient perturbation experiments to test specific C-MORE hypotheses                                             | A-C   | <ul style="list-style-type: none"> <li>Engineer and construct test model mesocosm (Year 1)</li> <li>Field test (Year 2)</li> <li>Deploy for specific hypothesis testing activities (Years 2-5)</li> </ul>                                                                                                                                                                                                                   | DeLong, Karl, Kemp, Zehr              | UH, MIT, UCSC        |

| Objective                                                                                                                                                 | Goals | Actions Required                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Responsible Person(s) *                                                          | Location(s)         |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|---------------------|
| I. Build more credible, mechanism-based models for predicting current and potential future dynamics of ocean microbes and their role in marine ecosystems | C     | <ul style="list-style-type: none"> <li>Build ecosystem models for North Pacific Subtropical Gyre for synthesis/interpretation of laboratory, field, remote sensing and mesocosm data (Years 1-2)</li> <li>Expand traditional ecosystem model capabilities to incorporate microbial genetic, evolutionary and metabolic characteristics (Years 2-3)</li> <li>Use models as testbeds for exploring hypothesis, processes and dynamics (Years 3-5)</li> <li>Incorporate model advances into regional and/or global 3-D ocean simulations for use in climate projections (Years 3-5)</li> </ul> | Bidigare,<br>Doney,<br>Karl,<br>Laws,<br>Letelier<br><br>* in alphabetical order | UH,<br>OSU,<br>WHOI |

## 2.7. Metrics

- A Libraries constructed, progress in bioinformatics analysis, including database development and findings; discoveries of new metabolic pathways and emergent properties of oceanic microbial communities (Objective A).
- B Attempts, failures and successes of cultivation efforts. New techniques developed or in development. Habitats where cultivation efforts have been attempted (Objective B).
- C Methods developed, experiments performed and findings regarding biophysical markers of energy sources and fluxes (Objective C).
- D Progress in obtaining trace metal and organic micronutrient cell quotas for key microorganisms in laboratory cultures, and comparisons regarding bioavailable trace metals and micronutrients in laboratory and field (Objectives B, D).
- E Progress in characterizing dissolved organic matter, interactions of dissolved organic matter with trace elements, and sources and fates of dissolved organic matter components (Objective E).
- F Progress in development of biological and biophysical sensors, including description of

instrumentation, and data from field deployments (Objective F).

- G Progress in development and analysis of remote sensing approaches and data analysis (Objective G).
- H Progress in model development progress, including scales, approaches and characteristics captured by the models (Objective H).

## 2.8. Financial Resources

C-MORE will benefit from multiple synergistic programs financed by other sponsors. These include research programs of the PIs (supported by the NSF, DOE and others), as well as institutional support (UH). Four PIs are supported by Gordon and Betty Moore Foundation Marine Investigator Awards. A facility for visiting scientists at UCSC (called MEGAMER) and research at MBARI for development of instrumentation (MEGA) are supported by the Gordon and Betty Moore Foundation. MBARI is also supporting the development of instrumentation with support from the Packard Foundation, NSF and NASA

### Resource Allocation

The allocation of resources specific to the C-MORE Cooperative Agreement is as follows:

|                 | Year 1    | Year 2    | Year 3    | Year 4    | Year 5    | Total      |
|-----------------|-----------|-----------|-----------|-----------|-----------|------------|
| <b>Research</b> | 1,941,832 | 2,478,905 | 2,333,894 | 2,312,523 | 2,295,452 | 11,362,606 |

## 2.9. Management Plan

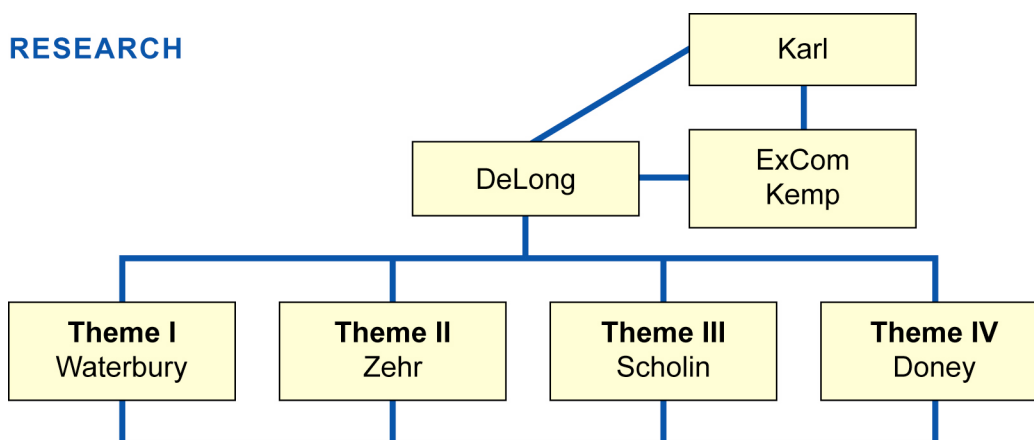
A visual summary of the management structure for the Center as a whole is provided in Section 1.1; an expanded view of the Research Management section is shown below. As Research Coordinator, Edward DeLong (MIT) has primary responsibility for oversight of research activities within C-MORE. He will work closely with the Director, Associate Director and the entire C-MORE team on all aspects of the research mission, including education, outreach and knowledge transfer activities. The Research Coordinator will track research progress by close interaction and communication with the co-PIs (Karl, DeLong, Chisholm, Zehr) and with the designated leaders of the four research themes: marine microbial diversity (John Waterbury), metabolism and biogeochemistry (Jonathan Zehr), remote and continuous sensing technology (Christopher Scholin) and ecosystem modeling (Scott Doney). The Research Coordinator will prepare a succinct annual summary of research

accomplishments and work in progress, with input from all C-MORE researchers.

The Research Coordinator will also serve as a member of the Center's ExCom (Executive Committee), the leadership team headed by Associate Director Kemp and comprised of Research Coordinator DeLong, Educational Coordinator Bruno, and the lead investigators at each of the partner institutions (DeLong, MIT; Letelier, OSU; Scholin, MBARI; Waterbury, WHOI; Zehr, UCSC). Finally the Research Coordinator will initiate, coordinate and oversee the review of incubator proposals for seed funding of novel research projects.

The C-MORE research activities will be coordinated via regular teleconference and video conferences of all participants, and monthly conferences of the PIs. Web-enabled technologies will be employed to facilitate reporting, exchange, and archiving of data and data products, and to facilitate interactions through collaboration tools.

### RESEARCH



## 3. Education

### 3.1. Vision Statement for Education

C-MORE will provide leadership in the development of educational programs related to microbial oceanography, and in the training of

educators and researchers engaged in microbial oceanography. In doing so, we will promote increasing knowledge and awareness of ocean microbes, their key roles in ocean processes, and their essential roles in the habitability and sustainability of life on earth.

### 3.2. Mission Statement for Education

Educate and train a diverse population of educators, undergraduate and graduate students in microbial oceanography.

### 3.3. Situational Analysis: Strengths, Opportunities and Challenges

#### Strengths and Opportunities

- A Education team consists of recognized leaders who represent local and national education and outreach networks and are experienced in nurturing and mentoring underrepresented students.
- B Local and nationwide educational programs are already established at partner institutions, including NOAA BWET and Ocean Explorers Programs, MIT's Open CourseWare Program, and OSU's SMILE (Science and Mathematics Investigative Learning Experience) Program.
- C Distance-learning instructional technology is already available at C-MORE partner institutions, providing enhanced learning opportunities for all, including persons with disabilities.
- D Availability of cruise berths (e.g. on the HOT and C-MORE cruises) enables at-sea training and experience for educators and students.
- E Private funding is earmarked for the development and implementation of a Microbial Oceanography training course at UH.
- F Hawaii State Department of Education (HIDOE) is committed to upgrade marine science curriculum, encourage teacher training, and recognize "Master Teachers." Hawaii is the only state with a statewide public school system, providing unique opportunities for education and outreach.
- G Synergic opportunities exist to provide additional college and secondary student and educator support, such as Hawaii EPSCoR, TCUP, BWET and other programs.
- H The lead institution (UH) serves a diverse population, including native Hawaiian and Pacific Island students and educators.

- I C-MORE team members are well positioned within their home institutions to impact curriculum content in microbial oceanography and ocean biogeochemistry.

#### Challenges

- A Given the structure and breadth of an ideal education plan, full implementation and coordination across all partner institutions will require additional funding and prioritization of immediate goals.
- B Distinct differences in learning cultures between education and research require that mutual respect and understanding be developed to achieve a successful program that integrates activities from both areas.
- C Prior commitments of team members require a delayed startup of selected secondary education curriculum development and teacher training objectives.

### 3.4. Goals and Objectives

#### Goals

- A Develop, and partner with existing, mentoring programs to increase the recruitment and retention of college students and researchers in the field of microbial oceanography.
- B Establish professional development programs for educators and opportunities for pre-college students to gain a greater understanding of microbial oceanography.
- C Develop/update, classroom-test and disseminate college-level microbial oceanography curricula and educational materials.

#### Objectives

- A Provide professional development opportunities for educators leading to an enhanced understanding of microbial oceanography (Goal B).
- B Develop/update instructional resources enhanced by research conducted at C-MORE partner institutions, and disseminate via workshops, courses, project web site, meetings, publications, and presentations (Goal C).

- C Recruit and retain undergraduate and graduate students in microbial oceanography research, technical work, and college teaching (Goals A-B).
- D Develop and strengthen partnerships with existing programs complementary to C-MORE educational goals (Goals A-C).

### 3.5. Strategies

- A Establish structure needed to facilitate the planning, coordination, dissemination and implementation of the education program, including an education advisory team composed of both educators and scientists (Objectives A-D).
- B Conduct a needs assessment, and examine existing instructional resources to be adapted, developed and/or aligned with state and national education standards and general learner outcomes (Objective B).
- C Classroom-test and revise instructional resources, ultimately for distribution to educa-

tors through workshops and courses (Objective B).

- D Develop and implement workshops and courses for educators (Objective A).
- E Engage secondary students in microbial oceanography learning at UH, including shipboard and laboratory experience (Objective C).
- F Engage undergraduate and graduate students and educators in summer mentoring and research internship programs with C-MORE scientists (Objectives C, D).
- G Develop a cadre of master educators to serve as leaders in the dissemination and use of C-MORE instructional resources (Objective D).
- H Develop, update, and implement summer graduate courses in microbial oceanography led by scientists from C-MORE partner institutions (Objectives A-D).
- I Facilitate the exchange of students and researchers across C-MORE partner institutions (Objectives A, C).



**Hawaii Ocean Science Bowl**



**Agouron Summer Institute**

### 3.6. Implementation Plan

| Objectives                                                                                                                                     | Goals | Action Required                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Responsible Person(s)            | Location                 |
|------------------------------------------------------------------------------------------------------------------------------------------------|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|--------------------------|
| C. Recruit and retain undergraduate and graduate students in microbial oceanography research, technical work, pre-college and college teaching | A-B   | For pre-college: <ul style="list-style-type: none"> <li>Review field-oriented experiences available to students (Year 1)</li> <li>Develop and provide field-oriented experiences including mentoring and accredited experiential course for high school students (Years 2-5)</li> </ul>                                                                                                                                                                                                                                                                 | Education Team                   | Primarily UH             |
|                                                                                                                                                |       | For post-secondary: <ul style="list-style-type: none"> <li>Review student services and experiences available for undergraduates and graduates (Years 2-3)</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                    | Education Team                   | All partner institutions |
|                                                                                                                                                |       | <ul style="list-style-type: none"> <li>Develop and provide student services and experiences (including mentoring) for undergraduate and graduate students (Years 1-5)</li> </ul>                                                                                                                                                                                                                                                                                                                                                                        | Education Team, all participants | All partner institutions |
|                                                                                                                                                |       | <ul style="list-style-type: none"> <li>Provide opportunities for C-MORE research students to interact with education majors and professionals (Years 1-5)</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                    | Education Team                   | All partner institutions |
|                                                                                                                                                |       | <ul style="list-style-type: none"> <li>Engage C-MORE students and scientists in educational endeavors (Years 2-5)</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                            | Education Team                   | All partner institutions |
|                                                                                                                                                |       | <ul style="list-style-type: none"> <li>Provide opportunities at other C-MORE center institutions (Years 1-5)</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                 | All participants                 | All partner institutions |
| D. Develop and strengthen partnerships with existing programs complementary to C-MORE educational goals                                        | A-C   | <ul style="list-style-type: none"> <li>Research programs and resources available nationwide and internationally (Year 1)</li> <li>Contact leaders of selected programs for possible partnership (Years 1-5)</li> <li>Develop program to connect C-MORE undergraduates, graduates, scientists to teachers with marine programs, particularly in Hawaii (Years 2-5)</li> <li>Facilitate student and educator exchanges among partners and other institutions (Years 2-5)</li> <li>Facilitate mentoring by microbial oceanographers (Years 1-5)</li> </ul> | Education Team                   | All partner institutions |

### 3.7. Metrics

- A Establishment of an Education Advisory Group (all Objectives).
- B Participation in semi-annual C-MORE meetings (Objectives A-D).
- C Complete needs assessment study for professional development workshops, courses or experiences (Objective A).
- D Numbers and kinds of professional development opportunities and experiences provided, and numbers of participating educators and scientists (Objective A).
- E Participant evaluations of workshops, courses or experiences (Objective A).
- F Complete review of available curricula and instructional resources, identifying gaps (Objective B).
- G Numbers and kinds of instructional resources developed, including course modules and curricula, number of inquiries, and usage by other institutions (Objective B).
- H Results of review of numbers and kinds of experiential opportunities for high school and higher education students (Objective C).
- I Accreditation of field-oriented experiences for secondary students (Objective C).
- J Number of secondary school, undergraduate and graduate students participating in field-oriented experiences (Objective C).
- K Approval of student services and experiences by UH and other C-MORE institutions (Objective C).
- L Number of undergraduate and graduate students involved in C-MORE microbial oceanography classes and programs (Objective C).
- M Number of C-MORE students and scientists interacting with science majors and professionals (Objective C).
- N Number of C-MORE students and scientists in educational endeavors (Objective C).
- O Complete review of available partner programs and resources (Objective D).
- P Contacts with potential partner programs, information provided, and responses from potential partners (Objective D).
- Q Number of student and educator exchanges facilitated among partner institutions (Objective D).

### 3.8. Financial Resources

#### Resource Allocation

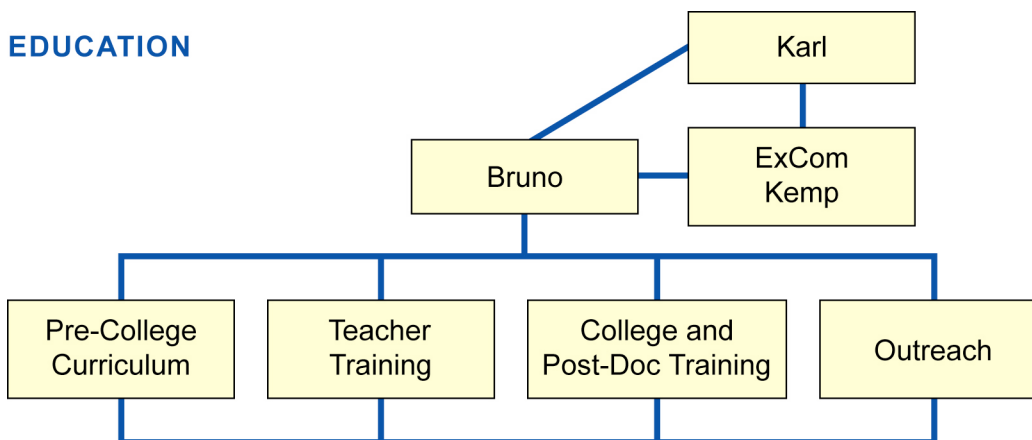
|                  | Year 1    | Year 2    | Year 3    | Year 4    | Year 5    | Total      |
|------------------|-----------|-----------|-----------|-----------|-----------|------------|
| <b>Education</b> | 1,405,184 | 2,266,104 | 2,352,139 | 2,364,318 | 2,384,042 | 10,771,787 |

### 3.9. Management Plan

The C-MORE Education activities will be managed by a full-time Education Coordinator (Barbara Bruno) assisted by a Curriculum Developer (TBN) and a Teacher Trainer (TBN), collectively referred to as the Education Team. The Education Coordinator will be responsible for oversight and leadership of all formal education activities of the Center including the tracking of progress in all areas. An Education Advisory Group will be formed through consultation among the Director, Associate Director and Education Coordinator and will be comprised of

the Education Team and representatives of identified stakeholders (e.g. partner institutions, HIDOE). The Education Coordinator will prepare a succinct annual report on accomplishments and work in progress within the educational and outreach program goals, with input from C-MORE participants as required. The Education Coordinator will also serve as a member of the Executive Committee and will work closely with the Director, Associate Director and Research Director to ensure that educational programs are enhanced by research efforts, and the converse.

## EDUCATION



## 4. Diversity

### 4.1. Vision Statement for Diversity

C-MORE will become a leader in increasing diversity among scientists, technical workforce, and educators engaged in the study, utilization, and education development focused on marine microbes, and the ecosystems that they inhabit.

### 4.2. Mission Statement for Diversity

Increase the number of students, staff, and faculty from groups underrepresented in science and engineering by fostering increased interest in microbial oceanography. Ensure diversity in all aspects of the Center. Encourage and facilitate involvement of students at our partner and minority serving institutions to pursue an undergraduate or graduate education in science or engineering.

### 4.3. Situational Analysis: Strengths, Opportunities and Challenges

#### Strengths and Opportunities

- A All C-MORE research partners (UH, MIT, UCSC, WHOI, MBARI, OSU) are committed to efforts to increase diversity among students, faculty, researchers and staff.
- B Culturally relevant, standards-based curricula already exist at UH; e.g. regarding water quality, microbiology, nutrient cycling, marine science; and water quality/health/safety in production

(<http://malama.hawaii.edu/schools/index.html> and <http://www.scihi.hawaii.edu>).

- C Through the EPSCoR program, partnerships already exist with the University of Hawaii System's minority serving campuses (Kauai, Windward, Leeward, Hawaii, Maui Community Colleges).
- D Numerous opportunities exist for outreach within Hawaii, which has an enduring legacy with the sea.
- E Partnership opportunities exist to work with the Hawai'i Academy of Science which sponsors the Pacific Symposium for Science and Sustainability, a program involving Hawaii and Pacific Islands students in professional conference experiences.
- F UH and partner institution MIT both participate in GEAR-UP, a program for underrepresented high school students, and can use this interaction to develop a C-MORE related microbial oceanography module to share with partner sites.
- G Programs increasing knowledge about and respect for different cultural perspectives and practices among C-MORE staff, teachers and underrepresented minority students and communities can provide models for outreach programs encouraging participation of women, minorities and persons with disabilities at research partner institutions.
- H Existing partnerships between the Education Coordinator, UH's Center on Disability Studies (CDS), ALU LIKE (a Native Hawaiian-serving organization) and several minority-

serving high schools to develop culturally responsive, career-oriented science curriculum (Education Coordinator is an affiliate faculty member of CDS).

## Challenges

- A Limited participation of underrepresented groups, especially Native Hawaiians, Pacific Islanders, African Americans, Hispanic Americans, and Native Americans, in marine microbial education and research programs, and STEM in general.
- B Finding sufficient resources to support involvement of teachers and K-16 students in field, laboratory and ship-based marine microbial research and learning.
- C High rates of teacher turnover and student dropout in minority-serving K-12 schools.
- D Difficulty in accommodating students and faculty with physical disabilities in field and ship-based research.
- E Social, academic, and financial challenges in recruiting and transitioning members of underrepresented groups into undergraduate and graduate programs at Center institutions.
- F Difficulty in recruiting underrepresented groups to faculty positions within the Center.

## 4.4. Goal and Objectives

### Goal

Increase the number of underrepresented minorities and persons with disabilities in all levels of Center research and education programs.

### Objectives

- A Recruit and mentor undergraduate and graduate students from a diverse student population, to reach the goal of 10% of Center students coming from underrepresented groups.
- B Provide research opportunities for underrepresented students at Center institutions.

- C Provide financial resources for students from underrepresented groups to pursue graduate education related to Center programs at Center institutions.
- D Develop diversity throughout the Center's staff, scientists, managers, administrators, and advisory board members.
- E Provide outreach and opportunities for interaction among Center staff, scientists, teachers and underrepresented students and communities.
- F Promote diversity in all Center teacher education, high school student enrichment and outreach programs

## 4.5. Strategies

- A Develop and implement an effective recruitment and retention program that includes secondary students as well as students at community colleges.
- B Provide research and training opportunities to secondary and undergraduate students through summer/after school programs, classes and mentoring.
- C Use Center resources to fund minority graduate students and seek additional funding opportunities — e.g., NSF Integrative Graduate Education and Research Traineeship (IGERT) — to supplement the Center budget.
- D Recruit and retain a diverse staff, foster professional advancement among junior and underrepresented staff members with training and professional opportunities.
- E Develop outreach including speakers, posters, videos and activities expressing diversity in informal and formal venues e.g., museums, aquaria, field trips, voyages, conferences, classes, and meetings.
- F Develop secondary and higher education, and teacher education programs, curricula, and outreach that present Center science in contexts that include diversity in culture, ethnicity, linguistics, genders and disabilities.

#### 4.6. Implementation Plan

| <b>Objective</b>                                                                                                                                                             | <b>Actions Required</b>                                                                                                                                                                                                                                                                                                                                                | <b>Responsible Person(s)</b> | <b>Location(s)</b>       |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|--------------------------|
| A. Recruit and mentor undergraduate and graduate students from a diverse student population, to reach the goal of 10% of Center students coming from underrepresented groups | <ul style="list-style-type: none"> <li>Identify current status and efforts to increase student diversity (Year 1)</li> <li>Identify specific opportunities and mechanisms to increase diversity (Years 1-5)</li> </ul>                                                                                                                                                 | All participants             | All partner institutions |
| B. Provide research opportunities for underrepresented students at Center institutions                                                                                       | <ul style="list-style-type: none"> <li>Identify and offer research opportunities to secondary and/or undergraduate students (Years 2-5)</li> <li>Recruit students through summer/after school programs, seminars, mentoring, and courses with C-MORE components (Years 1-5)</li> </ul>                                                                                 | All participants             | All partner institutions |
| C. Provide financial resources for students from underrepresented groups to pursue graduate education related to Center programs at Center institutions                      | <ul style="list-style-type: none"> <li>Develop mechanism to allocate existing C-MORE funds to support students from underrepresented groups (Years 1-5)</li> <li>Actively seek funding to provide additional resources (Years 2-5)</li> </ul>                                                                                                                          | All participants             | All partner institutions |
| D. Develop diversity throughout the Center's staff, scientists, managers, administrators, and advisory board members                                                         | <ul style="list-style-type: none"> <li>Develop written policies to ensure diversity is a priority in hiring and recruiting, and track demographics of Center-associated personnel (Year 1)</li> <li>Encourage professional advancement among junior and underrepresented staff members, including training and other professional opportunities (Years 1-5)</li> </ul> | Bruno, DeLong, Karl, Kemp,   | All partner institutions |
| E. Provide and participate in outreach with opportunities for interaction among Center staff, scientists, teachers and underrepresented students and communities             | <ul style="list-style-type: none"> <li>Develop outreach including speakers, posters, videos and activities expressing diversity in informal and formal venues including field trips, voyages, conferences, classes and meetings (Years 2-5)</li> </ul>                                                                                                                 | All participants             | All partner institutions |

| Objective                                                                                                  | Actions Required                                                                                                                                                                                                                                                            | Responsible Person(s) | Location(s)              |
|------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|--------------------------|
| F. Promote diversity in all Center teacher education, high school student enrichment and outreach programs | <ul style="list-style-type: none"> <li>Develop high school and teacher education programs, curricula, and outreach that present Center science in contexts that include and reflect diversity: cultural, ethnic, linguistic, gender and disabilities (Years 1-5)</li> </ul> | All participants      | All partner institutions |

#### 4.7. Metrics

Metrics for diversity are linked to those of education, especially in the recruitment of students at all levels. The following metrics measure the effectiveness of the Center in improving participation by underrepresented groups in microbial oceanography.

- A Recruitment initiatives and demographics. Numbers and kinds of recruitment activities (e.g., conferences, advertisements, talks, and other mechanisms). Number and demographics of students contacted in recruiting efforts (measured as those attending, participating, responding or requesting more information). Number and demographics of Center students successfully recruited. Summary assessment of the impact of Center recruitment and participation on students' educational and career choice.
- B Research opportunities. Numbers and demographics of students involved in Center research, including Center students, visiting students, and research experiences offered to classrooms (e.g. in-class demonstrations and presentations).
- C Financial resources. Numbers and kinds of educational opportunities provided to student members of underrepresented groups, and funds allocated. Demographics of student recipients. Efforts and success in obtaining additional funds directed to this purpose.
- D Diversity within the Center. Demographics of Center staff, scientists, managers, administrators, and advisory board members.

- E Outreach activities. Outreach events attended by Center personnel, including conferences specifically directed to outreach, and outreach events held in association with other conferences (e.g. science meetings). Numbers and demographics of students, teachers, and community members contacted and/or participating in interactions with Center participants.
- F Promotion of diversity. Record of participation by students and teachers from underrepresented groups in C-MORE related classes, workshops and student activities.

#### 4.8. Financial Resources

Diversity is an integral part of all Center activities, so resources for diversity have not been separated from those for education, research and knowledge transfer.

#### 4.9. Management Plan

The management of the Center's Diversity plan will be the responsibility of each and every senior member of the C-MORE Team at both the host and partner institutions. Issues related to the enhancement of Diversity will be integral to the Center's function and success. The Associate Director will co-ordinate and track the Center's progress toward the implementation of the Strategic Plan for Diversity, in part by developing reporting systems for routine use by C-MORE participants. All participants will be expected to provide information routinely regarding their efforts toward achieving diversity goals.

## 5. Knowledge Transfer

### 5.1. Vision Statement for Knowledge Transfer

C-MORE will lead the way not only in the creation of microbial oceanographic data, theory and synthesis, but also will be the international leader in transferring this knowledge to others.

### 5.2. Mission Statement for Knowledge Transfer

Engage in two-way knowledge transfer that benefits the Center, government and policy makers, industry, the public, and the academic community.

### 5.3. Situational Analysis: Strengths, Opportunities and Challenges

#### Strengths and Opportunities

- A Extensive PI experience in implementing comprehensive biogeochemical and molecular/genomic databases, data transfer, visualization systems, and web-based information systems.
- B Multiple C-MORE partner institutions facilitate knowledge transfer nationally and internationally.
- C Partnerships with non-C-MORE databases and efforts will foster knowledge dissemination.

#### Challenges

- A Lack of a dedicated public relations officer for C-MORE, for knowledge transfer outside the academic world.
- B Challenges in making the invisible microbial world tangible and visible.
- C Challenges associated with high volume data transfer and storage, integrating large heterogeneous datasets, and making them easily accessible and visible to C-MORE partners and others.

## 5.4. Goals and Objectives

### Goals

Transfer knowledge gained from C-MORE activities and microbial oceanography in general, to stakeholders including academic researchers, policy makers, industry, and the general public.

### Objectives

- A Disseminate scientific and technical knowledge to peers through publications and presentations.
- B Enhance public awareness of marine microbial oceanography and its importance, including programs to educate policymakers.
- C Promote economic development through commercialization and entrepreneurial use of C-MORE products such as biotechnology and remote sensing tools and technologies.

## 5.5. Strategies

- A Work with other data centers to disseminate scientific data; disseminate synthesized data and technical information via the C-MORE web page and publications (Goal A).
- B Conduct seminars on such topics as marine microbial genomics, ocean biogeochemistry, remote sensing and instrumentation, and global climate change; Integrate workshops with UH/Agouron Summer Course in Microbial Oceanography (Goals A, B).
- C Develop web pages; produce newsletter; hold workshops; work with UCSC and other professional journalism students to write articles (Goals A, B).
- D Provide professional development opportunities to the C-MORE personnel. Invite outside experts to give seminars; sponsor C-MORE personnel travel to attend short courses (Goals A, B).
- E Work through congressional delegations, including Hawaii and partner institutions, to involve policy makers in C-MORE workshops; work with AAAS/AGU congressional fellows (Goal B).

F Work with UH and C-MORE partner Institutions and staff to identify commercializa-

tion opportunities and manage intellectual property (Goal C).

## 5.6. Implementation Plan

| Objective                                                                                                                                                            | Actions Required                                                                                                                                                                                                                                                                                                                            | Responsible person(s)                                       | Location(s)                            |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|----------------------------------------|
| A. Disseminate scientific and technical knowledge to peers                                                                                                           | <ul style="list-style-type: none"> <li>Produce reports, present results at workshops and conferences</li> <li>Prepare and distribute annotated data, data summaries, and data interpretations using web based information systems in cooperation with other data centers</li> <li>Prepare and publish science papers (Years 1-5)</li> </ul> | Operations coordinators at all partner institutions         | All partner institutions               |
| B. Enhance public awareness of marine microbial oceanography and its importance, including programs to educate policymakers                                          | <ul style="list-style-type: none"> <li>Use web-enabled methods for outreach, information and data transfer</li> <li>Produce a C-MORE newsletter; journalism students contributing articles (Years 1-5)</li> <li>Present public lectures</li> <li>Provide briefing sessions for policymakers and their staff</li> </ul>                      | Bruno, DeLong, Karl, Kemp<br><br>All participants as needed | Primarily UH, all partner institutions |
| C. Promote economic development through commercialization and entrepreneurial use of C-MORE products such as biotechnology and remote sensing tools and technologies | <ul style="list-style-type: none"> <li>Conduct Center-sponsored workshops and seminars on C-MORE products, e.g. instrumentation, analyses, biotechnology tools (Years 1-5)</li> <li>Provide short courses, visitor training or other training opportunities for academia and industry (Years 2-5)</li> </ul>                                | Operations coordinators at all partner institutions         | All partner institutions               |

## 5.7. Metrics

- A Number of presentations by C-MORE faculty, staff, and students (Objective A).
- B Number of data sets made available to the scientific community (Objective A).
- C Number of peer-reviewed publications by C-MORE PIs, postdocs, students and associated personnel (Objective A).
- D Number of presentations given to public groups (Objective B).

- E Number of newsletter requests (Objective B).
- F Number of media articles written and contacts with media, information provided and number of articles resulting (Objective B).
- G Web download statistics (Objective B).
- H Contacts with and briefings provided to policymakers and their staff (Objective B).
- I Patent disclosures and awards (Objective C).

J Courses and workshops, their attendance and participant feedback (Objective C).

K Information products developed and number of such products disseminated (Objective C).

L Presentations to possible industrial partners (Objective C).

## 5.8. Financial Resources

### Resource Allocation

|                           | Year 1  | Year 2  | Year 3  | Year 4  | Year 5  | Total     |
|---------------------------|---------|---------|---------|---------|---------|-----------|
| <b>Knowledge Transfer</b> | 500,984 | 454,991 | 513,968 | 523,159 | 520,506 | 2,513,608 |

## 5.9. Management Plan

The Knowledge Transfer implementation plan will be managed by a small team consisting of the Director (Karl), co-Director / Research Coordinator (DeLong), Associate Director (Kemp) and the Education Coordinator (Bruno). The Associate Director will coordinate with lead

investigators at partner institutions to track and facilitate progress and troubleshoot any problem areas, and will be responsible for the annual summary of all Center related knowledge transfer related activities. Regularly scheduled meetings and periodic reports will be used as a management tool. Web-enabled technologies will be employed to facilitate reporting knowledge transfer activities.

## Appendix A. Data Policy and Management

### Biogeochemical and oceanographic data management and distribution plan

Distribution and management of biogeochemical and oceanographic data sets will be made publicly available following the model developed by the HOT program. Time series data from the HOT program is freely distributed using the web-based Hawaii Ocean Time series Data and Graphical System (HOT-DOGS). HOT-DOGS was developed by members of the HOT program based on the recognition that the oceanographic community required more efficient and user friendly means of accessing data. By providing access to continuous and discrete oceanographic and biogeochemical data, HOT-DOGS allows anyone with access to the internet to download individual or grouped data (as text files), and provides a user-friendly graphical interface to display time and space dependent changes ocean ecosystem properties. Thus, our use of the HOT-DOGS data distribution model relies on proven and previously successful technologies.

### Genomic and metagenomic data management plan

The development of metagenomic data collection, analyses, metadata tagging, and data transfer methods and standards is a large community challenge, but one that is critical to and relevant for the successful completion of goals and vision of C-MORE. Several sequencing and informatic Centers, notably the DOE Joint Genome Institute (JGI) and the California Institute for Telecommunications and Information Technology (CalIT2) at UCSD, are beginning to generically address this problem. Notably, a new Community Cyberinfrastructure for Advanced Marine Microbial Ecology Research and Analysis (CAMERA), has recently been established at UCSD to deal solely with this issue. While C-MORE alone will not solve all community issues related to metagenomic data analyses, handling and transfer, we plan to work in partnership, and lead by example, working other specialty institutes working on the problem. There will be yearly meetings with representatives of these groups and C-MORE personnel.

DeLong is currently Chair of the JGI Users Committee, and is a Scientific Advisory Board member for CAMERA) and will lead the coordination of these efforts.

In a rapidly evolving field of metagenomics where standards have yet to be developed, C-MORE will become an early adopter and beta tester of developing metagenomic databases, data analysis and data transfer systems. At the same time, we will manage data internally to avoid becoming reliant on systems that may not succeed or become universally adopted by the community. The general plan for this implementation follows.

### Metagenomic data analyses and transfer – CMORE internal users

Internally, metagenomic datasets and databases will be managed at mirrored sites, including UH, MIT, and possibly UCSC. DeLong at MIT maintains a 15 node, 30 processor cluster backed up by a RAID array for data storage and analyses. The data and analytical packages (blast, blat, TreePuzzle, Paup, Mr Bayes, fastDNAmI, EMBL package, etc) will be made available via a webserver to C-MORE users. These same systems can be used as blast servers for guest users, making data available to the wider community. A mirrored site at Univ. of Hawaii will be established to serve as a commons for metagenomic data storage and serving. The separate sites will also provide separate and redundant data backup facilities ensuring data security.

### Data release – standard implementation

This aspect of the data management effort needs to be well coordinated with ongoing informatic efforts and developing standards. Currently, there are no firmly established guidelines for release of metagenomic data. At most major sequencing centers (Broad Institute, JGI for instance), trace files of raw sequence data go directly from sequencing machines to the NCBI's tracefile archive. "Finished" metagenomic datasets that are ready for analyses typically have been deposited in either NCBI's environmental database (env\_nt, env\_nr) or Genome Sequence Survey database (GSS), either 6 months after se-

quence completion (see current examples of genomic data release policies, below), or upon publication.

We will follow these standard data release policies with metagenomic sequence data produced by C-MORE. Much of the sequence data that C-MORE will use is not generated by C-MORE but rather is obtained from leveraged projects funded by non-NSF funds (e.g. GBMF and DOE sequencing efforts). In these cases, data release will generally be handled and administered by the specific Sequencing Center that has produced the data. In this context, C-MORE is a sequence user, but importantly, also a metadata provider. As an example dataset, we have already deposited HOT sequence data into the NCBI's Genome Sequence Survey database. These data are tagged with relevant metadata on physical and chemical sample parameters, and represent the

first such dataset now deposited in GenBank. We anticipate that reciprocal links between sequence metadata fields and C-MORE-collected oceanographic data will be developed and implemented as C-MORE standard practice. These developments will depend on parties and programs outside C-MORE and the time frame is not clear at present.

### Currently implemented data release policies

(Note : These apply mainly to individual genome sequences rather than to metagenomic datasets, which are fundamentally different.)

NIH [www.genome.gov/10506537](http://www.genome.gov/10506537)

DOE [www.sc.doe.gov/ober/EPR/data.html](http://www.sc.doe.gov/ober/EPR/data.html)

JGI [www.jgi.doe.gov/sequencing/collaborators/datarelease.html](http://www.jgi.doe.gov/sequencing/collaborators/datarelease.html)

## Appendix B. Intellectual Property Agreement

|                                    |                                                                                                                                                                                                                                                               |
|------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Research Institutions:</b>      | University of Hawaii (UH)<br>Monterey Bay Aquarium Research Institute (MBARI)<br>Massachusetts Institute of Technology (MIT)<br>Oregon State University (OSU)<br>University of California at Santa Cruz (UCSC)<br>Woods Hole Oceanographic Institution (WHOI) |
| <b>Research Project Title:</b>     | Center for Microbial Oceanography: Research and Education (C-MORE)                                                                                                                                                                                            |
| <b>Research Funding Agency(s):</b> | National Science Foundation                                                                                                                                                                                                                                   |
| <b>Reference Award Number:</b>     | CCF-0424599                                                                                                                                                                                                                                                   |
| <b>Research Time Period:</b>       | 9/1/2006 - 08/31/2011                                                                                                                                                                                                                                         |

This Intellectual Property Agreement (this “Agreement”) is entered into between the Research Institutions set forth above (hereinafter collectively referred to as the “Parties,” and each singularly as a “Party”), in relation to the research project set forth above (the “Project”). This Agreement sets forth the mutually agreed terms and conditions of their relationship under the Project.

### RECITALS

**WHEREAS**, the Parties agree to abide by the regulations of the National Science Foundation (NSF) and to collaborate in developing the standards, requirements, and procedures of the Center for Microbial Oceanography: Research and Education (C-MORE); and

**WHEREAS**, the Parties will be collaborating on the Project, which is being funded by the National Science Foundation (“NSF”) as part of its Science and Technology Centers Program; and

**WHEREAS**, the Parties in the course of such collaborations may be using each other's facilities including laboratory space and research vessels; and

**WHEREAS**, each of the Parties is also separately governed by a Subaward Agreement which defines the scope of work to be carried out by

each Party in fulfillment of the goals and objectives of C-MORE; and

**WHEREAS**, the Parties agree that any patentable intellectual property (IP) that is conceived or reduced to practice in the performance of the Subaward Agreement, shall be owned by the institution that invented the IP and governed by the provisions of the Cooperative Agreement and Cooperative Agreement Financial and Administrative Terms and Conditions (CA-FATC); and any inventions conceived or reduced to practice in the performance of the Subaward Agreement, shall be specifically governed by Bayh-Dole 37 CFR 401; and

**WHEREAS**, the Parties wish to provide for the allocation of certain rights as among themselves relating to the identification, disclosure and commercialization of IP resulting from their cooperative and collaborative activities under the Project;

**NOW, THEREFORE**, in consideration of the promises and conditions contained in this Agreement, the Parties mutually agree as follows:

1. The Parties hereby agree that, in the event patentable inventions are conceived and first reduced to practice during the performance of the research conducted under the Project

(“Inventions”), the inventorship, and the ownership of such Invention shall be as follows:

- a. Ownership shall be determined by inventorship unless the inventions and discoveries of one Party are made using the facilities of another, in which event written facilities use policies or relevant state law shall also be used to determine ownership of such inventions and discoveries.
- b. Inventorship shall be determined in accordance with U.S. Patent Laws.
- c. For the proper determination of inventorship, the Parties shall fully and promptly disclose, in confidence, any and all Inventions in writing to the other Parties.
- d. Sole Inventions: Inventions made solely by employees of one Party shall be the sole property of that Party, and shall be disposed of in accordance to the internal policy of that Party.
- e. Joint Inventions: Inventions made by employees of more than one Party shall be deemed to be joint property of such Parties, each such Party having an undivided equal interest in the same.
- f. The Parties agree to consult with one another prior to taking any action to obtain patent protection of Joint Inventions and shall agree upon the patent filing and prosecution strategy of said Invention.
- g. Each Party’s ownership of and/or interest in the Inventions shall be disposed of in accordance with the internal policy of that Party.
- h. Each Party agrees not to assert patent rights in subject Inventions against any other Party for that Party’s research and educational purposes.
- i. Subject to the terms of the funding support from NSF, the Parties agree to cooperate to utilize and exploit any Joint Invention.
- j. Each Party will undertake actions to ensure that any subject Inventions obtain the benefit of the Cooperative Research

and Technology Enhancement Act of 2004.

2. Nothing contained in this Agreement shall be deemed to grant any Party directly or by implication, estoppel, or otherwise any license under any patents, patent applications, copyrights, trademarks, mask works, trade secrets or other intellectual property owned or developed before or independent of this Agreement by the other Party.
3. It is understood that it may be necessary for one or more Parties to disclose information to the other which is considered confidential in order to accomplish the work under the Project. Each Party agrees to take all reasonable precautions to prevent disclosure to third parties of such confidential or proprietary information in the absence of any written consent by the other Party of such disclosure. The receiving Party shall consider as “Confidential Information” such information, data or material which:
  - a. is disclosed by the another Party in written or other tangible form during the period of performance of the Project;
  - b. is conspicuously marked confidential or proprietary; and
  - c. is not available in the public domain.

It is agreed that the Parties shall disclose only information necessary to the work to be carried out under the Project. The disclosing Party shall send such information only to the Project Manager or Principal Investigator of the receiving Party. If disclosed orally, the disclosing Party shall subsequently provide a written summary of the information within thirty days of the oral disclosure. The Parties agree that, to the extent permitted by law, such Confidential Information shall remain the property of the disclosing Party and, for a period of five (5) years from the end of the Project, such Confidential Information shall not be disclosed to others by the receiving Party without the disclosing Party’s prior written approval, provided, however, that the foregoing obligation of non-disclosure shall

not apply to any portion of the Confidential Information which:

- a. is or shall have been known to the receiving Party before receipt thereof;
  - b. is disclosed to the receiving Party by a third party having no obligation of confidentiality to the disclosing Party;
  - c. is or shall have become known to the public through no fault of the receiving Party,
  - d. is independently developed by one or more of the Parties, or
  - e. the receiving Party is obligated to produce pursuant to an order of a court of competent jurisdiction or valid administrative or congressional subpoena, provided that receiving Party promptly notifies the disclosing Party.
4. This Agreement constitutes the entire and only agreement between the Parties regarding the disposition of intellectual property developed as part of the Project and all other prior negotiations, representations, agreements, and understandings are superseded hereby. No agreements altering or supplementing the terms hereof may be made except by a written document signed by all Parties.
  5. Notices and other communications required by the terms and conditions of this Agreement shall be made by first-class mail or private courier, postage prepaid, confirmation by facsimile to the cognizant administrator at each partner institution.
  6. This Agreement shall terminate with the expiration of the last to expire patent developed under the Project, or on abandonment of all patent applications developed under the Project, provided such abandonment is by mutual consent.
  7. If any disagreements arise, the Parties will use their best efforts to negotiate to resolve all differences. The collaboration of the Parties is paramount.
  8. Waiver by any Party of any breach or failure to comply with any provision of this Agreement by the other Party shall not be construed as, or constitute a continuing waiver of such provision or a waiver of any other breach of or failure to comply with any other provision of this Agreement.
  9. The invalidity, illegality or unenforceability of any provision contained in this Agreement shall not affect or render invalid, illegal or unenforceable the remainder of this Agreement.
  10. This Agreement shall be effective as of the date of the last signature below. This Agreement may be executed in one or more counterparts, which collectively constitute one agreement.

**IN WITNESS WHEREOF**, the parties have caused this Agreement to be executed as of the year and date below described as set forth by their duly authorized representatives.

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**For UH**

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**For MBARI**

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**For MIT**

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*Richard Cox*

*Director, Office of Technology  
Transfer and Economic  
Development*

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*C. Michael Pinto*

*Chief Financial Officer*

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*Lita Nelson*

*Director, Technology Licensing  
Office*

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**For OSU**

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**For UCSC**

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**For WHOI**

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*Craig Sheward*

*Director, Office of Technology  
Transfer*

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*Gerald Barnett*

*Director, Office for Management  
of Intellectual Property*

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*William McKeown*

*Director, Shore Operations and  
Technology Transfer*

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## Appendix C. Code of Ethics and Human Studies

All research, education and scholarship that is undertaken by the Center staff will be pursued in an environment in which high ethical standards are the norm. Academic institutions exist and operate on trust and this demands a responsibility for the integrity of the process involved in collecting, analyzing and publishing data collected through activities sponsored by the Center. At all C-MORE institutions, there are formal documents in place that articulate Ethical Standards in Research and Scholarly Activities (at UH it is entitled, Executive Policy E5.211). For example, the UH Ethics Committee is charged with investigating allegations of scientific misconduct which includes falsification of data, plagiarism, abuse of confidentiality, dishonesty in publication, deliberate violation of regulations, and failure to report fraud. This committee is appointed by, and reports to, the UH Vice Chancellor for Research. David Karl, the Director of C-MORE, was a member of this committee from 1993-1995 and served as Ethics Committee Chair from 1995-1998. A program of ethics training based on these and related documents, such as those published in 1996 by J. Woodward and D. Goodstein in *American Scientist* ("Conduct, misconduct and the structure of science," vol. 84: 479-490) and in G. Taube's 1993 special news report in *Science* ("Misconduct: Views from the trenches," vol.

261: 1108-1111), will be developed by the Center for all staff including faculty, visiting faculty, industrial fellows, post-doctoral fellows, graduate and undergraduate students, and technical assistants. In addition, UH offers a program for graduate student orientation on responsible conduct of research including: ethical violations, plagiarism, principles of authorship, conflicts of interest, and violation of relevant research policies and government regulations. There is additional training on working with human subjects, the matter of informed consent, and working with animals. This basic training program is modified to address target audiences and is expanded to address discipline-specific issues.

All research within the Center will be conducted using accepted procedures and policies as they relate to environmental health and safety, the use of radioisotopes and recombinant DNA. At all C-MORE institutions, there are well-established policies and procedures in place for oversight of Federal Regulations regarding the protection and management of risks to human participants involved in research. The UH Institutional Review Board (IRB) serves as an objective third party to enforce UH policies and procedures (<http://www.hawaii.edu.irb>). Requests made to this Board for C-MORE related research will be evaluated on a case-by-case basis.