STC Annual Report 2011: C-DEBI

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I. GENERAL INFORMATION

1a. Provide the following general information:

Date submitted 2/17/2011
Reporting period OCT 2010-Jan 2011
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1b. Provide, in one page or less, brief biographical information for each new faculty member by institution. Attach as Appendix A.

The external advisory board has been formed, see Appendix A.

1c. Provide the name and contact information for the primary person to contact with any questions regarding this report.

Name of Individual: Katrina Edwards
Center Role: Director
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2. Context statement

C-DEBI bundles three US-lead diverse deep subseafloor biosphere projects and coordinates them with international partners to accomplish an integrated, global scientific mission to solve questions regarding the nature, diversity, extent, and activity of the marine deep biosphere. This center is multi-institutional with international partnerships, with additional science and engineering liaisons and partnerships from a host of for- and not-for-profit agencies and a national laboratory. C-DEBI integrates scientific projects across two deep subseafloor biosphere environments (igneous ocean crust and sediments) that have historically been studied independently, and among locations that span the globe.

Marine sediments can accumulate in km thick sequences in coastal areas, margin terrain, and abyssal plains of the ocean. These sediments are mineralogical and geochemical reservoirs of information about the environment in which each layer was deposited. Chemical processes in sediments are often dictated by diffusion and reaction kinetics, which operate very slowly over long length scales. As such, sediments record

Earth's history, containing information about, for example, past glaciations and deglaciations and climactic and geochemical events. However, since the discovery of extant, metabolically active microbial life harbored within deeply buried sediments to at least 1km depth below the seabed, it is now known that they represent a complex reservoir of past and present life processes and biogeochemical activity, as well as localized time-capsules of microbial evolution.

The igneous ocean crust is composed of porous and permeable volcanic rock, principally basalt, which outcrops at mid-ocean ridges (MORs) where frequent eruptions build new crust. The crust moves off-axis and typically remains uncovered by sediments for thousands to millions of years on the flanks of the MORs, before being blanketed in the abyssal plains of the ocean, and eventually subducted at trenches. The upper ~500 m of igneous crust is fractured and permeable to fluid, and hosts the largest aquifer on Earth. Most of the oceanic crust is hydrologically active (at least 60%) and the fluid flux through the ocean crust rivals global riverine input to the oceans. Solutes and colloids—microbes included in this fraction—circulate actively through the crustal aquifer, but the degree to which microbes "take seed", colonize, alter, and evolve in subsurface rock is not known.

C-DEBI fuses research in the deep biosphere from the crust and sediment marine realms, through scientific integration of independently-developed US-lead deep subseafloor biosphere projects that have recently progressed through the Integrated Ocean Drilling Program System (IODP), in order to conduct an integrated global mission: to resolve the extent, function, dynamics and implications of the subseafloor biosphere. The three US-lead that form the core of our mission were developed by the PI group: Edwards (USC) and Wheat (UAF) (North Pond, mid-Atlantic); Fisher (UCSC) and Cowen (UH) (Juan de Fuca, Pacific NW); D'Hondt (URI) and Edwards (USC) (South Pacific Gyre). C-DEBI serves as: (1) a coordination and cyber infrastructural hub for an international community of researchers; and (2) a scientific incubator that will and revolutionize efforts to develop additional field, laboratory, and modeling experiments. C-DEBI integrates and collaborates with German, Japanese, Danish, and Chinese researchers, and bring deep subseafloor marine biosphere projects developed in those countries into the C-DEBI framework. C-DEBI serves as a bridge between the scientific community of subseafloor biosphere researchers and drilling partners (Integrated Ocean Drilling Program, Ocean Leadership, industry). C-DEBI's goals are to serve as an international model for project coordination and integration, establishing the intellectual, educational, technological, cyber-infrastructural, and collaborative framework needed for transformative experimental and exploratory research on the subseafloor biosphere.

C-DEBI is also creating distinctive educational programs at the K-12, undergraduate, graduate, and postdoctoral levels in order to train and foster the next generation of deep subseafloor biosphere researchers. This is critical to ensure the robust continued development of this new field, and will arm the field with the brightest and most creative young minds that can take what has been built over the past decade, to expand it in this decade via C-DEBI. C-DEBI also focuses on translating knowledge of the deep subseafloor biosphere and ocean sciences to the broader public. We will accomplish this in part through core education programs which will interact with public policy, administration, and other education fields, and also by diverse lecture programs and other outreach mechanisms that promote broad dissemination of information and increased awareness of the existence and potential importance of the subseafloor biosphere. C-DEBI will support undergraduate, graduate, postdoctoral studies and

research broadly across with collaborating investigator laboratories. C-DEBI is developing programs presently within the COSEE-West framework, and those of other existing programs in order to integrate C-DEBI faculty, postdoctoral, and graduate students into K-12 science education. As part of C-DEBI, faculty are working with COSEE-West staff and K-12 teachers to create new curriculum elements and lesson plans that explore the topics of C-DEBI research and link it directly to the California State Science Standards.

MAJOR ACCOMPLISHMENTS of the first three months of C-DEBI include:

1) successful execution of Expedition 327, Juan de Fuca;

2) successful execution of Expedition 329, South Pacific Gyre;

3) new partnerships with industry and scientists;

4) establishment of a comprehensive web-site;

5) establishment of our small grants programs (research, postdoctorals, and student fellowship) and successful funding of a number of new projects & researchers, including several that are new to deep biosphere research.

6) establishment of many of our education programs;

7) successfully secured new funding for C-DEBI for science and technology;

8) establishment of our External Advisory Board;

9) scheduling of our first all-hands meeting (May 14-15 2011);

10) planning complete for the DEBI RCN meeting in Chapel Hill, NC (March 7-9 2011).

II. RESEARCH

1a. Center's overall research goals and/or objectives

Deep subseafloor biosphere studies seek to answer questions that range in nature from exploratory and census-level to the most complex and fundamental in the Earth and life sciences. Deep subseafloor habitats are vast in scale —it is estimated that up to one third of the Earth's biomass is harbored in the deep marine subseafloor— and are physically and chemically vastly diverse. A common feature among all deep subseafloor biosphere habitats is that they exist in the dark, one or more steps removed from the photosynthetic activity that fuels the surface biosphere. Energy and carbon cycling in the deep subseafloor biosphere are potentially important issues in solving global redox and carbon budgets. However, quantification of the magnitude and activity of this dark biosphere and its organic versus inorganic energy and carbon sources is difficult, owing to a dearth of data concerning the nature of these deep ecosystems. Fundamental questions that have far reaching consequences for life on Earth and beyond include: What is the nature and extent of life on Earth? What are the physico-chemical limits of life on Earth? How metabolically active is the deep subseafloor biosphere, and what are

the most important redox processes? Are there exotic metabolic processes occurring? How are microbes dispersed in the deep subseafloor biosphere? How does life evolve in deeply buried geological deposits beneath the ocean floor? These questions are diverse and demand interdisciplinary research approaches in microbiology, molecular biology, geology, geochemistry, engineering, hydrology and more.

Our research has the potential to impact major current questions such as energy creation, climate change, and the very nature of evolution of life on Earth. To address these challenges, we focus and integrate across four broad C-DEBI Research Themes. We are addressing questions within these themes by linking deep subseafloor biosphere projects into the coherent deep-biosphere program of C-DEBI. The linked C-DEBI projects embrace a strategy of "contrast, compare, and integrate" between deep subseafloor biosphere sites where specific environmental controls, processes, and dynamics relating to C-DEBI research themes can be resolved. Our cross-site research agenda can only be accomplished via an integrative center infrastructure, which will fundamentally change the nature of how deep subseafloor biosphere research is conducted, resulting in transformative advances in this field.

1b. Performance and management indicators/metrics

Our mechanisms for research advancement include:

1. Develop and implement communication tools to build the community
2. Manage the three major field programs and develop momentum in new areas that transform the understanding of life, particularly subsurface life
3. Develop the four research theme areas in order to grow and cross fertilize between major field projects.
4. Develop and implement cross disciplinary and cross-institutional training through small grants programs: research grants, student and postdoctoral fellowships, research exchanges

1c. Problems encountered

C-DEBI was launched only in the fall of 2010. In the first three months, the most significant hurdles have been in launching the center and two of our three major field programs simultaneously, resulting in some delays, but none significant.

2a. Research thrust areas at the Center

The research thrusts can be split into two areas: i) focus study sites and ii) broad research themes. The current focus study sites are the Juan de Fuca Ridge (led by C-DEBI Co-Investigators Andrew Fisher and James Cowen), the South Pacific Gyre (Steven D'Hondt), and North Pond on the Mid-Atlantic Ridge (Katrina Edwards and Geoff Wheat). The research themes include the activity in the deep subseafloor biosphere (led by Wiebke Ziebis); the extent of life, including biogeography and dispersal (Andreas Teske); the limits of life (Tom McCollom); and evolution and survival (William Nelson).

i. *Focus Study Sites*

Juan de Fuca Ridge (5 July – 5 September 2010): The focus at this study site is on the hydrogeologic architecture of basaltic ocean crust, including the compartmentalization, anisotropy, microbiology, and crustal-scale properties on the eastern flank of the Juan de Fuca Ridge in the eastern Pacific Ocean. IODP Expedition 327 (Co-chief scientists: Andrew Fisher and Takeshi Tsuji) is part of a series of long-term multidisciplinary experiments that build from technical and scientific achievements and lessons learned during ODP Leg 168 and IODP Expedition 301, on the eastern flank of the Juan de Fuca Ridge. The main goals of these experiments are to evaluate formation-scale hydrogeologic properties (transmission and storage) within oceanic crust; determine how fluid pathways are distributed within an active hydrothermal system; establish links between fluid circulation, alteration, and geomicrobial processes; and determine relations between seismic and hydrologic anisotropy. Key goals of Expedition 327 included: installing subseafloor observatories (CORKs) in two new holes in oceanic crust; replacing an observatory in an existing hole (ODP Hole 1027C) after deepening that hole, to facilitate long term monitoring; and recovering and replacing an instrument string deployed in one of the Expedition 301 subseafloor borehole observatories in Hole 1301B. Secondary objectives included sediment coring at a series of sites adjacent to basement outcrops and buried basement highs to assess the nature of fluid, heat, and solute transport in the igneous crust. Instruments developed for the new CORK systems deployed on Expedition 327 include temperature and pressure loggers to monitor multiple depths, long-term fluid samplers, and microbiological incubation substrate. Following Expedition 327, a series of non-drilling expeditions will conduct single- and crosshole hydrologic experiments using a submersible/remotely operated vehicle, with the complete network of six observatory systems functioning as perturbation and monitoring points.

IODP Expedition 327 successfully completed the highest priority objectives of drilling and coring two new basement holes at Site U1362, located between Sites 1301 and 1026, and installing new long-term borehole observatories. Hole U1362A was cored and drilled to 528 meters below seafloor (mbsf) (292 meters sub-basement [msb]), subjected to geophysical logging and hydrologic testing, and instrumented with a multilevel CORK observatory. Hole U1362B was drilled to 359 mbsf (117 msb), subjected to a 24 h pumping and multi-tracer injection experiment, and instrumented with a single-level CORK observatory. Both CORK observatories include monitoring of pressure and temperature and downhole fluid and microbiology sampling. Wellhead samplers will be added and a long-term cross-hole test will be initiated during a post-drilling ROV expedition scheduled for Summer 2011. In addition, part of an instrument string deployed in Hole U1301B during Expedition 301 was recovered, and a replacement string of thermal sensors was installed. Finally, a program of shallow sediment coring was completed adjacent to Grizzly Bare outcrop, a suspected site of regional hydrothermal recharge. Thermal measurements and analyses of pore fluid and microbiological samples from a series of holes aligned radially from the outcrop edge will elucidate rates of fluid transport and evolution during the initial stages of ridge-flank hydrothermal circulation. Unfortunately, high priority objectives were not achieved in Hole 1027C because it was not possible to recover the old CORK observatory installed in this hole in 1996. Planning is now underway for retrofitting of the existing CORK observatory in Hole 1027C to permit long-term pressure monitoring using new scientific instrumentation during Summer 2011 ROV operations.

South Pacific Gyre (9 October – 13 December 2010): The focus at this study site is on the microbiology beneath the seafloor at the South Pacific Gyre. IODP Expedition 329,

led by Co-chief scientists Steven D'Hondt and Fumio Inagaki, cored and logged deep-sea sediment and basement at seven sites in the South Pacific Gyre. The seven sites were selected to test effects of oceanographic conditions (productivity, distance from shore, water depth, etc.) and basement conditions [basement age (6 Ma to 84-124.6 Ma), basement structure, aquifer recharge rate, etc.] on microbial communities in the subseafloor sediment and underlying basalt, respectively.

The primary purposes of this project are to (a) document the nature of microbial communities and test the energetic limit to life in the most food-poor deep-sea sediment, and (b) test the influence of basement age and sediment thickness on basement habitability, microbial communities, and the hydrologic evolution of crustal basalt. This project is addressing fundamental questions about subseafloor life, including the following: Are the communities in mid-gyre subseafloor sediments uniquely structured (*i.e.,* as this is the first mid-gyre microbiology expedition, how do these communities compare to those previously studied nearer to the continents)? Do they contain previously unknown kinds of organisms? Is their primary electron donor organic matter from the surface world or hydrogen from *in situ* radioactive splitting of water? Do their activities and composition vary with properties of the surface world, such as sea surface chlorophyll concentrations or organic flux to the seafloor? Is microbial activity sustainable in subseafloor basalt by mineral oxidation (*e.g.,* oxidation of iron in the basaltic minerals) or other processes for tens of Myrs after basalt formation? Are microbial communities recognizably present in subseafloor basalts older than 13 Ma?

The entire sediment column, from seafloor to sediment/basalt interface, was recovered at all sites; it ranged from site to site in thickness from 10.5 to 122.5 meters. Fragments of basaltic basement were recovered at all seven sites, and the basement was cored at three of the sites to between 35.5 and 103.3 meters below the sediment/basalt interface.

At the time of this writing, IODP Expedition 329 has just returned from sea. Samples and shipboard data are now being shipped to shore-based laboratories for post-expedition analysis and research.

<u>North Pond – Mid-Atlantic Ridge (scheduled for 16 September – 19 November 2011):</u>
The focus at this study site is on the microbiology of a sediment pond and the underlying young, cold, hydrologically-active ridge flank. IODP Expedition 336 (Co-chief scientists: Katrina Edwards and Wolfgang Bach) intends to drill a site known as North Pond, a shallow sediment pond on the western flank of the mid-Atlantic ridge. Prior expeditions to North Pond have set the stage, young oceanic crust (7-8 m.y.) with active, low temperature, oxygenated fluids that vigorously advect through basaltic basement. Such a thermal and hydrologic setting is characteristic of large portions of the global ridge flank system, where a significant fraction of lithospheric heat is lost via hydrothermal processes, and the associated fluid-microbe-rock reactions significantly alter the composition of the oceans and crust. The role that microbes play in altering the physical and chemical characteristics of the crust in ridge flank settings may be substantial, and quantifying this alteration is a fundamental goal of IODP in general. Evidence for microbial alteration exists, yet we lack robust molecular, biochemical, or physiological data so that we can understand the very nature of microbial processes in the oceanic lithosphere.

To address this lack of knowledge related to this fundamental crustal process, the Mid-Atlantic Microbial Expedition strives to answer three fundamental questions: (a) What is

the nature of microbial communities harbored in young ridge flanks and what is their role in ocean crust alteration? (b) Are these communities unique, particularly in comparison with seafloor and sedimentary communities? (c) Where do deep-seated microbial communities come from (sediment, rock, seawater, other)? To address these questions the expedition has two major thrusts. The first is to recover materials (sediment and basalt) for extensive chemical, microbial, and physical testing. Samples will be collected during the drilling expedition, but most of the analysis will occur ashore. The second thrust of the expedition is to deploy three borehole observatories, allowing one to place experiments within the borehole and also at the seafloor where plumbing systems pump fluids from within the basaltic crust to experiments on the seafloor. Several experiments and sampling protocols will be deployed providing a foundation of information, but a variety of additional experiments and samplers can be accommodated both during the initial deployment on the drilling expedition for downhole experiments and during the first submersible cruise, which will occur four months after drilling ceases, for seafloor-based experiments.

At the time of this writing, IODP Expedition 336 has not yet launched.

ii. *Research Themes*

As work at the focus study sites progresses with the initiation and completion of the IODP Expeditions 327, 329, and 336, C-DEBI research will be integrated across four broad themes. Here, we summarize the fundamental ideas behind each theme, but it is too early in the project to highlight significant accomplishments.

Activity in the deep subseafloor biosphere: This research theme targets function and rates of global biogeochemical processes. How and to what extent these processes exert fundamental influence on the biogeochemistry of the ocean and atmosphere are fundamental questions. The site survey cruises, especially the drilling expeditions at the focused study sites (Juan de Fuca, South Pacific Gyre, North Pond) will advance our understanding tremendously on the nature of the subsurface habitats and on the activities of sedimentary microbial communities. The investigations will shed light on how deep microorganisms persist in even the most oligotrophic areas of the world ocean, like the South Pacific Gyre, and will directly target questions on how the communities are sustained (energy, carbon sources). The highly successful site survey cruises to the South Pacific and the Mid-Atlantic have demonstrated that oxygen persists meters into the seafloor. In contrast to near-shelf sediments, oxygen appears to be the most dominant electron acceptor for microbial respiration. By drilling through the entire sediment column, we will know if oxygen penetrates all the way to the underlying crust. We need to know the respiration rates within different ocean areas and sediment depths to estimate the global respiration rates. Oxidation of organic carbon leads to a major source of dissolved inorganic carbon (DIC) to the ocean. Because the geographic and depth distribution of organic carbon degradation is poorly quantified, the global effect is not well known. Some important questions: Does an entirely aerobic community persist throughout the entire sediment column, or is it replaced by an anerobic community at depth? What are the potential electron donors supporting microbial communities especially at greater depth? Does a heterotrophic or autotrophic metabolism dominate? We know that there is fluid flow in the basalt, especially in young ocean crust. It remains an open question, however, to what crustal age fluid flow continues. We need to know the effects of oxidants being transported in crustal aquifers and diffusing upward into the overlying sediment on microbial activity and the nature of the microbial communities.

Water-rock weathering reactions in the ocean crust impose significant negative feedback on atmospheric CO_2, accounting for ~30% of the silicate-drawdown globally. Microbes are known to promote these reactions in the laboratory and at the seafloor, but the degree to which they influence these processes *in situ* in the subseafloor remains unknown. Through targeted support of research aiming to quantify geographic distributions of subseafloor sedimentary respiration, rates and magnitude of microbial crustal alteration, energy sources and carbon flow, C-DEBI will enable robust analyses linking subseafloor processes to global scales and biogeochemical cycles. An upcoming scientific meeting at the University of North Carolina (Microbiology in Marine Sediments, March 2011) will be a forum to present and discuss recent discoveries at the focused study sites. It will also provide the opportunity to define directions on how to move forward as a community to explore the activity in the deep subseafloor biosphere.

An online forum is presently being developed by this theme team leader (Ziebis) and postdoctoral Anand Patel.

Extent of life: This research theme targets subseafloor biomes and the degree of connectivity (biogeography and dispersal). It is widely accepted that there is a deep subseafloor biosphere—intraterrestrial microbes that appear to represent a significant biosphere in sediments and rock below the bottom of the ocean. How microbes are transported and dispersed in the deep subseafloor biosphere—the biogeography of microbes—is an open and intriguing problem. Questions concerning biogeography speak to the most fundamental problems in microbiology—the extent and diversity of microbial life across the full spectrum of microbial habitats on Earth—and date at least back to the Baas-Becking hypothesis that 'everything is everywhere, but, the environment selects'. The variety of dispersal mechanisms for microbes to deep subseafloor habitats, and the vast spatial- and time-scales we consider, presents opportunities to address fundamental questions in this field.

As discussed above, it is well documented that tremendous volumes of seawater infiltrate the crust and hence, seawater is likely a source of inoculum "seeding" subseafloor biomes. The transport time for fluid to travel through different crustal aquifers varies enormously, as do the physical and chemical conditions of these fluids and any microbiology they carry. Deep sea sediments remain in exchange with seawater at their top and bottom layers via the overlying water column and deep crustal aquifers. What microbes take seed and why? What are the most significant physical and chemical controls of these colonization processes? How similar or different are the resulting crustal and sedimentary ecosystems from deep subseafloor ecosystems and from each other? We expect that geochemical and physical site parameters will shape the patterns of archaeal and bacterial community compositions. Questions relating to biogeography are a cornerstone component of C-DEBI, because it is only through inter-project comparisons that true headway in comparing these ecosystems may be made. Each site and project is an island in and of itself, but when compared with this disparate set of habitats, will coalesce as a global model for biogeography of microbes below the ocean floor.

This theme is currently the major focus of the workshop being organized by theme team leader Andreas Teske, and participants Jen Biddle and Matt Schrenk (DEBI RCN March 9-11 2011, Chapel Hill, NC; see supplement 1 for details of participants to this workshop).

Limits of life: This research theme targets the extremes and norms of carbon, energy, nutrient, temperature, pressure, and pH, with the objective of understanding how these factors influence the distribution and diversity of life within seafloor sediments and ocean crust. One particular focus is to define the boundaries between habitable and uninhabitable environments. While high temperatures are likely to be encountered at depth and will probably be a critical limitation in many areas, this is likely to be convolved with other factors. Low availability of electron donors, limited fluid circulation, and accumulation of metabolic waste products are some other factors that may limit the distribution of life in the subseafloor. It is also anticipated that the very different environments within marine sediments and the igneous ocean crust will lead to substantial differences in the relative importance of critical factors in limiting subsurface life. Simply put, common microbial processes may be more thermotolerant than previously known. For example, an ongoing survey of near-surface hydrothermal Guaymas Basin sediments is extending the upper temperature limit of anaerobic methane oxidation, a process previously found only in cold marine sediments.

Activity in this thematic area will begin in earnest with a workshop currently being planned for late spring of 2011. This workshop will assess the current state of knowledge on the limitations of life and on conditions in the subsurface, and identify key areas where additional research (laboratory, theoretical, and field-based) is needed to address gaps in existing knowledge. A workshop report describing the findings will be widely distributed to the C-DEBI community, and will be submitted for publication in a scientific journal for broader exposure. In addition, the ongoing and upcoming field studies at Juan de Fuca, North Pond, and the South Pacific Gyre will provide raw data and new insights into the factors that limit subsurface life. So far, 16S rRNA sequencing has identified microbial communities in surficial sediments of the South Pacific Gyre. Also, sequences from deeper sediment layers were obtained only at the margins of the South Pacific Gyre, but indicated strong redox stratification of bacterial and archaeal communities.

This theme team leader (McCollom) is organizing a mini-workshop to develop this theme, to be held on Catalina Island in May of 2011.

Evolution and survival of life: This research theme targets microbial adaptation, enrichment, and repair. The question of persistence of life from the perspective of metabolic processes and growth can be distilled to the concept of survival at the edge of bioenergetics and redox processes. The metabolic rates proposed for subsurface microbes are up to six orders of magnitude below respiration rates observed in microbial cultures and in environmental microbes in surface sediments and challenge our current understanding of the functioning of life (*i.e.,* having enough energy to maintain charge potential across a cell membrane). Observations of living cells with intact polar membrane lipids lead to the inference that subseafloor sedimentary microbes must persist at extremely low rates of activity per cell. Additionally, studies have shown that the subseafloor hosts extremely unique microbial communities that are distinct from surface habitats. For example, the archaeal communities of oxic and nitrate-reducing South Pacific Gyre sediments form sediment-associated phylogenetic clusters branching off from previously known water column lineages; in deeper sediment layers, entirely different archaeal lineages predominate. Why are these microbial groups so prevalent in the subsurface? Are there distinct adaptations that are common to the subseafloor biosphere?

Since most subsurface microbes are recalcitrant to cultivation, answers to questions about their adaptation, evolution and survival need to be answered through genetic analysis. Genetic-based studies of deep subseafloor biosphere to date have used targeted polymerase-chain reaction (PCR) based approaches to examine phylogenetic genes and on occasion, ribosomal sequencing and analysis has been performed. More rarely, PCR based approaches for looking at functional genes encoding for important biogeochemical processes (methane, iron, etc.) have been targeted. However, research concerning questions about survival and evolution in the subseafloor has not yet emerged among the core foci in subseafloor biosphere studies, nor have research approaches that take a broader-scale view of the genetic content of microbes buried beneath the seafloor. We envision that studies will embrace a compare-and-contrast approach across our C-DEBI field projects examining the total gene content of the deep subseafloor biosphere using metagenomics-based approaches. The term "metagenomics" includes a variety of whole-genome approaches such as shot-gun sequencing, vector-based library tools, whole-genome amplifications, and other specialized methods.

Our first-glimpse at the use of metagenomics in the deep subseafloor biosphere illustrates its potential power for evolutionary questions. As part of the initial "census" of life in subseafloor sediments, it has emerged that globally, cell abundances decrease logarithmically with depth. A consequence of this decrease is that with depth, microbes become increasingly isolated from each other, owing to the fact that chemical exchange in sediments is dictated by diffusion, which operates slowly over long length scales. Hence, we may hypothesize that an evolutionary consequence of this increasing isolation may be the loss of genes for functions such as chemotaxis and quorum sensing, which may not be needed as cells become isolated. Indeed, metagenomic surveys of sediments from the Peru Margin show that genes for chemotaxis decrease with depth, suggesting that further metagenomics surveys and cross-comparisons may yield exciting new insights on microbial evolution on Earth. Through project integration with C-DEBI, we will be able to integrate and compare these finding with metagenomics surveys at other sites and in distinct biomes.

This theme team leader (Nelson) is organizing a mini-workshop to develop this theme, to be held on Catalina Island in June of 2011.

2b. Center's performance with respect to the indicators/metrics

1. Develop and implement communication tools to build the community
2. Manage the three major field programs and develop momentum in new areas that transform the understanding of life, particularly subsurface life
3. Develop the four research theme areas in order to grow and cross fertilize between major field projects.
4. Develop and implement cross disciplinary and cross-institutional training through small grants programs: research grants, student and postdoctoral fellowships, research exchanges

Successful achievement of these goals is indicated by:

1. Develop and implement communication tools to build the community

a. Developed a comprehensive website at www.darkenergybiosphere.org with research and education portals and resources
b. Maintaining and updating a mailing list that participants can sign up for on-line to receive notifications. We have actively recruited additional participants at our meetings, town halls, and workshops
c. Production and distribution of two newsletter to mailing list
d. Multiple talks, posters, and information booths at conferences (referenced in VIII. Centerwide Outputs and Issues 1b)
e. Community is over 300 members from 22 countries, approximately double from the start of the granting period (see participants Appendix C)

2. Manage the three major field programs and develop momentum in new areas that transform the understanding of life, particularly subsurface life
    a. Surveys in the community--
        i. Juan de Fuca Summer program 2010
        ii. IODP Expedition 329 survey of Participants
    b. See above reported activities for the three field programs
    c. Publications listed in VIII. Centerwide Outputs and Issues 1b
    d. New projects and funding streams to Center (referenced in VIII. Centerwide Outputs and Issues 2)
3. Develop the four research theme areas in order to grow and cross fertilize between major field projects.
    a. See above reported activities for the the four research theme areas
    b. Theme team first mini workshop scheduled for May 2011
4. Develop and implement cross disciplinary and cross-institutional training through small grants programs: research grants, student and postdoctoral fellowships, research exchanges (see below)
    a. First call deadline commenced with the start of C-DEBI; upcoming deadline is March 31st.
    b. Call was developed and written by the theme team leaders with oversight from ExCom; grants reviews by Steering committee and other community researchers
    c. One Student exchange funded; one research exchange funded; six postdoctoral fellowships funded at five institutions
    d. One research exchange pending; one graduate student fellowship pending; seven postdoctoral fellowships pending at seven institutions; eight research proposals pending

The following outlines the different small grants programs available through the Center.

1. C-DEBI Research Support Program

We have invited proposals in the range of $50,000 for projects that are relevant to deep biosphere research and in particular complement the scientific program of recent or scheduled IODP drilling expeditions. Proposals will be considered for pre- and post-cruise research, as well as for ship-board work and shore-based analyses. Special attention will be paid to the specific challenges that accompany microbiological investigations and the study of biogeochemical processes in the deep subsurface, which may require, for example, timely analyses of perishable samples, or experiments with live samples. Projects may also focus on refining or

adapting challenging techniques, or applying well-established methods to the analysis of substantial sample sets.

We also implemented a special “Call for Collaboration” for the summer 2011 CORK Dive Program, Eastern Flank of the Juan de Fuca Ridge. This is intended to enable new research/researchers to get involved in the Juan de Fuca CORK project, via collaboration with the C-DEBI PIs of this project (Fisher, Wheat, Cowen, Edwards).

2. Research Exchange Program

C-DEBI facilitates scientific coordination and collaborations by supporting student, postdoctoral, and faculty exchanges to build, educate and train the deep subseafloor biosphere community. Exchanges establish direct linkages among groups within individual institutions, which are intended to result in a well-connected community and the development of future deep subseafloor biosphere researchers and leaders. Exchanges allow a C-DEBI researcher (student/postdoctoral/faculty) to spend 1-6 months at a participating C-DEBI community host laboratory to carry out experiments, use analytical equipment, learn a new tool, and/or join a research cruise.

Exchanges may operate between any willing C-DEBI collaborating laboratories. Financial support for exchanges through C-DEBI will be ~50% of the total cost. Matching funds would be required, for example, a travel award from any program that supports student awards in this way (*e.g.,* Geological Society of America, NASA Lewis and Clark fellowships), or by other means, such as matching support from the researcher's institution or from a postdoctoral supervisor.

3. Postdoctoral Scholar Program

The C-DEBI Postdoctoral Scholar Program supports postdoctoral research in C-DEBI afilliated laboratories. Candidate fellows are encouraged to examine the IODP Expedition Schedule prior to developing their research proposal as all fellowship research is expected to align with the objectives of an IODP Expedition that involves research into the deep biosphere.

4. C-DEBI Graduate Fellow Program

Apply for C-DEBI graduate student funding. The C-DEBI Graduate Fellow Program supports graduate student research in C-DEBI community laboratories. Candidate fellows are encouraged to examine the IODP Expedition Schedule prior to developing their research proposal as all fellowship research is expected to align with the objectives of an IODP Expedition that involves research into the

deep biosphere. C-DEBI encourages underrepresented groups to apply. This funding is only available to graduate students sponsored in US institutions.

5. Graduate Courses

We are working with existing programs to integrate C-DEBI research into graduate thematic focus courses in which our faculty are heavily engaged, such as:

- Agouron Institute International GeoBiology Course--will examine microbe-mineral activity and its imprint during an intensive four-week course that includes travel to Yellowstone National Park in Wyoming; to the Colorado School of Mines in Golden, Colorado, and to USC research labs on Catalina Island.
- Hopkins Marine Station of Stanford University Microbiology Course--integrating concepts of microbial physiology, ecology, and evolution with hands-on activities in isolation of a wide range of microbes, experimental evolution, population genetics, clone library construction, and bioinformatic analysis
- Marine Biological Laboratory (MBL) Microbial Diversity Course-six and a half week course in microbiological techniques for working with a broad range of microbes, and in approaches for recognizing the metabolic, phylogenetic, and genomic diversity of cultivated and as yet uncultivated bacteria
- Existing graduate courses such as USC's GEOL 601, Seminar in Sedimentary Geology,

6. Small Grants

We are awarding small research and travel grants (up to $5K) for graduate students affiliated with the Center. These grants may be used to support research, travel for presenting C-DEBI research at meetings, or travel exchanges to other partner institutions or institutions that have new tools and techniques that can be applied to C-DEBI research.

Our DEBI RCN Graduate Student Education Exchange program also supports graduate student exchanges to facilitate collaborations among deep biosphere research groups with the end goal of building and educating the community.

Summary of Awards.

Small Grants Programs	Number of applicants	Granted	Pending

DEBI-RCN Student Exchange	1	1	0
C-DEBI Research Exchange	2	2	0
C-DEBI Graduate Student Fellowship	1	0	1 under final review
C-DEBI Postdoctoral Scholar Program	12	4	0
C-DEBI Research Grants	8	0	6 under final review

2c. Research plans for the next reporting period

The research plans for the next reporting period remain as initially stated, until data can be gathered via surveys or other results that indicate changes are needed. Samples and data collected as part of IODP Expedition 327 will be processed, investigated, and shared. Research plans associated with IODP Expedition 329 appear to be on target, and pre-cruise planning and development for IODP Expedition 336 is on schedule. It is envisioned that research activity around the four broad research themes discussed above will increase demonstrably during the next reporting period. Changes in direction or level of activity are not foreseen.

III. EDUCATION

1a. Describe the Center's overall education goals and/or objectives.

Our highest priority is to create distinctive, targeted education programs at the K-12, undergraduate, graduate and postdoctoral levels in order to train and foster the next generation of deep subseafloor biosphere researchers. This is first and foremost to ensure the robust continued development of this new field, and to arm the field with the brightest and most creative young minds that can take what has been built over the past decade and greatly expand it in this decade via C-DEBI.

This reporting period focused on creating broad based educational opportunities that allow the Center's newly generated knowledge to thrive and designing focused programs to provide opportunities for all segments of our society, while ensuring that our scientist participants are representative of the full diversity of our society. These students will become the next generation of deep subseafloor biosphere researchers who fully integrate the Center's tools and technology into their science. Additionally, we must translate knowledge in and of our field to the broader public, in part through our core education program (which will flow to public policy, administration, and other education fields in addition to academic fields) — but also via programs that promote broader dissemination of information and increased awareness to the public about the

tremendous fraction of life on Earth that appears to be buried below the seafloor in sediment and rocks.

1b. Inform us of the performance and management indicators.

The performance and management indicators of C-DEBI remain as indicated in the Strategic Plan. Our progress is indicated below each measure.

-Increase public awareness of an excitement in the deep biosphere

To date, C-DEBI has been highlighted in the LA Weekly, USC COLLEGE Magazine, and The Why Files: The Science Behind the News. The National Science Foundations September 9, 2010 press release, "Subseafloor Observatories Installed to Run Dynamic Experiments" was picked up by an additional 46 web, media, and blog sites. In addition to the outreach of print, C-DEBI scientists, staff and students have presented and exhibited at the Society for the Advancement of Chicanos and Native Americans in Science Fall 2010, American Geophysical Union (AGU) 2010 Fall Meeting, Geological Society of America (GSA) 2010 Annual Meeting, and the International Society for Microbial Ecology (ISME) 2010. PI Edwards also participated in a radio program "the Conner Bubble: the Oceans and YOU" at Pasadena City College to promote C-DEBI and ocean research.

-Increase the total number of C-DEBI Associated individuals

C-DEBI is working to extend its reach through on-line promotion, newsletters, social networking, face-to-face connections, and partnerships. In the conferences mentioned above, over 150 new contacts were made. The high school outreach program has made over 25 new contacts.

-Introduce C-DEBI content into K-12-junior college-undergraduate-graduate and informal science centers.

In response to the overwhelming numbers of students who use the junior college as a pathway of retraining and retooling, C-DEBI has established partnerships with Pasadena Community College and Santa Monica Community College and is working with Pierce Community College and Glendale Community College as well. The goal of this connection is to enhance science instruction by providing research findings impacting current questions as well as encourage students to pursue their education and interest in the sciences. In addition to the junior college and before mentioned secondary education, C-DEBI is actively seeking connections with informal science centers and organizations.

-Scientists engaging students in K-12-junior college via teacher training

Through outreach to high schools, meetings, and presentations Dr. Katrina Edwards, Dr. Geoff Wheat, Dr. Anand Patel, Amanda Turner, Erica Green, Cynthia Joseph, and Don Wiggins have all had opportunities to engage students and teachers in different aspects of C-DEBI science.

1c. Discuss any problems you may have encountered in making progress toward the Center's education goals/objectives during the reporting period as well as any problems anticipated in the next period.

As a new center our most immediate challenge is defining processes and aligning programs to meet goals. To address these hurdles, we meet regularly and draw on the experience and expertise of our various team members. We are also working with existing partners such as COSEE-West (Centers for Ocean Sciences Education Excellence) to create teacher training lectures and workshops and partnering with Deep Earth Academy to expand education objectives that coordinate with ongoing and scheduled IODP (Integrated Ocean Drilling Program) Expeditions.

2a. Describe the Center's internal educational activities in the reporting period. Include in the narrative a discussion of how the various internal education activities enable the Center to meet its education goals/objectives described above.

As C-DEBI is a distributed center, the need for collaboration between students, postdoctoral and faculty is critical to the achievement of our overall mission. Scientific coordination is facilitated by the award of small grants allowing a C-DEBI researcher (student/postdoctoral/faculty) to spend 1-6 months at a participating C-DEBI community host laboratory to carry out experiments, use analytical equipment, learn a new tool, and/or join a research cruise. Exchanges establish direct linkages among groups within individual institutions, which are intended to result in a well-connected community and the development of future deep subseafloor biosphere researchers and leaders. To date two individuals has been funded and the RFP remains open to enhance the ability of the Center to respond to needs as they arise.

The C-DEBI Postdoctoral Scholar Program and Graduate Student Scholarship Fund supports postdoctoral research and graduate student research in C-DEBI laboratories. C-DEBI provides support for fellowships awarded on the basis of scientific excellence and the appropriateness of the subject matter to Center objectives. The goal of the postdoctoral and graduate fellowships is to stimulate the advancement of deep biosphere research through the training of a new generation of innovative scientists. Currently one graduate student fellowship is under review and six postdoctoral fellowships from 5 institutions have been awarded with seven under review from seven institutions.

Activity Name	Research Support Program
Led by	Management Team
Intended Audience	Graduate students, postdoctorals and faculty involved in C-DEBI research
Approx Number of Attendees (if appl.)	Currently open for application

C-DEBI is the community-initiated means of providing the collaborative framework and support that we believe is needed for new research projects to be developed in the deep subsurface biosphere. Proposals for small grants in the range of $50,000 for project are reviewed for relevance to deep biosphere research and in particular complement the scientific program of recent or scheduled IODP drilling expeditions. Currently eight proposals from six institutions are under consideration.

Activity Name	Global Environmental Microbiology (GEM)
Led by	Dr. John Heidelberg and Dr. Eric Webb
Intended Audience	Undergraduate students, specifically Community College students
Approx Number of Attendees (if appl.)	Scheduled for Summer 2011.

The goal of this course is two-fold: to provide an opportunity for hands-on research to undergraduates and to engage a diverse student population in the intellectual community of C-DEBI research and discoveries. The course introduces theory and techniques to undergraduate students but goes beyond the text book by taking students to where bacteria live and outlining their role in the global biosphere as both consumers and producers. This creates a context for further research in areas such as the deep subseafloor biosphere where the role of microbes are being discovered. Currently nine students have applied for this course. Through a partnership established with Pasadena City College, this course is being actively promoted to over 100 community colleges to connect students who are outside the traditional research university to C-DEBI. In addition, C-DEBI participants have actively promoted the course at Santa Monica Community College, Pierce Community College, East Los Angeles Community College, and Glendale Community College.

2b. Summarize the participation of Center students in professional development activities in the reporting period.

Students are involved in a variety of professional development activities. Weekly lab meetings give students an opportunity to present their research to peers, answer questions, receive direction and correction, and practice communication skills. In addition, it readies students for participation in conferences (see VIII. Center-wide outputs). These activities prepare students for collaboration in research as well as develop the linkages necessary to continue the robust development of this new field. By speaking to a variety of audiences whose expertise varies from novice to expert, students learn to communicate about findings in effective and productive ways. Researching expertise is insufficient for impacting administration and policies unless communication skills are present to highlight significant impacts and suggest alternate activities.

2c. Describe the Center's external educational activities in the reporting period.

Activity Name	High School Outreach
Led by	Partnership (see below)
Intended Audience	Students 7-12
Approx Number of Attendees (if appl.)	6 students

In partnership with Consortium for Ocean Leadership, The Deep Earth Academy's "Adopt a Microbe" program, C-DEBI, QuikSCience Challenge (California wide education program sponsored by USC and QuikSilver, Inc.) six local high school students are expanding on research being done on IODP Expedition 329. The QuikSCience Challenge program provides a platform for a science project requiring students to teach to their peers, engage the local community and propose further scientific research. As this is a student lead activity, C-DEBI has provided resources and internet links, visits and lectures, Skype communication to the research vessel *JOIDES* Resolution as well as a postdoctoral mentor. The projects are to be completed by February 22, 2011.

Activity Name	High School Outreach
Led by	Cynthia Joseph
Intended Audience	High School students and high school science teachers
Approx Number of Attendees (if appl.)	20

To introduce teachers to the emerging field of deep subseafloor biosphere research, C-DEBI has begun to establish partnerships with science teachers in the surrounding area.

Animo Leadership Charter High School, whose goal is to provide college preparation for an underserved, largely bi-lingual population, is within 10 miles of the University of Southern California. C-DEBI is establishing a partnership with the science department to provide them with cutting edge research, class-room support and student development. This outreach began with a visit to the school. The goal of this outreach event was to introduce C-DEBI to the high school students and to engage students in activities focused on size and scale. Graduate students and a postdoctoral staff presented on earth's evolutionary history and the ocean, the IODP Expedition 327 Juan de Fuca Hydrogeology, and the role of computer programming in data collection. Students were led through a series of hands-on activities explaining size and scale including building models and group investigation. For immediate assessment, students were to identify their favorite ocean fact. Examples of this are: "Less than 1% of the bottom of the ocean has been studied," "The fact that there is more life way deep down in the sea," "The process of hydrothermic circulation on the sea floor," and "90% of the Earth's volume is water."

Activity Name	High School Outreach
Led by	Cynthia Joseph
Intended Audience	High school students and high school science teachers
Approx Number of Attendees (if appl.)	23

C-DEBI outreach continued by bringing the students of Animo Leadership Charter High School to the University of Southern California when they could observe on a typical day of classes, activities and normal student life. High school students were able to experience higher education and were exposed to its wide array of opportunities. Students began the day with a presentation by C-DEBI lead PI, Dr. Katrina Edwards, learned about tools to study microbes in the ocean's crust, toured the machine lab that made the tools, learned about strategies for managing projects, experienced metric measurements and looked through microscopes.

Activity Name	National Science Teachers Association Meeting March 2011
Led by	Cynthia Joseph, Dr. Beth Orcutt, Amanda Turner, Ocean Leadership Consortium (Jennifer Collins), and Deep Earth Academy (Sharon Cooper)
Intended Audience	High school and middle school science teachers

Approx Number of Attendees (if appl.)	TBA

C-DEBI is working with multiple partners to introduce research of the deep ocean to middle school and high school students. For the upcoming annual conference, we are preparing a poster, presentation and exhibit that links the process of scientific research to real scientists as well as finding linkages between topics and standards addressed in K-12 education and microbial ecology.

Activity Name	Intro to Marine Biology: from the coastline to the deep subsurface
Led by	Dr. Anand Patel, Cynthia Joseph
Intended Audience	Los Angeles County Community Colleges
Approx Number of Attendees (if appl.)	TBA

Dr. Anand Patel, C-DEBI postdoctoral research associate in coordination with Cynthia Joseph, is developing a new kind of community college class that encompasses the whole ocean biosphere. The deep-sea is by far the most dominant realm in the ocean and the microbes are by far the most numerous organisms that live there. The immense body of information gathered in the fields of marine microbiology and deep-sea research over the last two decades must now be delivered to students at the introductory stage of exposure to the massive subject that is marine biology. This introduction to both deep-sea (and subsurface) microbiology, and further, the logistical difficulties and high-tech intensive engineering hurdles deep-sea and subseafloor research face can also effectively excite and recruit the next generation of scientists and engineers. In addition USC post-qualifying exam Ph.D. graduate students and postdoctoral research associates would be recruited to deliver lectures to the junior college students. There by giving them real world teaching experience far beyond what they get from teaching assistant courses here on campus.

2d. Describe and discuss the ways in which the Center integrated research and education in the reporting period, with examples as appropriate.

C-DEBI is actively involved in the integration of research and education through the availability and involvement of graduate students, postdoctorals and faculty in outreach opportunities. Through the High School Outreach program, C-DEBI is providing practice and feedback to the new scientists in this emerging field. Also, through weekly lab meetings where undergraduates, graduates and postdoctorals present their research, students learn the importance of the language used to communicate the science as well

as skill of presenting the research. Use of the language appropriate to the audience that expresses the complexities and importance of the deep subseafloor biosphere is of vital importance to peer connections, policy discussions, education applications and conversations with the general public.

In addition, we have developed a comprehensive ethics policy for C-DEBI participants based on existing models starting with NSF and integrating with specific IODP and other institution policies.. This sets forth a community standard to minimize and resolve conflicts effectively. The on-line ethics training is mandatory for all C-DEBI participants and completion by deadline is being tracked. To further support ethical compliance, an ethics panel has been established to resolve any complaints within a sixth month time frame.

2e. Describe how the Center is doing with respect to the indicators/metrics listed above. Include any data that have been collected on the indicators/metrics.

1. Increase public awareness of an excitement in the deep biosphere
2. Increase the total number of C-DEBI Associated individuals
3. Introduce C-DEBI content into K-12-junior college-undergraduate-graduate and informal science centers.
4. Engage scientists in K-12-junior college via teacher training.

Successful achievement of these goals is indicated by:

1. Non-scientific publications and informal science events
    a. Three non-scientific publications and one radio program
    b. NSF September 9, 2010 press release, “Subseafloor Observatories Installed to Run Dynamic Experiments” picked up by 46 other web, media and blog sites (Appendix B)
    c. Exhibited at four science events
    d. Five PI presentations at conferences; four student presentations or posters at conferences
2. Increase in contacts, members and participants and individuals and institutions receive funding from C-DEBI
    a. One hundred and fifty new contacts from education activities
    b. One Student exchange funded; one research exchange funded; six postdoctoral fellowships funded at five institutions
    c. One research exchange pending; one graduate student fellowship pending; seven postdoctoral fellowships pending at seven institutions; eight research proposals pending
3. Introduce C-DEBI content into K-12 junior college-undergraduate-graduate and informal science centers

    a. One meeting upcoming National Science Teacher's Association (NSTA) meeting in March 2011 partnering with the Ocean Leadership Consortium, the Deep Earth Academy
    b. High School and Middle School Lesson plans from conference to be posted on the website
    c. Marine Science class for junior college under development
4. Scientists engaging students in K-12-junior college via teacher training
    a. Seven C-DEBI participants to date
    b. One institution to date aligning to four junior colleges

2f. Describe your plans for internal and external educational activities for the next reporting period with attention to any major changes in direction or level of activity. Also, list plans for developing new educational partnerships, if any, for the next reporting period.

C-DEBI is committed to the continued development of broad-based, targeted education programs that train and foster the next generation of deep subseafloor biosphere researchers. Our objectives are:

1. Establishing symposiums using telecommunication equipment to connect labs from partnering institutions.
2. Presentation of a public lecture and workshop through COSEE-West.
3. Ongoing High School Outreach program that includes standards-based lesson plans and activities delivered to teachers, outreach opportunities for graduate students and postdoctorals, campus visits, and student development opportunities.
4. Strengthening of partnership with community colleges by providing cutting edge research to faculty, promotion of undergraduate course and exploring new linkages.
5. Expanding the web site to include downloadable lesson plans and activities for teachers while pursuing the expansion of teacher contacts in local schools.
6. Augmenting the existing partnerships with the Consortium for Ocean Leadership's Deep Earth Academy by evolving new ways to enhance existing curriculum to coordinate with upcoming IODP expeditions.
7. Using networking, existing organizations, social networking tools and local contacts to increase the scope of C-DEBI's impact.
8. Promotion of calls for graduate student fellowships, travel grants, and postdoctoral researchers to attract the next generation of innovative scientists.

IV. KNOWLEDGE TRANSFER

1a. Describe the Center's overall knowledge transfer goals and/or objectives. If the Center's overall knowledge transfer goals/objectives changed since the last

reporting period, how did they change and why? [In section 2 below, please describe progress the Center has made toward reaching these objectives.]

Our core C-DEBI goals for knowledge transfer are to implement effective mechanisms and pathways to facilitate intellectual exchange between institutions and partners of various types that will support the sharing of knowledge, information, and application of new technology. Knowledge transfer is critical to the growth of the Center and the impact of the science conducted by the Center. While strong partnerships among various organizations are the basis of C-DEBI, additional institutions and partners need to continually be identified to reach the full potential for technological development and innovation. Establishment of open access to all details of C-DEBI technologies is also required to sustain knowledge transfer within and beyond C-DEBI.

1b. Inform us of the performance and management indicators the Center has developed to assess progress in meeting its knowledge transfer goals/objectives.

-Import/export/share innovations and develop partnerships with other fields, research institutions, industry and government.

Our approach is to engage, involve and impact organizations and individuals, bringing together a broad and diverse community to tackle the questions at hand and to develop new pathways for discovery and innovation. We achieve these objectives through contact mechanisms, both directly and indirectly. Organizations and individuals are targeted at meetings, events and other interactive venues.

-Communicate new innovation in the field through creation and maintenance of web tools and data.

We are also using web-based products, including composites of published material and repositories of metadata related to C-DEBI activities. The combination of these actions will form the foundation to develop protocols that guide future activities that outgrow the Center's original scientific objectives, activities and hypotheses.

1c. ***Discuss any problems you may have encountered in making progress toward the Center's education goals/objectives during the reporting period as well as any problems anticipated in the next period. Include your plans for addressing these problems.***

C-DEBI is a distributed Center with co principal investigators residing literally in all corners of the U. S., we have a great need for a comprehensive reporting system. During the upcoming year we will develop an on-line reporting function to capture Center activities and serve as a repository of information uploaded from major field projects. We do not anticipate other issues in meeting the goals outlined in the SIP document during the next period.

2a. List organizations with which knowledge transfer occurs and the frequency and type of interactions. Describe the Center's knowledge transfer activities in the current reporting period and discuss how they enable the Center to meet its knowledge transfer goals/objectives listed in 1a above.
Narrative: For each activity above, briefly describe the activity, its goals/objectives, outputs and the outcomes or impacts in the current reporting period.

Knowledge transfer activities during the inaugural months of C-DEBI range from research collaboration to tool/sensor development, continuing education, and publications. As Section II. Research, Section III. Education, and Section VIII. Center-wide Outputs and Issues have outlined their activities, this section focuses on a variety of tool/sensors in the developmental phase. Each item has potential industry applications and uses.

Knowledge Transfer Activity Name	Debi-Dot
Led by	G. Wheat, B. Kirkwood
Organizations Involved	
Name	Address
1 University of Alaska Fairbanks	3295 College Rd Fairbanks, AK 99709
2 Monterey Bay Aquarium Research Institute	7700 Sandholdt Rd. Moss Landing, CA 95039

1. **DEBI-DOT** has been developed by G. Wheat (University of Alaska Fairbanks) in collaboration with B. Kirkwood (Monterey Bay Aquarium Research Institute). It is presently an inventoried item with a commercial vendor (RDR, a company that has been providing data loggers and capabilities to the oceanic community for decades). This tool is a downhole instrument that measures and records dissolved oxygen and temperature for periods up to six years. This instrument has applications for moorings and other deployments where recovery maybe yearly or longer.

Knowledge Transfer Activity Name	DEBI-t
Led by	K. Edwards
Organizations Involved	

Name	Address
1 University of Southern California	3551 Trousdale Parkway Los Angeles, CA 90089
2 Jet Propulsion Laboratory	4800 Oak Grove Drive Pasadena, CA 91109

2. **DEBI-t** is in development (K. Edwards, University of Southern California) in partnership with the Jet Propulsion Laboratory, Lamont-Doherty Earth Observatory and Photon Systems. This tool detects microbial cells *in situ*. The intended use for this tool is for detecting microbial life in an oceanic borehole. Although not complete, an offshoot of this technology is the development of a bench-top system that can be used at sea or in the laboratory. DEBI-T will be deployed in September 2011 in an oceanic borehole and the bench top system is scheduled for completion in 2011.

Knowledge Transfer Activity Name	Downhole E-Chem
Led by	B. Glazer
Organizations Involved	
Name	Address
1 University of Hawai'i	1000 Pope Road Honolulu, HI 96822

3. **Downhole E-Chem** (B. Glazer, University of Hawaii) is an adaptation of a bench-top electrochemical method for borehole and wireline use. Additional applications including deployment on moorings and cabled observatories. This tool should be completed in 2011 or 2012.

Knowledge Transfer Activity Name	ROV/Submersible Underwater Connector
Led by	H. Jannasch
Organizations Involved	
Name	Address
1 Monterey Bay Aquarium Research Institute	7700 Sandholdt Rd. Moss Landing, CA 95039

4. The **ROV/submersible underwater connector** developed by H. Jannasch (Monterey Bay Aquarium Research Institute) allows one to easily make a hydraulic coupling subsea with a two o-ring seal. This coupling was developed after failed attempts with commercial products. The initial deployment occurred on subseafloor observatories in 2010. Outputs include machine drawings of the coupler that are available in a publication that is in press and will be promoted on the C-DEBI website and within the ocean and oil industries.

Knowledge Transfer Activity Name	BioSled
Led by	J. Cowen
Organizations Involved	
Name	Address
1 University of Hawai'i	1000 Pope Road Honolulu, HI 96822

5. The **BioSled** is undergoing modifications based on results from the initial deployments in 2009 and 2010. This sled is being developed by J. Cowen (University of Hawaii). The sled is coupled to hydraulic lines on a wellhead and pumps fluid from the wellhead into sample containers and filters and past sensors for physical and chemical detection. The first publication describing the tool will be submitted this year and has applications for oil and gas companies.

Knowledge Transfer Activity Name	New Seafloor Observatory System
Led by	T. Pettigrew, B. Orcutt
Organizations Involved	
Name	Address
1 Stress Engineering	13800 Westfair East Drive Houston, TX 77041
2 Aarhus University	Ny Munkegade 116, 1535, 123 800, Aarhus C Denmark

6. T. Pettigrew (Stress Engineering) is in the process of developing **a new seafloor observatory system** for microbiological, geochemical and hydrogeology investigations. These novel designs incorporate oil-field tools and adapts them to

meet scientific goals. Such advanced observatories provide a framework for future oilfield applications. In cooperation with T. Pettigrew, B. Orcutt (Aaruhus Universtiy) is testing oilfield materials for leaching properties so that the best materials are incorporated into the final observatory design.

Knowledge Transfer Activity Name	New Dual Pack System for Borehole Applications
Led by	T. Pettigrew, B. Rinehart, G. Wheat
Organizations Involved	
Name	Address
1 Stress Engineering	13800 Westfair East Drive Houston, TX 77041
2 Texas A&M University	401 Joe Routt Boulevard College Station TX 77843
3 University of Alaska Fairbanks	Global UnderSea Research Unit PO Box 475 Moss Landing, CA 95039
4 TAM International	4620 Southerland Rd. Houston, TX 77092

7. T. Pettigrew (Stress Engineering), B. Rinehart (Texas A&M University), and G. Wheat (University of Alaska Fairbanks) are working with TAM International to develop a **new dual pack system for borehole applications**. This system combines two products (an inflatable packer and a swellable packer into one unit, providing two means to seal off a borehole, each decoupled from the other. Machine drawings have been completed and are on file with the integrate Ocean Drilling Program and in the construction phase at TAM International.

2b. Describe any other outcomes or impacts of knowledge transfer activities not listed above. Discuss, in particular, applications of Center research in industry, Federal Laboratories or elsewhere not discussed above.

None.

2c. Describe how the Center is doing with respect to the indicators/metrics listed above. Include any data that have been collected on the indicators/metrics.

1. Import/export/share innovations and develop partnerships with other fields, research institutions, industry and government.
2. Communicate new innovation in the field through creation and maintenance of web tools and data.

Successful achievement of these goals is indicated by:

1. Import/export/share innovations and develop partnerships with other fields, research institutions, industry and government.
    a. Networking at interdisciplinary meetings (See VIII. Center-wide Outputs and Issues)
    b. Developing target partnerships and interactions for new applications of existing or budding technologies (See Knowledge Transfer Activities and awards in VIII. Center-wide Outputs and Issues)
2. Communicate new innovation in the field through creation and maintenance of web tools and data.
    a. Implementation of audio/visual tools in development stage
    b. Web repository for information exchange related to Major Field projects, CORK, and other data in early development stages
    c. Protocols and procedures for C-DEBI publications and presentations implemented

2d. Describe your plans for knowledge transfer activities for the next reporting period with attention to any major changes in direction or level of activity. Include plans for new knowledge transfer partnerships, if any.

C-DEBI is planning long-range knowledge transfer activities for the next reporting period and throughout the remaining funding period that include:

1. Further partnerships with other fields, research institutions, industry and government by
    a. Focusing fundamental research goals specific to each major funded project
    b. Outlining ways that collaborations between partners can advance those goals
    c. Center-developed or produced research media (e.g., cell lines, reagents, or isotopes)
    d. Distribution of center-produced research hardware.
2. Outcomes of Knowledge Transfer Activities (actual application of Center products in industry, federal laboratories, or elsewhere.)
    a. Licenses based on Center patents or other work
    b. Spin-off or start-up companies that emerged from Center research

V. EXTERNAL PARTNERSHIPS

1a. Describe the Center's overall goals and/or objectives for developing external partnerships. If the Center's overall partnership goals/objectives have changed since the last reporting period, how did they change and why? [In section 2a below, please describe progress the Center has made toward reaching these goals/objectives.]

Please see Knowledge Transfer section (above), where new partnerships for technology are described, and the Education and Diversity section (below) for new partnerships for E&O. A complete list of participants and affiliates is given in Appendix C.

1b. Inform us of the performance and management indicators the Center has developed to assess progress in meeting its partnership goals/objectives.

1. Strong cross-disciplinary goals.
    a. Created RFPs for small research and travel grants for graduate students
    b. Publications listed in VIII. Center-wide Outputs and Issues
2. Strong cross-institutional program.
    a. Developing theme team mini workshops
    b. Holding regular yearly all hands meetings for participants
3. Develop partners with other fields, research institutions, industry and government.
    a. Networking at interdisciplinary meetings
    b. Describing and promoting C-DEBI at organizational meetings
    c. Soliciting industrial and governmental partners.

1c. Discuss any problems you have encountered in making progress toward the Center's partnership goals/objectives during the reporting period as well as any problems anticipated in the next period. Please include your plans for addressing these problems.

As a distributed Center, C-DEBI recognizes the strength of its reach and transformative discoveries is linked to the quality of its partnerships. As such, the STC is committed to collaboration across disciplines, institutions, industry and government. As the center is newly funded our greatest challenge is putting into place the mechanisms for facilitating cross communication. A comprehensive website has been designed and a information depository is being developed to support these broad ranging goals.

2a. Describe and discuss the activities that are conducted as part of partnerships, which are not listed in another section of this report. Be sure to discuss how the Center's partnership activities enable the Center to meet its partnership goals/objectives listed above.

Activities as result of partnerships are discussed above in Knowledge Transfer and in Education and Diversity sections. A complete list of C-DEBI participants and affiliates is given in Appendix C.

2b. Describe any other outcomes or impacts of partnership activities not listed elsewhere.

See 2a above.

2c. Describe how the Center is doing with respect to the indicators/metrics listed above. Include any data that have been collected on the indicators/metrics.

1. Strong cross-disciplinary goals.
    a. Created RFPs for small research and travel grants for graduate students
        i. One Student exchange funded; one research exchange funded; six postdoctoral fellowships funded at five institutions
        ii. One research exchange pending; one graduate student fellowship pending; seven postdoctoral fellowships pending at seven institutions; eight research proposals pending
    b. Publications listed in VIII. Center-wide Outputs and Issues
2. Strong cross-institutional program.
    a. Developing theme team mini workshops--two scheduled for Spring/Summer 2011
    b. Holding regular yearly all hands meetings for participants--May 16-17, 2011
3. Develop partners with other fields, research institutions, industry and government.
    a. Networking at interdisciplinary meetings listed in VIII. Center-wide Outputs and Issues
    b. Describing and promoting C-DEBI at DEBI Research Coordination Network Meeting March 7-9, 2011
    c. Soliciting industrial and governmental partners.

2d. Describe your plans for partnership activities for the next reporting period with attention to any major changes in direction or level of activity.

We are planning to leverage newly created partnerships for the development of new partnerships in the next reporting period. We also will continue our web-based and email forms of communications to the existing and future C-DEBI partners for dissemination of information and opportunities.

VI. DIVERSITY

1a. Describe the Center's overall goals and/or objectives related to increasing diversity at the Center.

The primary focus of C-DEBI's diversity objectives is to train and educate a new, diverse generation of undergraduate, graduate students and postdoctoral deep subseafloor biosphere researchers within an integrated and collaborative multidisciplinary community. We are committed to improving the educational pipeline (particularly for students from under-represented groups),and helping to form a community of young

scholars making sure that future scientists are representative of the full diversity of our society.

C-DEBI is committed to educate, inform, and translate knowledge of the deep subseafloor biosphere via a coordinated program across primary, secondary, and higher education programs. In seeking to impact broad audiences it is imperative for C-DEBI scientific participants to learn how to communicate scientific and technical results directed by the audience's prior knowledge. This allows for the dissemination of information to a diverse group of learners. As such the Center's goals are to :

(1) Increase the diversity of participants in all levels of C-DEBI from undergraduate, graduate and postdoctorals through to participating researchers and staff;

(2) to actively seek K-12 teachers who work with under-represented groups and prepare lesson plans linked to State Science Standards that explore the topics of C-DEBI research, provide opportunities for professional development, and furnish extensions beyond the classroom;

(3) provide a unique educational experience in the form of a special summer course for 16 undergraduates targeting underrepresented groups each year;

(4) establish partnerships with junior college faculty to aid in the transition of non-traditional students to research universities.

1b. Inform us of the performance and management indicators the Center has developed.

-Increase number of individuals from underrepresented groups who enter as graduate students, participate in C-DEBI activities or are funded by C-DEBI

To assure that there are robust opportunities for underrepresented groups to engage in C-DEBI activities, partnerships are being leveraged to communicate, support and draw in new participants.

-Increase the number of C-DEBI women, underrepresented groups and persons with disabilities considering STEM careers as indicated by self-reporting surveys

C-DEBI's first step in connection with diversity goals was to establish connections to teachers and professors who have contact with students outside the normal scope of a research university. The thrust of our programs is both high school outreach and partnerships with junior colleges.

Additionally, a recruiting tool, C-DEBI scientists, staff and students have presented and exhibited at the Society for the Advancement of Chicanos and Native Americans in Science Fall 2010.

1c. Discuss any problems you have encountered in making progress toward the Center's diversity goals/objectives during the reporting period as well as any problems anticipated in the next period. Include your plans for addressing these problems.

As a new center we are focusing on utilizing resources that are immediately available to us and then branching out into new partnerships. This presents opportunities to develop tracking and coordination networks that compliment and support the dispersed nature of our center. To date, we are working to develop a comprehensive reporting system that captures all of the Center's activities. We do not anticipate other issues in meeting the goals outlined in the SIP document during the next period.

2a. Describe and discuss Center activities which contribute to the development of United States human resources in science and engineering at the postdoctoral, graduate, undergraduate, and pre-college levels.

-Increase the diversity of C-DEBI participants

Programs and partnerships with local high schools, organizations, and Community Colleges (described in the activities section) are in process and moving forward to assist under-represented students within those organizations. Our goals are to act as a resource—exchanging information, lesson plans, and development support to expose students to cutting-edge science research and opportunities within the STEM fields.

The Center has developed and dispersed a survey to all C-DEBI participants requesting the voluntary reporting of diversity data.

We also have strong representation of diversity among our newly formed External Advisory Board (Appendix A), which includes three African Americans, one Hispanic, and four women.

-Increase the number of diverse science and technology practitioners.

We are committed to making sure that future scientists are representative of the full diversity of our society. The high school outreach program brought four high school science teachers, 17 students and 2 parents to campus who interacted with a graduate student, postdoctoral staff member, Professor, and University Admissions, Diversity and Education staff. Of the students, 94% were Hispanic with 16 out of 17 indicating their interest in going to college was very high. When asked to rate their interest in Biology, Chemistry, Geology, Physics and Engineering, 81% of students indicated a very high interest in these fields. C-DEBI will continue to provide ways to meet the needs students identified and to support them in their interest in STEM fields and higher education.

The Undergraduate Summer Course seeks to engage a diverse student population in hands-on activities that introduce them to the role of microbes. It requires no prior experience and is designed to inspire their intellectual curiosity. As an attempt to draw students from diverse backgrounds that are not in research universities into STEM fields, the Center is focusing recruitment on the Junior College and establishing on-going relationships with professors who teach there.

2b. Discuss the impact of these programs or activities on enhancing diversity at the Center.

C-DEBI centers its efforts on reaching educators and students through partnerships that engages curiousity and connects new discoveries to textbook science. These partnerships form the foundation of our outreach. Teachers such as Mark Friedman at Animo Leadership Charter High School and Dr. Joe Connor at Pasadena City College are the linkages for C-DEBI scientists to connect the center to students. We can then provide instructors the experiences and tools to enhance their reach to students potentially interested in STEM field training and learning.

2c. Describe how the Center is doing with respect to the indicators/metrics listed above. Include any data that have been collected on the indicators/metrics.

1. Increase number of individuals from underrepresented groups who enter as a graduate students, participate in C-DEBI activities or are funded by C-DEBI
    a. C-DEBI High School outreach program is working with schools within the Los Angeles Unified School district, one of the most diverse districts in the nation.
    b. Active promotion of graduate students and postdoctoral fellowships on many web sites including www.pathwaystoscience.org that focuses partnering for diversity in STEM fields.
    c. Requests for proposal are open for C-DEBI small grants program through March 2011 as well as the Research Exchange program which remains open throughout the year. This allows the Center to respond to evolving collaborations between participants.
2. Increase the number of C-DEBI women, underrepresented groups and persons with disabilities considering STEM careers as indicated by self-reporting survey
    a. Promotion of undergraduate summer course to be held Summer 2011 through partnering institutions and junior college collaborators.
    b. Nine applicants to date 44% are women, 22% Hispanic/Latino and 22% first generation college applicants.

2d. Describe your plans for programs, activities, or partnerships to enhance diversity for the next reporting period.

1. Identifying and leveraging support services and potential connections, organizations and institutional resources within partnering Universities to promote diversity.

2. Promoting all funding opportunities through partners and organizations that focus on support for under-represented groups.
3. Strengthening partnerships with local junior colleges and finding new ways to link research content and scientists to professors and students.
4. Actively promote and develop the undergraduate summer course to our current partners as well as Historically Black Colleges and Universities and other Minority Serving Institutions.

VII. MANAGEMENT

1a. Describe the Center's organizational strategy and its underlying rationale, if changed since the last reporting period.

Our administration and management goals are to create a structure and system that ensures that C-DEBI is successful in attaining all of its research, education, outreach, and diversity goals. We are create assessment and reporting structures that assure accountability and transparency at all levels for constant improvement of C-DEBI function.

See Appendix D.

1b. Inform us of the performance and management indicators the Center has developed to assess its progress in organizational and management goals/objectives.

The following goals/objectives have been established for the management team.

-The decision-making process needs to be defined, transparent and effective to lead to a high degree of confidence, ownership, and engagement by STC participants in the Center.

STC leadership needs to remain focused on the critical goal that motivated formation of C-DEBI in the first place: creating a vibrant, innovative, and focused community, who will work together to achieve what cannot be accomplished by individuals working alone, to transform the nature of deep biosphere research.

-Effective communication patterns and components need to be in place to facilitate the exchange of science, education of students, and promote the sharing of other STC activities and opportunities.

It is fundamental for C-DEBI leadership to maintain trust and support among a diverse and interdisciplinary community of scientists, educators, and technologists.

-Students and postdoctorals need to be engaged in cross-center training and collaboration.

The establishment and funding of Research Exchange and Small Grants is fundamental to the education of students and postdoctorals in C-DEBI.

-Pathways of communication between STC participants at partner institutions should be monitored to enhance efficiency and facilitate the development of new projects that would not have been realized without the mechanism of the STC.

While regular administrative PI and lab meetings are necessary to keep all of C-DEBI linked and informed, we are using participant surveys to measure effectiveness of these pathways.

-Develop strategies, tools, and resources for sustainability of C-DEBI activities.

Center PIs and participants in collaboration with each other, their universities, other funding agencies, and serendipitous opportunities are pursuing extra-center funding opportunities as they arise.

1c. Describe how the Center is doing with respect to the indicators/metrics listed above. Include any data that have been collected on the indicators/metrics.

1. The decision-making process needs to be defined, transparent and effective to lead to a high degree of confidence, ownership, and engagement by STC participants in the Center.
2. Effective communication patterns and components need to be in place to facilitate the exchange of science, education of students, and promote the sharing of other STC activities and opportunities.
3. Students and postdocs need to be engaged in cross-center training and collaboration.
4. Pathways of communication between STC participants at partner institutions should be monitored to enhance efficiency and facilitate the development of new projects that would not have been realized without the mechanism of the STC.
5. Develop strategies, tools, and resources for sustainability of C-DEBI activities.

Successful achievement of these goals is indicated by:

1. The decision-making process needs to be defined, transparent and effective to lead to a high degree of confidence, ownership, and engagement by STC participants in the Center.
    a. Weekly administration meetings as well as bi-weekly PI meetings enable clear and effective management of the Center
    b. Major Field Project web pages under construction

    c. We have recently surveyed the scientists, participants and educators of cruise 329 regarding preparation, ease of work and desired functionality of the STC
    d. Survey to be developed to establish effectiveness of leadership teams, decision making, and Center engagement
2. Effective communication patterns and components need to be in place to facilitate the exchange of science, education of students, and promote the sharing of other STC activities and opportunities.
    a. Website launched with data tracking in place
    b. Newsletter distributed quarterly to C-DEBI participants and affiliates which highlights upcoming events, opportunities for funding, and education partners
    c. Private login site under construction for downloads and community postings
    d. Graduate student and postdoc development grant proposal guidelines were developed and funding opportunities have been posted with 11 solicitations received
    e. Survey already posted on our web site to identify who users are and ask how we can help to meet their needs
3. Students and postdocs need to be engaged in cross-center training and collaboration.
    a. All Hands meeting planning underway with students and postdoctorals taking an active role
    b. Theme leaders have begun organizing mini-workshops that will engage graduate students, postdocs and scientists
    c. Meeting scheduled for May 16-17, 2011
4. Pathways of communication between STC participants at partner institutions should be monitored to enhance efficiency and facilitate the development of new projects that would not have been realized without the mechanism of the STC.
    a. Supporting Major Field Project IODP Expedition 327, Ridge-Flank Hydrogeologic Properties and Processes
    b. Supporting Major Field Project IODP Expedition 329 South Pacific Gyre
    c. Supporting Major Field Project IODP Expedition 336 North Pond
    d. Other small projects listed in awards
5. Develop strategies, tools, and resources for sustainability of C-DEBI activities.
    a. New funding sources gathered by C-DEBI participants listed in VIII. Center-Wide Outputs
    b. Target for year 1 of $100,000 already exceeded
    c. To further the educational goals of the Center six funding sources with educational components have been added to the Center (shown by *)

1d. Discuss any problems (e.g., technical, personnel, communication) you may have encountered in realizing the Center's organizational strategy or management

goals/objectives in the reporting period as well as any problems anticipated in the next period. Include your plans for addressing any problems.

C-DEBI strives for open communication and strategies of collaboration between partnering institutions. Our goals remain in focus and we are on track with the establishment of regular communication patterns to deal with any problems that arise. There are currently no problems to report.

2. Describe and discuss the management and communications systems being used to develop a fully integrated STC.

As C-DEBI is geographically disbursed, STC leadership is making full use of communication tools that are available. First, a bi-weekly phone conference maintains open communication between the PIs on the project. The weekly administrative meeting also utilizes phone conferencing when all members cannot be present. Currently in the planning stages, the videoconferencing seminars will be held monthly allowing for scientific presentations from Theme Teams as well as graduate students and postdocs. To further enhance this culture of collaboration and cross-disciplinary thinking, we have begun developing cyber-infrastructure for a website enabling public access and data sharing among the C-DEBI research community. The architecture for our online communities for collaboration and learning for has two principal objectives: 1) to support the connection among scientists and others in the C-DEBI project research community and 2) to foster the connections between C-DEBI scientists and educators through the online learning workshop program.

The field of deep subseafloor biosphere research is young; hence, in addition to phone and videoconferencing, direct interaction between our members is crucial for success. An annual meeting for the DEBI RCN is planned for March 6-9, 2011 in Chapel Hill, North Carolina. The focus of the meeting is Microbiology in Marine Sediments. The goals of the RCN are to develop community, facilitate coordination of science, stimulate interaction and education, and enable synthesis and integration.

The Center is also hosting an "All Hands" meeting on May 16-17, 2011 in Los Angeles, CA which is comprised of leadership meetings with advisory boards as well as science presentations and interactions between scientists, students, postdocs and educators.

3. Provide a list of names and affiliations of the Center's internal and external advisors or advisory bodies in the reporting period.

See Appendix A for biographical sketches.

Name	Affiliation

External Advisory Board Members	
1 Estella Atekwana	Oklahoma State University
2 John Baross	University of Washington
3 Antje Boetius	University of Bremen
4 Luis Cifuentes	Texas A&M University
5 Joe Conner	Pasadena City College
6 Susan Humphris	Woods Hole Oceanographic Institution
7 Mary Ann Moran	University of Georgia
8 Mitch Sogin	Marine Biological Laboratory
9 Henry Neal Williams	Florida A&M University
Internal Advisors to the Director	
10 Tom Jordan	University of Southern California
11 Tony Michaels	University of Southern California
12 Dave Karl	University of Hawaii

VIII. CENTER-WIDE OUTPUTS AND ISSUES

1a. List all Center publications in the reporting period using a standard citation format. Please distinguish among the following publication types:

peer reviewed publications
books and book chapters
other non-peer reviewed publications

Submitted peer-reviewed pubs:

1. Fisher, A. T., C. G. Wheat, K. Becker, J. Cowen, B. Orcutt, S. Hulme, K. Inderbitzen, A. Turner, T. Pettigrew, E. E. Davis, H. Jannasch, K. Grigar, R. Adudell, R. Meldrum, R. Macdonald, and K. Edwards (2011), Design, deployment, and status of borehole observatory systems used for single-hole and cross-hole experiments, IODP Expedition 327, eastern flank of the Juan de Fuca Ridge, in Proc. IODP 327, edited by A. T. Fisher, T. Tsuji and K. Petronotis, p. in review, Integrated Ocean Drilling Program, College Station, TX. C-DEBI Contribution 101.

2. Fisher, A. T., J. Cowen, C. G. Wheat, and J. F. Clark (2011), Preparation and injection of fluid tracers during IODP Expedition 327, eastern flank of Juan de Fuca Ridge in Proc. IODP 327, edited by A. T. Fisher, T. Tsuji and K. Petronotis, p. in review, Integrated Ocean Drilling Program, College Station, TX. C-DEBI Contribution 102.

3. Wheat, C. G., H. W. Jannasch, M. Kastner, S. Hulme, J. Cowen, K. J. Edwards, B. N. Orcutt, and B. Glazer (2011) Fluid sampling from oceanic borehole observatories: design and methods for CORK activities (1990-2010), in Proc. IODP 327, edited by A. T. Fisher, T. Tsuji and K. Petronotis, p. in review, Integrated Ocean Drilling Program, College Station, TX. C-DEBI Contribution 103.

1b. List all conference presentations in the reporting period using a standard citation format.

Becker, K., Fisher, A.T., Tsuji, T., Mrozewski, S., Winslow, D. 2010. IODP Packer Experiments in Young Juan de Fuca Crust Suggest Lateral Continuity of Hydrological Structure on Ridge-parallel Scale of ~1 km K. AGU Fall Meeting, San Francisco, CA. Poster Presentation.

Bennett, S.L., Hoffman, C.L., Moffett, J.W., Edwards, K.J. 2010. Siderophore production in high iron environments. AGU Fall Meeting, San Francisco, CA. Oral Presentation.

Colwell, R., 2010. Intraterrestrial Life town hall. AGU Fall Meeting, San Francisco, CA. Oral Presentation.

Cowen, J. P., Lin, H., Rappe, M., Jungbluth, S., Glazer, B. T., Matzinger, M., Amend, J. P., Boettge, J. 2010. Window into Sediment-Buried Basement Biosphere: Fluid Sampling from CORK Observatory Seafloor Platforms, Juan de Fuca Ridge Flanks. AGU Fall Meeting, San Francisco, CA. Poster Presentation.

Edwards, K. 2010. Carbon in the earth system. AGU Fall Meeting, San Francisco, CA. Oral Presentation.

Edwards, K.J. 2010. Opportunities and challenges in studies of deep life. AGU Fall Meeting, San Francisco, CA. Invited Oral Presentation.

Edwards, K.J., Wheat, C.G. 2010. Intraterrestrial life in igneous ocean crust: advances, technologies, and the future. AGU Fall Meeting, San Francisco, CA. Invited Oral Presentation.

Fisher, A., Becker, K., Wheat, G. 2010. Heterogeneity, anisotropy, and compartmentalization of fluid, heat, and solute transport in the upper ocean crust on ridge flanks. AGU Fall Meeting, San Francisco, CA. Invited Oral Presentation.

Girguis, P., Herren, C., deCharon, A. 2010. Capitalizing on Education and Outreach (E/O) Expertise to Broaden Impacts. AGU Fall Meeting, San Francisco, CA. Invited Oral Presentation.

Hulme, S., Wheat, G. 2010. Fluid and chemical fluxes along a buried-basement ridge in the eastern Juan de Fuca Ridge flank. AGU Fall Meeting, San Francisco, CA. Poster Presentation.

Inderbitzen, K., Becker, K., Davis, E.E., Hulme, S., Wheat, C.G. 2010. Middle Valley in perspective: New outlooks from changes in local hydrothermal venting. AGU Fall Meeting, San Francisco, CA. Poster Presentation.

Kastner, M., Solomon, E. A., Wheat, C. G., Jannasch, H. 2010. Long-Term Hydrogeochemical Records from Ocean Drilling Program Borhehole Observatories in the Costa Rica Subduction Zone. AGU Fall Meeting, San Francisco, CA. Poster Presentation.

Lin, H., Cowen, J. P., Amend, J. P., Albert, D. B., Glazer, B. T., Rappe, M., Jungbluth, S., Matzinger, M. 2010. Organic chemistry of fluids from sediment-buried young basement: discrete sampling from ODP borehole 1301A & 1025C. AGU Fall Meeting, San Francisco, CA. Poster Presentation.

Orcutt, B. N., Bowman, D., Turner, A., Inderbitzen, K.E., Fisher, A.T., Peart, L. W. 2010. The “Adopt A Microbe” project: Web-based interactive education connected with scientific ocean drilling. AGU Fall Meeting, San Francisco, CA. Poster Presentation.

Orcutt, B., Bach, W., Becker, K., Fisher, A., Hulme, S., Toner, B.M., Wheat, G., Edwards, K.J. 2010. Microbial borehole observatories deployed within the oceanic crust: Design considerations and initial results from long-term colonization experiments. AGU Fall Meeting, San Francisco, CA. Invited Oral Presentation.

Orcutt, B., Bach, W., Becker, K., Fisher, A., Wheat, G., Edwards, K.J. 2010. The subsurface ocean crust biosphere: using observatories to investigate life on the rocks. ISME Conference, Seattle, WA. Oral Presentation.

Peart, L., Orcutt, B. N., Fisher, A. T., Tsuji, T., Petronotis, T. 2010. Trials at Sea: Successful Implementation of a Unique Two-Month Professional Development Program. AGU Fall Meeting, San Francisco, CA. Poster Presentation.

Singer, E., Emerson, D.E., Webb, E.A., Nelson, W.C., Heidelberg, J.F., Kuenen, H., Edwards, K.J. 2010. Genomic Insights Into the First Cultured Member of the Zeta-Proteobacteria, the Fe-Oxidizing Mariprofundus Ferrooxydans PV-1. AGU Fall Meeting, San Francisco, CA. Oral Presentation.

Sylvan, J.B., Bennett, S.A., Edwards, K.J. 2010. Biogeochemical cycling and microbial composition in hydrothermal plumes from Loihi Seamount, Hawaii. ISME Conference, Seattle, WA. Poster Presentation.

Turner, A., Edwards, K.J. 2010. Bioalteration of seafloor basalt and sulfides: Using synchrotron x-ray radiation to investigate key microbe-mineral interactions. GSA Conference, Denver, CO. Oral Presentation.

Turner, A., Turner, M., Edwards, K.J. 2010. Deep ocean research meets the special education classroom. AGU Fall Meeting, San Francisco, CA. Poster Presentation.

1c. Briefly describe any other dissemination activities not included elsewhere in the report.

2. List all awards and other honors with names of those honored and source in the reporting period. Please classify the award type indicating whether the award or honor is scientific, education-related, industry-related, a fellowship, or other.

Recipient	Reason for Award	Award Name and Sponsor	Date	Award Type
K. Edwards, K. Becker, I. Aeillo	* Collaborative Research: The Basalt-Hosted Biosphere at North Pond - A Subseafloor Mid-Atlantic Ridge-Flank Microbial Observatory	NSF	2/1/2011-1/31/2013 (Recomended)	Scientific
K. Edwards	IODP Renewal leadership Team	COL	8/1/2010-7/31/2011	Scientific
K. Edwards	IODP Expedition 330: Louisville Seamount Chain	COL	8/13/2010-7/12/2011	Scientific
K. Edwards	RAPID: DEBI-t: development of a Deep Exploration Biosphere Investigative Tool	NSF	9/1/2010-8/31/2011	Scientific
K. Edwards	DEBI-t: development of a Deep Exploration Biosphere Investigative Tool	Sloan	9/1/2010-8/31/2011	Scientific
S. D'Hondt	US Science Support IODP Expedition 329	COL	10/10/2010-10/9/2013	Scientific

A.T. Fisher, C.G. Wheat, J.P. Cowen, J.F. Clark, K. Becker	* Collaborative research: Large-scale, long-term, multi-directional, cross-hole experiments in the upper oceanic crust using a borehole observatory network	NSF	10/1/2010-9/30/2013	Scientific
A.T. Fisher, C.G. Wheat, J.P. Cowen	* Ridge-Flank Hydrogeologic Properties and Processes, IODP Expedition 327	COL	7/1/2010-6/30/2013	Scientific
A.T. Fisher	Characterization of multi-scale permeability using borehole and regional hydrothermal models	COL	7/1/2010-6/30/2013	Scientific
C.G. Wheat	G. Wheat participation in IODP Expedition 332	COL		Scientific
J.P. Cowen	RAPID: Funds to Complete Seafloor CORK Instrument Sleds for Imminent Deployment	NSF	10/1/2010-9/30/2013	Scientific
J.P. Cowen	* J. Cowen participation in “Ocean Leadership Distinguished Lecture Series (lectures on Deep Subseafloor Biosphere at 7 US institutions)	COL--HONOR		Education
J.P. Cowen	* Astrobiology Winter School: ‘Water and the Evolution of Life in the Universe’	Astrobiology Magazine		Education, Industry
J. Huber, P. Girguis, B. Glazer	* Collaborative Research: Characterization of Microbial Transformations in Basement Fluids, from Genes to Geochemical	NSF	6/1/2011-5/31/2014 (recommended for funding)	Scientific

	Cycling			
W. Ziebis	W. Ziebis participation in "IODP Expedition 329 - South Pacific Gyre Microbiology"	COL		Scientific
A.T. Fisher, K. Edwards	* Ocean Renewal Leadership Team	COL--HONOR		Education
K. Edwards	Elected to Fellow	AAM--HONOR	2/2010	Fellowship

* Indicates education component to funding award

3. List any undergraduate, M.S. and Ph.D. students who graduated during the reporting period. Include their current placement. Include the number of years taken since entering graduate school to complete the Ph.D. List postdoctoral associates who left the STC during the reporting period, and include their current placement.

None during this time.

4a. List, to the extent known, the general outputs of knowledge transfer activities since the last reporting period. Include patent name, number, application date, receipt date:

None to report at this time.

4b. Describe any other outputs of knowledge transfer activities made during the reporting period not listed above.

None to report.

5. List all participants in Center activities alphabetically classified by the categories and demographic characteristics listed below the table. Center affiliates may also be included in this table, but MUST be distinguished from participants.

See Appendix C.

6. Provide a summary listing of all of the Center's research, education, knowledge transfer and other institutional partners (the total number of academic institutions and non-academic organizations, including industry, states, and other Federal agencies which work or share resources with the Center).

See Appendix C and Knowledge Transfer above. The institutions and summary data are shown in Appendix E.

7. For internal NSF reporting purposes, provide a Summary Table on participants, affiliates, and partners.

See Appendix C.

8. Describe any media publicity the Center received in the reporting period. Provide in Appendix any appropriate media materials that can be used to disseminate.

To date, C-DEBI has been highlighted in the LA Weekly, USC COLLEGE Magazine, and The Why Files: The Science Behind the News. The National Science Foundations September 9, 2010 press release, "Subseafloor Observatories Installed to Run Dynamic Experiments" was picked up by an additional 46 web, media, and blog sites. In addition to the outreach of print, C-DEBI scientists, staff and students have presented and exhibited at the Society for the Advancement of Chicanos and Native Americans in Science Fall 2010, American Geophysical Union (AGU) 2010 Fall Meeting, Geological Society of America (GSA) 2010 Annual Meeting, and the International Society for Microbial Ecology (ISME) 2010. PI Edwards also participated in a radio program "the Conner Bubble: the Oceans and YOU" at Pasadena City College to promote C-DEBI and ocean research.

USC's College magazine reported on C-DEBI in a cover "The Power and Promise of the Ocean" in the Fall of 2010:
http://college.usc.edu/news/stories/734/the-power-and-promise-of-the-ocean/Also see

LA weekly http://www.laweekly.com/2010-05-20/la-life/katrina-edwards-mistress-of-the-dark-world/

The Why files
http://whyfiles.org/2010/life-in-the-oceans/

NSF release
http://www.nsf.gov/news/news_summ.jsp?cntn_id=117649

Also see Appendix B.

IX. INDIRECT/OTHER IMPACTS

1. Please describe any international activities in which the Center has engaged. If they are described elsewhere in the report, highlight them here without going into great detail.

(1) Two international cruises have taken place with the integrated ocean drilling program (Exp. 327 - Fisher & 329 - D'Hondt).

(2) Two PIs (Edwards & Fisher) served on the Integrated Ocean drilling program renewal writing committee.

(3) Numerous talks and meetings have been attended (see above).

2. Please use this space to describe other outputs, impacts, or influences related to the Center's progress and achievement during the current reporting period that may not have been captured in another section of the report. (optional)

Nothing to report.