Project Title: **Implementing the GEN EnGlobe Portal for NOAA Educational Learning Modules Based on Prediction Model Output**

Theme: **Technologies for Collaboration and Visualization**

NOAA Program:	NCEP Routing Code: W/NP2
Project Principal Investigator:	**Jordan Alpert**
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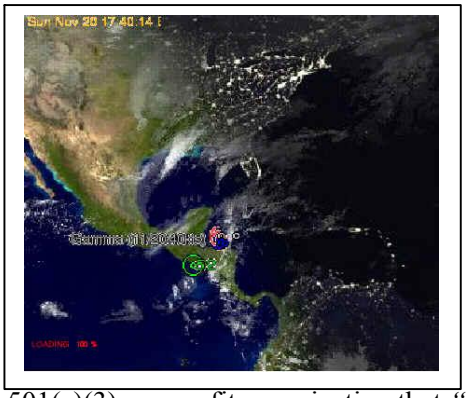
Proposed Start Date:	April, 2006 (upon award)
Proposed End Date:	April 16, 2007
Amount Requested:	$99,000
Program Match:	$20,000 (20%)

External Partner:	**National Council for Science and the Environment**	External Partner:	**George Mason University**
Partner Contribution	$6,000 (6%)	Partner Contribution	$17,000 (17%)

Introduction

The goal of this project is to develop templates for learning modules in earth and environmental sciences and the means of implementing these modules on an online interactive three-dimensional virtual planet system. This system will be constructed from satellite images and will feature environmental data from observations and computer-modeled forecasts. Students who use the learning modules will be able to view conditions on the virtual planet from the tropics to the poles and to zoom in over any region or territory. They will also be able to view changing conditions in animated time sequences, to access information about environmental systems in visual formats with graphic overlays, and to obtain more detailed information by clicking on icons or highlighted portions of texts. Because the images and overlays used to construct the virtual planet will be periodically refreshed, users will also have the sense that they are viewing actual conditions on planet Earth.

Two existing systems have demonstrated that satellite images and data can be used effectively as learning tools in the study of environmental systems--the GLOBE (Global Learning and Observations to Benefit the Environment) and Science on a Sphere. These systems provide users with some understanding of the earth as a global system. However, they do not use computer-based modeling and forecasting systems in environmental science as the basis for developing educational modules and implementing these modules on an online interactive virtual planet system.



This grant proposal originated in a dialogue between NOAA research scientist Jordan Alpert and the founders of the Global Environmental Network (GEN). The mission of GEN is to *"to translate our best scientific understanding of what will be required to resolve the environmental crisis into a form that can serve as the basis* for *articulating viable solutions to environmental problems."* The interactive virtual planet platform that will serve as the basis for making these translations is called the EnGlobe Portal. To enhance the prospect of accomplishing its mission, GEN has established partnerships with the School of Computational Sciences at George Mason University and with the National Council on Science and the Environment (NCSE), a 501(c)(3)non-profit organization that *"has been working since 1990 to improve the scientific basis for environmental decision making,"* Over the last few years, NCSE created the Council of Environmental Deans and Directors (CEDD), an organization that includes representatives from 141 research programs in environmental science in American colleges and universities.

NCSE and CEDD are in the process of developing an online encyclopedia of environmental science in wiki format called the Encyclopedia of Earth that already features thousands of entries. After environmental scientists create entries, this material is vetted online by experts in the related fields before it appears in the encyclopedia. Users of the EnGlobe Portal will be able to access material in the Encyclopedia of Earth by clicking on highlighted scientific terms and constructs. Equally important, GEN will have will access through the member institutions of CEDD to a wealth of research in environmental science that could be implemented on the EnGlobe Portal and to a functional online vetting system for the research and environmental information that appears on this portal.

Statement of Problem

The learning modules on the EnGlobe Portal should motivate students to care about the future of society and to feel that they can make a meaningful contribution to that future. And these modules should also enhance the willingness of students to commit themselves to the timely resolution of environmental

problems. (Rowe, 2002). The process of developing these modules will link the goals of promoting environmental education and literacy in the NOAA educational program to the scientific and technological goals articulated in the National Weather Service (NWS) Strategic Plan. According to this plan, the mission of NOAA/NWS is to "serve society's needs for weather and water information" by strategies endorsed by the NWS. These strategies include cooperation between U.S. government agencies, partnerships with non-governmental organizations, broad-based educational initiatives, and widespread distribution of educational products. The proposed development effort is consistent with these strategies and provides the means for the educational community to make effective use of NOAA's technology and its interoperable approach to data management.

Addresses NOAA mission goals

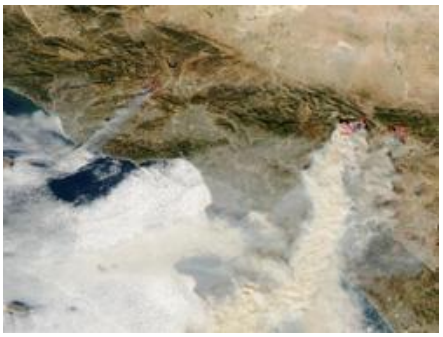
Ecosystem Approach to Management	Demonstrates system interrelationships
Understand Climate	Displays weather and causes/dynamics
Weather and Water Information	Detailed 3D weather & ocean is displayed

Supports NOAA educational plan strategies

Integrate NOAA science into quality education	Sample learning object & templates for education
Improve access to NOAA educational resources	Provides access to NOAA data & modeling
Educator development in use of NOAA sciences	New access to NOAA data Sample learning objects & template to build more
Promote NOAA careers	Demonstrates importance of field & NOAA's role
Leverage partnership for science education	Partners NCSE & GMU and CEDD
Build NOAA educational excellence	NOAA data +access to scientist-vetted info

Solution

The NOAA resource that is foundational to the proposed development program is the NOAA Operational Mode Archive Distribution System (NOMADS). The operational model suite of products in NOMADS will be the source of the simulations used on the EnGlobe Portal. This technology offers real time access to results from forecast models and to data from satellites and ground observation systems on a broad range of environmental phenomena. These phenomena include weather and climate, natural hazards such as hurricanes, floods, tornadoes, draughts, fires and earthquakes, and all major environmental subsystems. In development efforts that lie beyond the scope of this proposal, the GEN project plans to greatly increase the utility of the EnGlobe Portal interactive planet system by making effective use of the full range of forecast models, environmental data, and satellite images from NOMADS.



The templates for educational modules that would be developed in the proposed program would allow educators to create grade specific interactive learning exercises and testing procedures and to access real time data sets from NOMADS. These templates will be developed in accordance with learning module standards and they will be tailored for use in specific learning communities. The project plans to involve environmental scientists associated with NCSE and CEDD in the effort to develop learning modules for use in college level science courses. And we also plan to involve faculty at George Mason University expert in developing computer-based learning software for students in middle school and high school in this effort. The learning modules for students at the college level will place a special emphasis on environmental forecasting and some examples of such modules are described below.

Definition of learning goals
Study materials
Pre-test
EnGlobe data extracts
Data selections & observations
Hypothesis formation
Testing hypotheses
Reporting results
Post-test

Alignment with science standards

Scientific method	A virtual laboratory – observe, hypothesis, test
Science as inquiry	A virtual laboratory – collect, analyze, report
Content - motion	Atmospheric & ocean motions are displayed for analysis
Content – energy transfer	Displays energy transfer driving atmosphere & ocean
Content – environment	Demonstrates interconnectedness

Task 1. Adapt GEN EnGlobe Portal

The EnGlobe Portal for online display and interaction with a virtual planet made of satellite images will be modified and extended to access and display the NOMADS forecast modeling results and to interface with the proposed sample and template learning modules. EnGlobe provides the user with simple controls to view the virtual earth from any direction, zoom to any location, add overlays for one or more environmental variables, animate any time interval or display sequence for which there is data, and query any display to learn more.

Integrating NOMADS data will permit EnGlobe users to produce animated sequences from historical observations through current conditions to forecasts for many environmental variables. Physically, this project will establish a NOMADS server co-located with an EnGlobe server. The NOMADS server would be updated each time forecast model results become available. The EnGlobe would tap the latest forecasts along with historical forecast data as requested. Co-location will permit the fastest possible response using these huge datasets. As proposed, this server would be hosted at partner George Mason University.

Learning module data access will be presented within EnGlobe with user controls to select among NOMADS datasets and variables, automate time sequences, and record data excerpts as needed for the requirements of the learning module. Examples of such data range from tomorrow's forecast temperature at a specific location to the state variables of a volume of air as it moves along in the forecast for next few days.

Task 2. Integrate NOMADS data

NOMADS is a working prototype employing client-server technology and freely distributed utility programs to disseminate and document digital data. The software effectively includes the NOAA real time operational NWP model data sets from the National Centers for Environmental Prediction (NCEP) as well as archived data from the National Climate Data Center (NCDC) in a distributed system for serving data to the public and federal agencies and scientific/education community. A wide range of metadata, or environmental information in digital form with the necessary supporting infrastructure, is available from NOMADS. Metadata description files for each data set are man and machine readable and a list of these data sets can be founds in Rutledge (2006). This list includes the NWS operational suite of products, the Global Forecast System (GFS), North American Model (NAM), Rapid Update Cycle (RUC) model, Climate Forecasts system (CFS), the Climate Data Analysis System (CDAS) and many other archived and real time products.

EnGlobe will interface with NOMADS as a client and request specific services ranging from specific datasets and specific values to NOMANDS generated images. This data and images will be displayed on the EnGlobe virtual planet system. Additional multimedia NOMADS products will be incorporated as videos and 3D images.

Task 3. Sample learning objects

The proposed sample learning modules provide "out-of-the-box" functionality for students and allows teachers to assess how effectively students can apply scientific knowledge to real world situations. The process of designing and testing these modules will provide valuable insight into how to develop templates for making effective modules, see Task 5.

1. "*Find the Best Forecaster*" is a group of low difficulty learning objects designed to familiarize students with the scientific method by gathering data, using the objective root mean score to analyze a set of data, and presenting the results in a paper written in scientific format. Students are first instructed on how real time predictions of high and low temperatures are made on the operational models of NWS. They are then told how to read daily forecasts from line or bar graphs of temperature changes over a period of time and how to use real time predictions. Next, students are asked to select the highest value for a single day temperature and to determine the highest temperature over a given period of time. After studying a meteogram chart, the students are introduced to the concept of universal time and how to correctly use daylight savings and standard time.

In a related exercise, students are asked to record the weather predictions of a well known television weather forecaster and to compare these predictions with those of a forecast model. In an exercise designed to determine which predictions are the most accurate, students construct a data sheet with columns for each set of predictions, calculate the differences between forecast values and actual values in another column, and the square of the differences between them in a third column. The skill measure is then calculated as the average of the last columns and the square root is the RMS error. This learning module illustrates the steps that will be followed in developing other learning modules--observations, formulating hypotheses, testing hypothesis, and analyzing and reporting results. This module will also include mechanisms to assess learning outcomes based on tests before and after students interact with the learning resources.

2. "*Probability of a Weather Event*" is an intermediate level learning module that highlights the importance of understanding the function of probabilities in making forecasts. In debates on global warming, this lack of this understanding is very apparent in those who argue that scientists who make predictions about the future impacts of climate change based on probabilities are not practicing "good science." In this learning module, students select a weather event to study, such as frost, gale winds, or floods associated with rainfall amounts and calculate the probability that this event will occur based on temperature, wind speed, and precipitation. The selected event can have any range of basic parameters and a timeframe of one to seven days. The probability associated with the occurrence of the event is calculated as a percentage. After the forecast timeframe has past, the student can compare the probability of the event occurring with observations to see if the event did actually occur.

This learning module features materials that allow students to understand NWS methodologies used in probability forecasting. They learn that ensemble forecasts deal with uncertainties in the NWP models by running different models and using slightly altered starting conditions. The students then learn how the results of these model runs are used to make probability predictions of weather events and to create indexes that are used to predict severe or calm weather. For example, the NCEP operational models make eleven separate model runs, called ensemble components, many times each day. Students learn how to predict the probability of a particular weather element by dividing the total number of model runs used to make a prediction into the number of times the event occurs. (Alpert and Wang, 2004). NOMADS can provide these model results directly with a web URL address query. For example, this URL address-command returns the minimum temperature at Denver (Stapleton) airport for a 5 day forecast of minimum temperature in a period made on 15MAR2006. This address-command process would have to be repeated for all the ensemble runs, checking each one for a weather event such as "What is the probability that the minimum temperature is below freezing (or a frost)?", and counting the number of times the event occurs divided by the total number of runs. This is done automatically at this website. However, with EnGlobe, linked directly to the learning modules this process can be made more transparent and easier, so the student can focus on learning that forecasts are associated with probabilities not certainties like observations.

3. "*Simulated Atmospheric Dynamics*" is a high level learning module. The learning objective in this module is to achieve an enhanced understanding the how both the atmospheric state evolves and models can simulate these changes. This learning process begins with observations of NOMAD model results showing the atmospheric structure of a cyclone. These can illustrate the cellular nature of circulation around fronts and the role played by low pressure in east coast snow storms. The motion dynamics of such a system can be simulated for a particular case, for example, "The Storm of the Century", to produce a 3 dimensional space and time animation presented as both EnGlobe overlays and as a video of the 3D structure. This video would show how a field of air converges at the surface of a storm system and triggers vertical motion as well as a divergence of air flows over the top of this system. And it also shows how a field of air sinks over a wide area to complete the cycle and how this process influences neighboring systems.

Since models simulate the temperature and moisture structure, the advance of mass and moisture, and heating modification from the interaction, each can comprise separate learning resources. Eventually, students can explore scenarios tracking parcels of the atmosphere as the dynamics move and change their state and examine the forcing functions along their path. Such detailed analyses can bring a much greater appreciation of the underlying beauty of science in all its forms.

The proposed learning modules builds on existing capacity to create teaching resources by supplying the framework for delivering the data that can be effectively used by educators and students over the global electronic telecommunications system. This is accomplished by using a service orientated architecture

(SOA) that allows for distant distributed computer servers to present data in response to queries entered interactively on EnGlobe.

Learning modules like those described here can be developed by accessing global and regional three dimensional simulations and observational data from state of the art NWP simulation models of the NWS using NOMADS. The coupling of real time and archived "simulation" data with the EnGlobe Portal is the next logical step in the process of producing dynamic educational resource content.

Task 4. Classrooms testing of sample learning objects

Needs assessment

Virtual laboratory for science & environment	Many simple virtual labs, few demonstrating real world complexities
Specific need – meteorology	Alpert teaches Met 111 at Howard CC
Specific need – Environmental science & public policy	Nadeau teaches Env Sci & Public Policy at GMU

The sample learning modules will be tested in Spring semester 2007 for learning outcomes and effectiveness in courses taught by two of the principals in this project. These tests will provide the feedback required to develop a template for creating more effective learning modules. PI Jordan Alpert teaches a course in meteorology (METO-111-550) at Howard Community College that focuses on the study of weather, climate and the atmosphere. He has identified the need for the "*Find the Best Forecaster*" and "*Probability of a Weather Event*" modules. Robert Nadeau teaches courses in environmental science and public policy at George Mason University (GMU). In these courses, Nadeau makes extensive use of satellite images and observational data from satellites and ground observation system to illustrate the dynamics involved in the complex interactions between human and environmental systems and has recognized the need for the "*Simulated Atmospheric Dynamics*" module. The courses taught by Alpert and Nadeau will serve as an effective beta test site for the EnGlobe interactive planet system and the learning modules implemented on that system. We also plan to involve environmental scientists associated with the 141 programs in environmental science represented in the Council of Environmental Deans and Directors in the process of developing learning modules that could be implemented on the EnGlobe Portal.

Project effectiveness

Collect evaluation data	Web-based usage statistics Class-based pre- & post-exams
Metrics & targets	Unique users … 250K after 1 year Repeat users … 100K after 1 year School users by urls … 500 after 2 years Class outcome assessment … 25% improvement
Data analysis	Plot data by time against target
Evaluation reporting	Continuing onsite charts of effectiveness, summarized in project reports

The learning modules will feature online pre- and post-testing with questions chosen for the learning objectives and the results will be automatically calculated. Simple processing of the test data would plot the change in the student scores on pre-tests and final tests. To eliminate bias, the questions would be randomized and normalized over all students. Student feedback would be solicited on online forms and teachers would be asked to submit comments and suggestions for improvements.

Task 5. Generalizing learning module creation in a template

The sample learning modules developed in the proposed project would serve as the basis for developing a template that would facilitate the development of large numbers of learning modules for particular learning communities. This template will allow educators to provide their students with interactive learning experiences that meet the highest educational standards and to evaluate the outcomes of these experiences with automatic testing procedures. These learning experiences will feature data collection, problem solving, the generation and testing of hypotheses, and analyzing and reporting on results. The template for developing learning modules will have a user-friendly interface that guides educators through each step of the process and provides transparent access to appropriate NOMADS data sets. After educators create new learning modules, these modules will reviewed and evaluated online by other educators before being implemented on the EnGlobe Portal. And all of the teaching modules and other instructional materials used on this portal will be thoroughly vetted by science educators.

Timeline for implementation

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Award	**5th**												
Tasks													
1. Adapt EnGlobe	**--**	**-------**	**-----**	**-----**	**--X--**	**--------**	**-----**	**-----**	**---- X**	**---X**			
2. NOMADS data		**-------**	**-----**	**-----**	**------**								
3. Learning Modules			**-----**		**------**	**--------**	**--X-**	**-----**	**---X**	**---X**			
4. Class test											**---X**	**---X**	
5. Template										**-----**	**-----**	**---X**	
Reports*													
financial		**19th**	**16th**	**14th**									
performance							**16th**						**16th**
Server		**order**				**install**							
Funds obligated	**sign NCSE**	**buy server**			**18th**								

* "Each performance report will consist of 1 Microsoft PowerPoint slide (with associated talking points) and a short financial report. Templates for performance and financial reports may be obtained from the Office of Education."

Project accountability

Inputs	**Track budget, schedule**
Outputs	**Track pre- & post-test scores**
Reactions	**Feedback requested**
Learning objectives	**All learning modules have stated objectives, data compiled, targets, and evaluation**

Contributes to cross-cutting themes

Integrated global obs & data mgmt system	**GEN EnGlobe Portal is a global data mgmt system using the NOAA GEO-IDE framework**
Environmental literacy & education	**Sample learning objects & template**
Reliable research	**Vetted presentation**
Homeland security	**Compilation & presentation of hazards**

Budget breakdown

NOAA

Responsible for NOMADS data & programming, server administration, learning modules, and template development and testing

- Jordan Alpert: Ph.D. in Atmospheric Sciences from the University of Michigan. Alpert worked at Goddard Space Flight Center/NASA and at the National Meteorological Center's Development Division (forerunner of NCEP/EMC). In 1992, he became the head of the EMC system development group. In this role, Alpert was responsible for modernizing data management services, implementing physics parameterizations in NCEP models, and developing the framework for distributed access data sets in NOMADS. Since 1999, Alpert has worked on sub-grid scale interactions with mountains in NCEP models including model improvements from high resolution Doppler radar wind data.
- Jun Wang: M.S. in Computer Science from GSU and Meteorology from IAP, CAS. Wang is employed by SAIC and assigned to work at EMC/NCEP/NOAA. She contributes to software development and data maintenance for NOAA Operational Model Archive Distribution System (NOMADS) project and to regional spectral model and regional climate studies.

NCSE

Responsible for EnGlobe programming, interface to CEDD and Encyclopedia of Earth

- Peter Saundry: Ph.D. in Physics from USC. Saundry, the executive director of NCSE, is an experienced builder of coalitions of diverse individuals and organizations that promote the use of research in environmental science to deal with societal concerns. He has served as a Congressional Science Fellow, a chairperson of the Sierra Club Clean Coastal Waters Task Force in LA., and treasurer of Global Children's Health and Environment Fund.
- Ralph Sklarew – PhD in Physics from UC. Sklarew is an entrepreneur who holds a dozen patents. He has contributed to research projects on nuclear weapons effects, space industrialization, atmospheric modeling, air pollution simulation, and environmental impact studies. Sklarew has also been involved in developing new technologies in areas as diverse as pen computing, emergency response management, human-computer interface, and traffic management. Early in his career, he worked at NASA, NOAA and US EPA.

GMU

Responsible for GEN Center interface, server hosting, supporting learning module development & testing

- Robert Nadeau – Ph.D. from the University of Florida. Nadeau is an interdisciplinary scholar who has published nine books in diverse subject fields. His most recent books have been in the area of environmental science and public policy with particular emphasis on economic solutions to environmental problems. Nadeau is a full professor at George Mason University and a member of the Department of Environmental Science and Public Policy and the School of Computational Sciences. He is now serving as the director of the Global Environmental Network Center at GMU.

Other direct costs:

- Server – to store and serve the massive NOMADS database – dual Xeon/Opteron CPU, 8GB ECC RAM, redundant hot-swap power supplies, 2 80-200GB operating system disks on independent RAID-1 controller, plus RAID-5 up to 15TB with hot spare disks 1 for 1, from tier 2 vendor as meets cost estimate - $15,000
- Travel – 2-4 one-person trips to present papers and increase awareness at technical education or environmental meetings within budget- $5,000

Summary table:

Institution	Person	Task	Time (hrs)	Cost ($K)	Charge ($K)
NOAA	Alpert	PI, NOMADS interface, learning modules	200	15	-
	Wang	Programming, administration	440	25	20
		NOMADS & GEN server		15	15
		Match		20	
NCSE	Saundry	NCSE, CEDD, Encyclopedia interface	60	6	6
	Sklarew	EnGlobe programming	600	50	50
		EarthPortal, Encyclopedia of Earth	60	6	-
		Travel		5	5
		G&A @ 4%		3	3
		Contribution		6	
GMU	Nadeau	GEN Center interface, learning modules	200	15	-
		Co-location for server hosting	40	2	-
		Contribution		17	
		Total match & contributions		**43**	
		Percentage match & contributions		**43%**	
Total			**1600**	**142**	**99**

Leverages EdMG funds

NOAA match	**$20,000 (20%)**
Partner contributions	**$23,000 (23%)**
Integration with larger GEN projects	**Nodes at GMU & NCSE, many more planned**
Incorporation of NCSE Encyclopedia of Earth	**Scientist-vetted environmental articles**
Widespread dissemination	**Planned distribution via major Web portals**

Sustainability

Emergent issue	**Environmental awareness Global warming**
Expansion plans	**Part of Global Environment Network, growing environmental data access**
Partners	**NCSE, GMU GEN Center, more planned**
Long term funding	**Further donations& grants Revenue from partnership with major Web portal**

Support letters

I approve our participation as stated in this proposal but reserve the right to change personnel as required by any staffing changes.

Stephen Lord	Peter Saundry	Robert Nadeau
Director Environmental Modeling Center, NOAA	Executive Director, National Council for Science and the Environment	Director Global Environment Network Center, George Mason University

(Signed originals on file with Jordan Alpert, PI)