Cyberinfrastructure Development for the Western Consortium of Idaho, Nevada, and New Mexico

Introduction. The Western U.S. faces daunting challenges. Populations are increasing; demand for fresh water exceeds the available supply; and regional and global climate change and variability affect natural resources, disturbance regimes, and the region's economies and citizens. Responding to these challenges, in 2008, Idaho, Nevada, and New Mexico independently submitted NSF EPSCoR Track 1 Research Infrastructure Improvement (RII) proposals that focused on infrastructure to support research on climate change, water resources, and related challenges.

In spring 2008, the state Project Directors created the Western Consortium (ID, NV, and NM; hereafter "Consortium") to identify key areas of overlap and opportunities for leveraging resources so that the cumulative impact of NSF RII investments in the three states could exceed the sum of the parts. The Consortium agreed to: (1) hold a combined annual meeting to facilitate regional partnerships that support "critical mass" in key scientific areas; (2) convene meetings among the Consortium's project leadership to identify and act on leveraging opportunities; and, (3) key to this proposal, form a Cyberinfrastructure (CI) Committee that will identify and adopt data, metadata, communication, and web standards and protocols, as well as coordinate regional cyberinfrastructure development.

The CI Committee has coordinated Track 1 CI Strategic Plans among the three states and identified common CI challenges and needs. The Consortium utilized a consensus-based approach to prioritize the challenges and needs that support the Track 1 climate change focus, and that serve as the basis for Track 2 efforts. In determining needs, the Committee also took into account recommendations for our states and region resulting from the 2007 EPSCoR Cyberinfrastructure Assessment Workshop in Lexington KY (NSF, 2007). Through this process, the CI Committee identified three priorities for the Consortium, all supporting the underlying theme of climate change research: (1) improving connectivity within, between, and beyond the Consortium states and institutions; (2) achieving data and model interoperability to support community science; and (3) utilizing CI to integrate research with education. The Committee matched state-level expertise with the three priority areas so that common regional objectives could be optimally realized. We envision that this collaborative, multi-faceted effort will transform communication, climate change science, and education in our region. Moreover, a key outcome will be sustained partnerships among our jurisdictions that will enhance our competitiveness for research funding and enable us to better address 21st Century grand scientific and societal challenges.

Roadmap to this Proposal. Section 1 provides an overview of the current status of the Consortium's CI landscape. **Section 2** summarizes relevant CI activities supported by NSF for each state. **Section 3** describes the Consortium's plan to increase connectivity and bandwidth, create data and model interoperability solutions, and use CI to integrate research and education. **Section 4** documents how the proposed CI will benefit underrepresented groups within the Consortium. **Section 5** presents our plan for communicating results throughout the Consortium. **Section 6** includes our evaluation and assessment plan. **Section 7** explains how the CI activities will be sustained beyond this project. **Section 8** describes how Consortium activities will be coordinated and managed across the three states, and includes the mentoring plan for postdoctoral associates. **Section 9** concludes with a synopsis of the project's intellectual merit and broader impacts.

1. Status of the Consortium's Cyberinfrastructure Landscape

Cyberinfrastructure planning within each state, coupled with past NSF EPSCoR investments, has enhanced research opportunities in the Consortium by improving connectivity, increasing high performance computing capacity, and adding visualization and collaboration technologies. Significant challenges remain, particularly with respect to increasing connectivity to smaller, more remote institutions, supporting data and model interoperability, and training a CI-literate workforce. Here, we discuss how each state's existing and proposed CI landscape fits into the overall research and education vision.

1.1 Idaho

The primary public high performance computing facilities in Idaho consist of Beowulf clusters in its universities. The University of Idaho (UI) has about 256 nodes divided among three clusters, and is about to add 512 nodes, each of which is more than twice as fast as anything it has currently. Boise State University (BSU) has a cluster with 256 nodes, and Idaho State University (ISU) has a small cluster of Xservers (50-60 nodes). The ISU and BSU facilities are integrated into genomics and proteomics cores, respectively. UI facilities are primarily dedicated to statistical modeling and computational biology. Idaho also has state-of-the art remote sensing and GIS research and teaching facilities. For example, at the Idaho Water Center in Boise, ISU has computational workstations, a server, and supporting hardware and software, and a compressed video IP-based system. The Water Center also hosts Idaho's Hydrologic Information System (HIS) database. The UI in Moscow hosts a dual wireless smart board and very high-resolution projector system to enable simultaneous presentation of geospatial imagery. Boise State has a 3-D visualization facility. A CAVE facility is planned at the new Center for Advanced Energy Studies building in Idaho Falls. Two Idaho universities also host Access Grid Nodes to support collaboration.

Idaho's universities are connected to the Internet, Internet2, and other global information networks through multiple partnerships. ISU partners with the Utah Education Network, which gives it access to Internet2 and the National Lambda Rail (NLR) and membership in the Front Range GigaPop. The UI is linked to Internet2 via the Pacific Northwest GigaPoP (through Seattle) with a 2.4Gb/s hookup as a result of the National Institutes of Health IDeANet's Lariat project. BSU recently connected to Internet2 and NLR through the Idaho Regional Optical Network (IRON). Chartered in late 2007, IRON associates include BSU, UI, the Idaho Department of Administration, Washington State University, Idaho National Lab, Brigham Young University-Idaho, Lewis-Clark State College, and the Idaho Hospital Association.

Idaho also has invested in distance education and streamlining access to geospatial information. Idaho's extensive network of compressed video facilities includes over 75 video sites that facilitate research collaborations and distance education in the absence of high-speed connectivity throughout much of the State. The Idaho Geospatial Committee recognized INSIDE (Interactive Numeric and Spatial Information Data Engine) Idaho, operated through the UI, as the State of Idaho's official statewide geospatial data clearinghouse. INSIDE Idaho serves as the mechanism to share data, resources, technologies, and expertise to meet the increasing demands for Idaho's geospatial information by educational institutions, government and business professionals, and citizens.

1.2 Nevada

Computing has been expanding in Nevada through campus-based initiatives. With the National Supercomputing Center for Energy and the Environment (NSCEE), the University of Nevada at Las Vegas (UNLV) has a 32 CPU SGI, an I2 Visualization lab, several clusters, and a large robotic tape library. The other research campuses have focused on consolidation of various computer clusters in order to create a larger resource. At the University of Nevada at Reno (UNR) the campus grid currently has several hundred core and several disk arrays. The Desert Research Institute (DRI) has a 44 CPU SGI Altix, a 32 CPU SGI Altix, and several small clusters. DRI has also implemented a shared campus grid that has consolidated several clusters at its two major campuses.

Connectivity for the educational and research institutions in Nevada is handled through a Nevada System of Higher Education (NSHE) sponsored organization called NevadaNet – a robust statewide backbone network that provides data connectivity and IP based video conferencing services to approximately 200 predominately rural Nevada locations. These sites include NSHE college campuses, K-12 schools, hospitals, Native American communities, and some state and federal government entities.

NevadaNet consists of a backbone connecting four major hub sites: Las Vegas, Elko, Reno, and Carson City. From these major hub sites, radial spurs consisting of primarily full or fractional T1 leased circuits extend to the individual rural site locations. The major part of the network is based out of two metro rings: one in the north (Reno), and the other in the south (Las Vegas). These two metro rings are connected by a 1GB/s leased fiber link with 2 OC3 circuits through Salt Lake City as backup. Connectivity to Commodity Internet is available from the south ring via a 1 GB/s line. Connectivity to Commodity Internet as well as Internet 2 and NLR is available through a 2 GB/s link from the north ring over the I-80 corridor to CENIC in Sacramento. UNR, UNLV, and DRI each have 10 GB/s networks on campus between buildings with 1 Gb/s to desktops (10 Gb/s can be provided where needed).

Connectivity for distance education and research is provided through IP-based video conferencing hardware and software as well as locations to use the video conferencing. NevadaNet provides Video/Collaborative Conferencing capabilities, with the campuses providing the endpoint hardware. There are several Connectivity Rooms used for Access Grid Network and distance education connections, some of which were funded through a previous NSF EPSCoR grant (2002-2004). The Track 2 cyberlearning component will utilize CI capabilities established through the Track 1 and Track 2 projects for training faculty, students, and postdocs, and outreach to K-12 classrooms.

1.3 New Mexico

The New Mexico Science and Technology Plan recommended a specific initiative for enhancing statewide CI capacity. The initiative — the NM Computing Application Center (NMCAC) — includes as its centerpiece the recently commissioned *Encanto*, an SGI/Intel High Performance Computer system (HPC) capable of 172 trillion calculations per second (172 teraflops) which, for a short time at least, makes it one of the most powerful supercomputers in the world. NMCAC also includes three "exemplars" (2 teraflop systems with the same architecture) that are located at the three research universities: the University of New Mexico (UNM), New Mexico Tech (NMT), and New Mexico State University (NMSU). Cumulatively, the four HPCs provide significant computing power required for the climate change, hydrological, and socioeconomic modeling efforts described in our recently funded RII Track 1 project.

In addition to the $11M investment in NMCAC, New Mexico is advancing connectivity to all colleges and universities throughout the state. In keeping with the NM Science and Technology Plan, each university will have state-of-the-art visualization centers and distance education facilities. The architecture is based on a hub-and-spoke model, whereby the research and regional universities serve as the hubs for high-speed connections to the state's regional universities and Tribal and community colleges. The State is contributing $1M to Track 2 as cost-share to support the increased connectivity among colleges and universities statewide. This increased connectivity will enable implementation of an ambitious plan by the New Mexico Higher Education Department that will allow courses taught at one university to be delivered electronically to other schools. This capacity for distance education is critical in New Mexico where requisite faculty members are not present on every campus and travel times between campuses are long.

2. Results from Relevant Prior Support

Past EPSCoR investments have enhanced existing CI and created new capacity throughout the Consortium. Here, we highlight some of the most relevant NSF EPSCoR-supported activities that were designed to increase capabilities with respect to networking and communication, computing and visualization, and information dissemination and delivery.

2.1 Idaho

Since 1989, NSF EPSCoR awards have helped transform Idaho's academic R&D infrastructure and have catalyzed a transition from individual research projects to community-science-oriented efforts that utilize CI. In 2000, EPSCoR (EPS-0080935) helped establish an independent, self-sustaining research Institute for Bioinformatics and Evolutionary Studies whose research emphasizes parallel and distributed bioinformatics, simulation and analysis, statistical analyses, and self-repairing fault tolerant programs. The grant provided a powerful, expandable Beowulf computing system for teaching and research and led to an interdisciplinary graduate program in Bioinformatics and Computational Biology at the UI.

In 2001, Idaho received EPSCoR RII award EPS-0132626, with three research foci: biocomplexity, neuro-fuzzy computing, and nanomaterials. The computing focus resulted in computational infrastructure at the UI. The Biocomplexity focus resulted in Idaho's first Access Grid Nodes at UI and ISU. Other CI-related accomplishments include standard NSF grants related to: (1) Idaho's participation in GEOscience Network (GEON) (EAR-0225421) for interdisciplinary information integration and tool sharing, and (2) funding (EAR-0549324 and EAR-0650855) for the national INTERdisciplinary alliance for digital Field data ACquisition and Exploration (INTERFACE) for collaborative development of software tools, data management capacity, and community training support for geoscientists. EPSCoR funds also enabled creation of a GeoVisualization facility at UI for advanced analysis and interpretation of digital databases.

Through NSF EPSCoR award EPS-0447689, BSU and the Idaho Water Center improved hardware and achieved a high bandwidth connection that increased access to the Hydrologic Information System (HIS) Server that supports the Idaho Experimental Watershed Network (IEWN). Publishing of data using WaterOneFlow web-services makes the IdahoWaters node compatible with the WATERS network of hydrologic information systems. The RII also facilitated community (public domain) software development including web interfaces, the EPA BASINS model, and an open standards-based GIS software system (MapWindow.org) that has been downloaded by 107,000 users throughout the world.

Idaho's newest NSF EPSCoR RII (EPS-0814387) includes CI to support research on *Water*

Resources in a Changing Climate. Output and simulations from modeling, downscaled climate scenarios, hydrologic data, and field data will be organized and managed for efficient use and dissemination. Three areas for CI emphasis are: (1) collaboration and communication through web-based desktop sharing and conferencing software; (2) storage, exchange, management, and analysis of time series and point observation data by enhancing a data management and sharing system, as well as future and parallel statewide research, with hardware, software, and new web development; and (3) exchange, management, and analysis of spatial and remote sensing data. Idaho researchers are central to Track 2 data management, archiving, and model interoperability efforts (Section 3.2).

2.2 Nevada

Nevada has used NSF EPSCoR funding to create nationally competitive programs that have increased total NSF awards to the State. Since 1989, CI has played an integral role in the success of its programs by providing state-of-the-art computing resources in support of instrumentation and facilities such as the UNR Genomics Center (EPS-9977809) and the Nevada Center for Bioinformatics (EPS-0132556).

The Advanced Computing in Environmental Sciences (ACES) program (EPS-0132556) initiated a new strategic direction of advanced computing, modeling, and visualization in 2001. ACES created a communications grid, based on dispersed Access Grid nodes, which is now a statewide resource that facilitates communication within the academic community in Nevada. ACES also established and equipped the DRI VisLab, a state-of-the-art scientific visualization laboratory. Around the same time, the Army's Simulation and Training Technology Center (STTC) funded the “CAVE project," a suite of high-end virtual reality visualization systems. The merger of ACES with the CAVE in 2005 formed the Center for Advanced Visualization, Computation, and Modeling (CAVCaM) with the vision to utilize developing technologies in computer graphics, computer interfaces, and scientific computing for the enhancement of environmental science research. The CAVCaM will soon move to its new, largely state-funded, $20M DRI facility that will feature the western United States’ first six-sided CAVE.

Nevada NSF EPSCoR took a new CI direction in 2004 with the formation of a statewide program in Cognitive Information Processing (CIP) (EPS-0447416). CIP uses non-human computational systems to mimic common but complex mental processes. The CIP program focuses on surveillance and security applications using real-time computer interpretation of visual images; modeling and inversion of environmental data; bioinformatics data-mining techniques for analyzing nucleic acid and protein sequence information; and design and control of bio-mimetic robotic systems. Within three years of its inception the CIP program built significant new capacity by hiring 10 new faculty members with expertise in bioinformatics, biorobotics, modeling and inversion, and computational intelligence in games.

Nevada’s most recent NSF EPSCoR RII award in 2008 (EPS-0814372) utilizes CI to integrate a multidisciplinary program in Climate Change Science, Education, and Outreach. A data portal is the CI centerpiece and will provide data storage, documentation, and archiving from multiple sources. Software frameworks will aid data analysis and integration of information from different sources. Data structures and standards will permit exchange and integration of data with existing and planned observational networks (e.g., CUASHI, NEON). New computing clusters for advanced climate modeling plus other networks and resources will be linked via high bandwidth networks enabling real-time monitoring. Interactive visualization of science data for researchers, the public, and decision-makers will be enabled using DRI’s CAVCaM and a new “Solutions Room” at UNLV. The CI structure will include virtual organizations that will bring together geographically scattered communities and individuals to facilitate interdisciplinary research, education, and outreach. Nevada will lead the Consortium’s efforts related to connectivity and bandwidth (Section 3.1) and in the area of cyberlearning (Section 3.3).

2.3 New Mexico

New Mexico became an EPSCoR state in December 2000 and in March 2002 received a RII award (EPS-0312632) focusing on natural resources, nanotechnology, and connectivity. This support significantly increased connectivity through the addition of T1 lines to three regional universities in 2003, doubling their capacity. RII1 developed the Institute for Natural Resource Analysis and Management (INRAM), a collaborative of statewide facilities supporting biodiversity databases, state-of-the-art chemical analyses, and GIS development and training. Key components of INRAM are now written into the Federal Southwest Forest Health and Wildfire Prevention Act of 2004. In 2005, AAAS determined that INRAM had attained its goals and become self-sustaining.

A second award in March 2005 (EPS-0447691) built on the first award and addressed three critical issues of state and national importance: nanotechnology, education, and water. RII2 contributed to the purchase of a supercomputer cluster for nanoscience research at UNM which is available to EPSCoR researchers statewide, and purchased computing clusters and storage at UNM and NMT for hydrology data storage, analysis, and modeling. A key achievement was the development of New Mexico EPSCoR Fluxnet, an 18-site high density ET network with real-time instrumentation in the Rio Grande corridor (>60,000 km^2) from northern NM mountains to the Mexican border. RII2 also increased connectivity between ground-based and satellite-based data and the analysis and modeling facilities, and enabled timely visualization and dissemination of geospatial model outputs through open standards.

A third award in 2008 (EPS-0814449) improves observational modeling and analysis of high elevation hydroclimatology by strengthening the instrumentation and modeling infrastructure. Relevant CI components include: deployment of collaboration software; network connectivity upgrades at NMT; data acquisition/processing/management support at UNM, NMT, and NMSU; replacement data and application servers; data acquisition, processing, service, and client interface/portal programmers at UNM; and supercomputer code development support resources at the NMCAC to facilitate the execution of complex hydrologic, climate, and economic models. The enhancements will allow for mirrored data ingest and storage at NMT and UNM, and web and web-service-based data (ground observations, remote sensing imagery, model outputs, and synthesis products) distribution to partner colleges and universities, state agencies, and the public. Products available through the portal will range from raw data and processed geospatial products, virtual products generated based upon user queries, basic transformation and analysis tools and services, online visualization tools, and standards-based imagery and data services. New Mexico will lead model and data interoperability (Section 3.2) and cyberlearning (Section 3.3) efforts.

New Mexico EPSCoR also helped establish a new Bureau for Math and Science Education at the Public Education Department which helped shape a comprehensive long-range strategic plan for math and science education reform (*A Strategic Action Plan for Advancing Math and Science Education in New Mexico, 2007-2010*). The Track 2 cyberlearning component will allow us to support this Strategic Plan.

3. CI Development for the Western Consortium of Idaho, Nevada, and New Mexico

Many of the most vexing problems facing humanity are so complex, pervasive, and large-scale that they cannot be solved through traditional collaborations among a few researchers (NAS 2004). To address such problems, the concepts of *community science* and *virtual organizations* have evolved where facilities supported through cyberinfrastructure make computing infrastructure, data, models, collaboration and visualization tools, and intellectual capacity available to large interdisciplinary research communities.

Previous RII activities within the Consortium focused on building state-specific infrastructure capacity and expertise with respect to scientific disciplines in the individual states. For the first time, the current RII awards to Idaho, Nevada, and New Mexico share a common overarching theme and challenge—climate change. State-specific foci of scientific interest and expertise and long-term Consortium investments are shown in Figure 1. The impetus for this Track 2 proposal has been the recognition of the complexity and scale of the scientific challenge coupled with deteriorating economic conditions in the three states and subsequent ramifications for science, education, and economic development. ***The goal of this project is promote knowledge transfer to scientists, educators, students, and citizens within and beyond the Consortium by enhancing state CI, and enabling the community science needed to address regional to global scientific and societal challenges.*** To meet this goal, the Consortium proposes three high priority objectives that will enhance CI, enable community science, and promote knowledge transfer to scientists, educators, students, and citizens within and beyond the Consortium.

Objective 1: Significant effort will focus on promoting communication and collaboration by improving connectivity infrastructure within the Consortium. Proposed and future Consortium efforts to improve research competitiveness, STEM education, and economic development rely on this basic infrastructure.

Objective 2: We will promote discovery by supporting community-based climate change science through enhanced interoperability between models and other software components, providing improved access to and usability of Consortium data products by adopting standards-based data management and access models, and supporting new data assimilation, analysis, and visualization capabilities.

Objective 3: The Consortium will enhance learning by utilizing CI to integrate research with education. The Consortium will focus on graduate students, postdoctoral researchers, and faculty development; extend science education into middle and high schools; and improve outreach to business and industry.

Each of the three CI improvement activities supporting these objectives is described in detail below. First, the CI challenge is described. Second, we specify the activities that are designed to address the challenge. Next, we highlight the deliverables and milestones, and then link the activities to the resources that are required. We conclude with a description of expected project outcomes, explaining how the improvement activity meets present needs, and positions the Consortium to tackle future challenges.

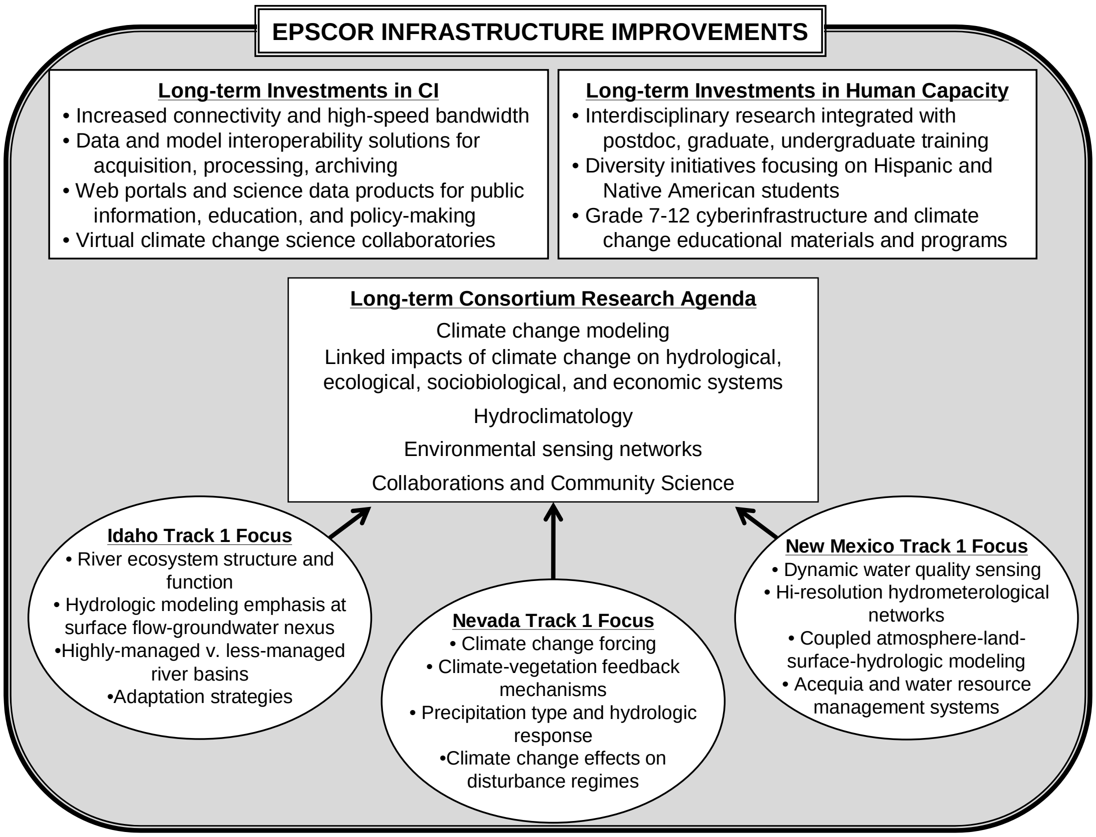

Figure 1. State-specific EPSCoR RII Cyberinfrastructure and Human Capacity Investments, long-term Consortium-based research, and Track 1 research foci.

3.1 CI Improvement Activity: Increased Connectivity (Objective 1)

3.1.1 The Consortium's Cyberinfrastructure Challenge

Increased connectivity and high-speed bandwidth are essential for supporting community science and addressing our common needs to enable collaborative climate change research and to support learning among educators, students, scientists, and engineers in virtual communities. EPSCoR states lag non-EPSCoR states in cyberinfrastructure, as described in the *EPSCoR Cyberinfrastructure Assessment Workshop* (Odom, 2006). Western EPSCoR states are at a distinct disadvantage due to the large distances between major population centers and the geographically dispersed communities. Track 2 investments in communication and networking infrastructure will enable climate change scientists, other researchers, and educators to develop a virtual organization among the three states. Members of the Consortium will have greater access to the worldwide scientific community; in turn, research and education products developed within the Consortium will be broadly accessible.

3.1.2 CI Improvement Activities

The high speed networking connectivity activities in Track 2 will focus on promoting communication and collaboration by improving connectivity within and between the states (Figure 2). Each state in the Consortium is in a different phase of CI development (Section 1). Idaho is improving campus connectivity and is also now focused on the development of the Idaho Regional Optical Network (IRON) to connect sites within the state and to increase throughput between researchers. Nevada began improving its connectivity several years ago and has recently focused on visual connectivity and collaboration rooms as well as computational infrastructure; it now seeks to improve both its high-speed network connectivity and its visual connectivity. New Mexico has recently focused on backbone upgrades up the Rio Grande basin and proposes to improve connectivity to 4-year institutions across the state and to enhance visual and collaborative connectivity.

Idaho. Idaho seeks to upgrade infrastructure to deliver between 100 Mb/s and 1Gb/s network connections to key university researchers' labs and desktops. IRON will also help connect difficult-to-access sites within Idaho, including research facilities of importance to present and past EPSCoR RII Track 1 programs in southern Idaho such as the UI Research and Extension (R&E) Center in Kimberly and the Fish Culture Experiment Station in Hagerman.

The long-term goal is to enable the Kimberly R&E Center and faculty associated with Idaho's new Track 1 RII award to increase WAN connections to Gb/s via IRON. This will aid transfer of large remote-sensing and hydrologic datasets for Track 1 research. Track 2 will provide support to add a new IRON Point of Presence (POP) in southern Idaho. This will stimulate the growth and success of IRON by increasing the opportunity for connections to UI facilities throughout the State, and connections for the College of Southern Idaho and Idaho Hospital Association sites.

Nevada. The initial focus in Nevada is to increase the connectivity *into* the state network. This will take the form of improved connectivity in the north from NevadaNet in Reno to CENIC in Sacramento. This connection upgrade for I1 and I2 from 2 GB/s to 10 GB/s will require switch blade changes and configuration, as well as annual connection fees. As part of the Track 2 project, NevadaNet will provide significant state match for this important connectivity.

With the connectivity increased into the state, the next step is to improve connectivity *within* the state through several networking and video conferencing upgrades, as well as networking monitoring tools across the state. Some of these networking and hardware upgrades will increase bandwidth capabilities of parts of NevadaNet in preparation for a state-funded new fiber run from the north to the south of the state. The new fiber will dramatically increase NevadaNet's connectivity and bandwidth, particularly to one of the states four year colleges and some of its satellite campuses along the path of this fiber.

New Mexico. Enhancing connectivity to academic institutions is key to supporting and strengthening STEM education in order to build the future science and technology workforce. Because of its importance, the work proposed in this section will be funded by the state and serve as the match for New Mexico's portion of this Track II proposal; therefore, no NSF funds are requested for this activity.

New Mexico plans to establish a distributed computing and collaboration infrastructure that consists of compute nodes at portals or gateways at college campuses throughout the state. Connection bandwidths from each gateway to the central computing facility will range from only a few Mb/s to hundreds of Mb/s. Through Wire New Mexico and other initiatives, New Mexico will work to increase connectivity to a minimum of DS-3, with many portals expected to have OC-3 or greater connectivity.

3.1.3 Deliverables and Milestones

Idaho.

- Formalize a plan for the UI to utilize IRON to access university facilities in southern Idaho (year 1).
- Purchase and install networking equipment at state universities for LAN upgrades and building uplinks that provide 1 to 10Gb/s service to several key research buildings (years 1-2).
- Purchase and install an aggregation switch (Point of Presence) on IRON. Aggregate traffic onto IRON's backbone in Twin Falls to include sites in Hagerman and Kimberly (years 2-3).

Nevada.

- Purchase and install switch upgrades for network connectivity upgrades: from NevadaNet in the north to CENIC in Sacramento, as well as NevadaNet connectivity to Elko and other parts of the state (years 1-3).
- Purchase and install networking monitoring and security software and hardware (years 2-3).
- Purchase and install video conferencing hardware in the north and south (years 1-2).

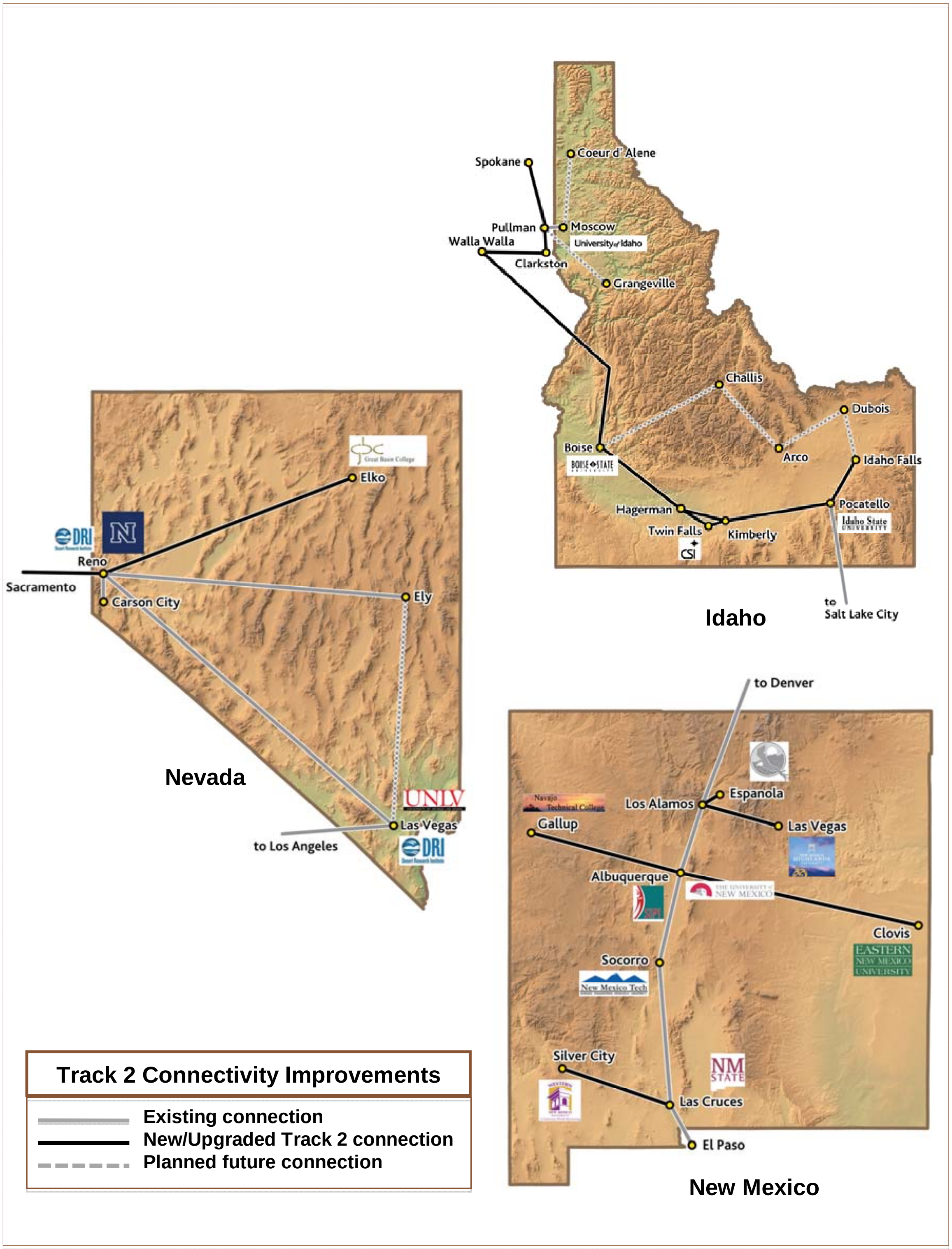

Figure 2. Proposed Track 2 improvements in connectivity and bandwidth, which will promote communication and collaboration within the Western Consortium. In addition to serving the major research universities and state colleges, these improvements will also help connect community colleges, tribal colleges, and minority serving institutions in geographically disadvantaged areas.

New Mexico.

- Purchase and install gateways at the three large research campuses and connect them to six Hispanic-serving and Native American-serving campuses in New Mexico (years 1-2).
- Purchase and install software for integrating all components of the gateway systems into a single, user-friendly system along with data compression software to minimize the amount of bandwidth needed for connectivity between the sites (years 1-3).

3.1.4 Resources Required

Idaho.

- Networking equipment at state campuses, including hardware to improve access and distribution.
- Aggregation switch on IRON at Twin Falls to create a POP.
- Subscription to enhanced bandwidth service via IRON.

Nevada.

- Switch upgrades for network connectivity.
- Network monitoring and security software and hardware.
- Videoconferencing hardware in the north and south.
- Cost-share by the State of Nevada includes the NevadaNet CENIC connection at the 10 Gb/s bandwidth and operation cost of networking and videoconferencing equipment.

New Mexico.

- Equipment provided as cost-share by the State of New Mexico to the gateway campuses will have the following capabilities: (1) teleconferencing between multiple sites; (2) high definition (1080p) videoconferencing; (3) 3-D high definition (1080p) stereo visualization; (4) instructor workstation and up to 35 student workstations; (5) Silicon graphics 16-core (3.0 GHZ processor) blade server with file storage system; (6) integrated graphical user interface; (7) Blu-Ray DVD player, stereo sound system, and distributed microphones; and (8) high definition video camera and a document camera. The videoconferencing and 3-D stereo visualization will employ one of three systems: overhead front projection system, rear projection system, or dual-display system (DLP, plasma, or LCD).
- State of New Mexico cost-share will purchase and install software for integrating all components of the gateway systems into a single, user-friendly system along with data compression software to minimize the amount of bandwidth needed for connectivity among sites.

3.1.5 Outcomes

EPSCoR Track 2 investments in connectivity will facilitate new data-intensive research, scientific collaborations, distributed experiments, grid-based data analysis, social networking, and cyber-enabled learning. Network improvements on Consortium campuses will remove bandwidth bottlenecks and allow university faculty involved in climate-related research at each university to take full advantage of available bandwidth for research and education.

EPSCoR Track 2 funds will promote communication and collaboration by:

- Providing faculty and research staff in the Consortium states with access to expanded research bandwidth, linking campuses to Internet2 universities as well as governmental research laboratories, companies, and research facilities throughout the world.
- Enabling scientists to access visualization facilities and out-of-state high performance computing facilities for advanced modeling related to climate change (e.g., hydroclimatological modeling).
- Supporting network capabilities to mirror data with other universities in the Consortium.
- Positioning the Consortium in the future to connect K-12 schools as well as provide for economic development and other opportunities that can result from high-bandwidth access (e.g., distance STEM education, tele-health instruction and support, and sharing of economic and community development materials).

3.2 CI Improvement Activity: Enabling Community-based Climate Change Science through Model and Data Interoperability Solutions (Objective 2)

3.2.1 The Consortium's Cyberinfrastructure Challenge

Community science, with its multidisciplinary collaboration, is essential for addressing complex, large-scale challenges like climate change. Current collaborations among researchers within the Consortium in climate modeling, hydrologic response, and changes to landscape or stream ecology tend to be opportunistic and discipline-specific, resulting in steep learning curves in model applications and duplicative efforts in assembling data sets. Moreover, supporting community science in the field of climate change has barriers due to disparate data sets and computational models (Zhou and Cruz, 2007; Bulatewicz and Cuny, 2006; Kohout et al, 2001). For instance, each state struggles with 'first mile' challenges related to the efficient ingestion of data and model outputs and the generation of metadata related to these products. In particular, regional climate model outputs are needed to drive surface processes models (Shulz et al, 2005; Nerheim, 2008). While all three states have some capabilities to downscale output from regional climate models, they do not cover the region that encompasses the Consortium. Therefore, the Consortium needs to share, expand, and link regional climate models of the intermountain west to existing modeling efforts to evaluate the consequences of regional climate change. An overarching challenge is to provide cyberinfrastructure that will promote discovery and add value to the existing research community by enabling Consortium scientists to interact more effectively regionally and to contribute to global research related to climate change.

3.2.2 CI Improvement Activities

The proposed collaborative CI development overcomes existing challenges by focusing on two closely related activities: (1) establishing a model and data interoperability software framework based on emerging national and international standards, along with scenarios and applications that make use of that framework; and (2) the implementation of a Consortium data archive model that is based upon open data and metadata standards and supports standard data interoperability models. These activities will use web interfaces to communicate the availability of data, models, training, and activities of researchers (Section 5), will extensively leverage existing national/international resources, and will make any code that is developed available through open source outlets.

Each state will contribute to achieving overall Consortium objectives according to their specific strengths and capacity. Teams of multi-state collaborators are engaged in each activity, with individual states providing leadership and expertise where appropriate (Section 8). For instance, Idaho will provide leadership with respect to data communication standards (identification and implementation); experimental watershed networking; and integrated modeling using web-services. Nevada will lead the development of a new generic software interoperability framework; prototype application scenarios that couple models across environmental sciences, projects, and states; assist with definition and implementation of data exchange standards; deploy new CRUD (create/update/delete) services; and contribute to installation of replicated database and file systems across the Consortium. New Mexico will lead development of the base framework for the interoperable data archive and will partner with Nevada and Idaho in the development and testing of the software interoperability framework. Details about the two CI improvement activities are provided below.

(1) Model and Data Interoperability Framework. The framework will allow users to specify, maintain and update—through a central user interface and a common methodology—software tools (wrappers), as well as the interconnections between tools needed to accomplish climate research tasks. The system will link the models in specific sequences of operation and will allow more efficient and unified data exchange (Zhou and Cruz, 2007; Bulatewicz and Cuny, 2006; Chin et al, 2006). The framework will enable physically consistent coupling of atmospheric and hydrologic models with disparate temporal and spatial discretizations in order to support enhanced hydroclimatic simulation and prediction. This effort will be coordinated with the NSF-funded Community Surface Dynamics Modeling System (CSDMS), which produces protocols for community-generated, open software for the study and prediction of environmental systems and processes. Furthermore, CSDMS distributes model software and tools that are compatible with the established protocols (see CSDMS Letter of Collaboration to NM). The atmospheric model will be the Weather Research and Forecast Model (WRF) developed at the National Center for Atmospheric Research (NCAR). Surface process and hydrologic models will be evaluated for coupling with WRF based on interactions with CSDMS scientists and software engineers.

Specific actions include:

- *Design and implementation of the software interoperability framework (NM, NV, ID)*. New Mexico will evaluate and use the Earth System Modeling Framework (ESMF), OpenMI (Model Interoperability), and the Common Component Architecture (CCA) frameworks to develop and implement the core software infrastructure for coupling the WRF atmospheric model to hydrologic and surface processes models such as TopoFlow, TRibs, and CHILD. Nevada will design and implement solutions for model interconnectivity focusing on user interface (Chin et al, 2006) and Human-Computer Interaction (HCI) aspects (Benyon et al, 2005; Heim, 2007). Idaho will provide feedback on the framework's design and operational capabilities.

- *Testing and usability studies (NV, NM)*. Nevada and New Mexico will test software (Sommerville, 2006) and perform usability studies (Tullis and Albert, 2008) that involve stakeholders from the groups that are targeted in the Track 1 projects, including researchers in environmental sciences, educators, policy-makers, students, and the public.
- *Creation and runs of specific research scenarios using the framework (NV, NM)*. Consortium scientists who model atmospheric, hydrologic, and ecological processes will run use-case scenarios that include: (i) multi-model watershed analysis and monitoring, (ii) coupling of atmospheric and hydrologic models, and (iii) downscaling of regional climate models to local scales.

Development and implementation of interoperability tools supporting data analysis and visualization involves three Consortium activities that are led by Idaho:

- *Demonstrate the extension from distributed server-based data storage and sharing to operational modeling systems in a fully-linked, modular, extensible, and reproducible system (ID, NV, NM)*. This effort will combine the strengths of the standards-based WaterML data communication language (from CUAHSI) with the OpenMI standard for communication of inputs, outputs, and parameters between multiple climate-water models or sub-models using open source software libraries and commercial off the shelf (COTS) software, as appropriate.

(2) Interoperable Data Archive. Our goal is to create an interoperable data archive that will enable streamlined discovery of and access to data products generated by all three state EPSCoR programs. We will develop data management systems that are based upon a core set of open standard formats and interfaces. This goal will be accomplished through: (1) the development of increased infrastructure (personnel, connectivity, storage capacity, and software components); (2) the identification, selection, and implementation of core interoperability formats and interface standards; (3) the integration of existing resources (e.g. WATERs) into the data interoperability framework; and (4) development of enhanced analysis tools that make use of the developed data interoperability capabilities.

The specific interoperability standards that will be targeted for implementation within the archive include the CUASHI HIS/WaterML; geospatial standards from the Open Geospatial Consortium (OGC); NetCDF; and the OpenMI specification for communication of data input/outputs and parameters between models in a workflow for model integration. Current and emerging nationally- and internationally-compliant metadata standards such as Federal Geographic Data Committee (U.S.) and ISO 19115 (international) geospatial metadata standards will be adopted as metadata standards by the Consortium.

Specific actions include:

- *Definition of data and metadata format standards for data and metadata representation and communication (NM, ID)*. New Mexico will define formats that will be supported for data and metadata ingestion, internal data and metadata storage standards, and deliverable data and metadata formats for end users. Idaho will identify and implement data and metadata format standards and tools for storing and delivering spatial and temporal observation data for water resources, climate, and related projects in the Consortium. Idaho will implement and configure the HIS databases and file systems required to enable access to shared data for each participating institution.
- *Develop, Create/Update/Delete (CRUD) service model for management of archive content across three states (NM, ID, NV)*. New Mexico, in coordination with Idaho and Nevada, will define resource model, and states associated with archive resources; define REST-style archive actions that create new archive objects; update existing objects; and delete objects. CRUD services will be implemented for management of archive objects within mirrored systems. This effort will be coordinated for inter-state mirroring; intra-state mirroring will be a parallel activity. The Idaho HIS server will be utilized and updated for this task.
- *Develop the required database and file systems and configuration of those systems for replication across all three states (NM)*. Database models will be designed and deployed, and based upon data and metadata standards. A file system will be implemented that enables efficient and scalable

management of file-based archive objects and that is based on identified data and metadata storage formats and CRUD service design.

- *Coordinate data ingestion from existing watersheds, facilities, and networks (ID, NM)*. Scientists from the Consortium and beyond will benefit from improved first mile data ingestion, expanding upon the Idaho Experimental Watershed Network sites. Idaho will co-locate the servers from Track 1 and 2 with the Idaho Department of Water Resources (IDWR) to create an Environmental Observatory Data Management facility at the Idaho Water Center in Boise (see IDWR Letter of Collaboration to ID). The postdoctoral scientist at BSU will serve as a liaison between field data collection sites in the IEWN and the Hydrologic Information System experts at ISU. The person will serve as a high-end user of the HIS in order to inform field scientists on how to best organize field data collection methods to take advantage of the HIS, and how to optimize data delivery methods. The proposed Data Manager will be located at the Center. The data manager will supervise the ingestion of new data into the data system, help Consortium researchers and state agencies access the data and information, and facilitate researchers' access to state data sources. This new position, along with existing personnel from IDWR, the University of Idaho, and Idaho State University will create a critical mass of 16 IT support people at the Water Center, with additional expertise from Boise State University. This investment will overcome barriers related to inadequate CI support, a key limiting factor to cyberinfrastructure development in the EPSCoR states (Odom, 2006).

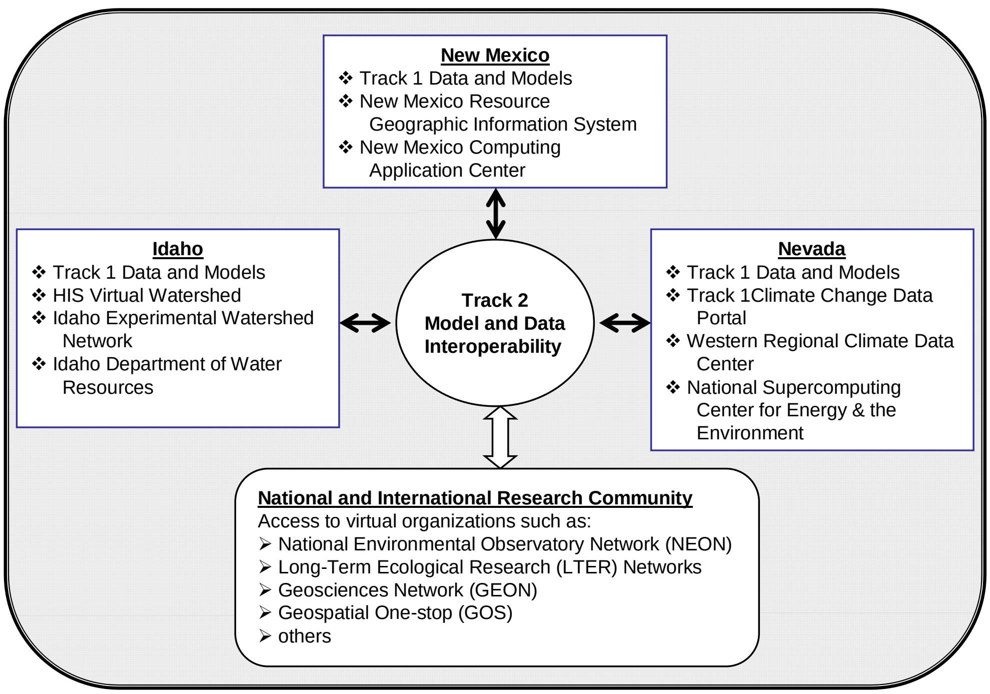

Figure 3: Model and Data Interoperability objective leverages and builds on existing State and National initiatives.

3.2.3 Deliverables and Milestones

Model and Data Interoperability Framework.

- Evaluation of the Common Component Architecture (CCA) and OpenMI environments for coupling WRF to surface process and hydrologic models and selection of one of these environments for further development (year 1).
- Evaluation and selection of appropriate surface process and hydrologic models for coupling to WRF, focusing on both hydroclimatic and hydrometeorological time scales (year 1).
- Requirements analysis and design of interface between WRF atmospheric model and surface process/hydrologic models, focusing on the disparate temporal and spatial scales and associated mass and energy conservation requirements for coupling such models (year 1).

- Design, development, and usability testing of a generic software interoperability framework (year 1: initial prototype, year 2: operational prototype, year 3: enhanced prototype).
- Development of prototype Initialize, Run, Finalize (IRF) wrapper code for WRF for coupling with surface process and hydrologic models focusing on hydroclimatic and hydrometeorological time scales (year 2).
- Build out full-featured coupling software infrastructure for WRF and selected surface process and hydrologic models (year 2).
- Comprehensive testing of model coupling, focusing on the development of reproducible test cases and on confirmation of required mass and energy conservation (year 3).
- Publication of reference test cases, delivery of software to CSDMS repository (year 3).

Interoperable Data Archive.

- Definition of data and metadata format standards for the data products to be archived (year 1).
- Implementation of the CRUD services for management of archive objects within the mirrored systems (year 1: initial prototype, year 2: deployment).
- Development of required database and file systems, and configuration of those systems for replication across all three states (year 1: initial prototype, year 2: operational prototype, year 3: deployment).
- Develop complete use case(s) and specific scenarios using the interoperability framework (e.g. involving HIS, WaterML, OpenMI) (year 2: initial prototype, year 3: deployment).
- Develop and implement interoperability tools supporting data analysis and visualization (HIS, WaterML, OpenMI (years 1-3).

3.2.4 Resources Required

Idaho.

- A full time data manager (to be partially <u>cost-shared</u> during the award).
- Two postdoctoral associates for model interoperability, networking, archiving, and HIS activities.
- Summer faculty salary related to the HIS.
- Computer hardware (<u>cost share</u>) for development and deployment of the interoperable data archive.

Nevada.

- Summer faculty salaries for project management and software interoperability framework development.
- Postdoctoral associate and graduate research assistant costs related to software frameworks, data archives, and tools and applications development.
- Computer hardware for development and deployment of the interoperable data archive.

New Mexico.

- Two postdoctoral research scientists who will develop and implement connectivity between WRF and surface process and hydrologic models.
- One graduate student to support HIS implementation.
- Staff, research faculty, IT contractor, and costs related to the development and deployment of the interoperable data archive.

3.2.5 Outcomes

EPSCoR Track 2 investments will provide new model and data interoperability solutions and an integrative software framework that will transform exploration, experimentation, and innovation in climate research. Project activities build upon existing resources within Idaho, Nevada, and New Mexico, are designed to leverage other major NSF-supported initiatives (including CUASHI HIS, GEON, and CSDMS), and will result in open source solutions that will be available to the broad community (Figure 3).

EPSCoR Track 2 funds will promote discovery and enhance research productivity and competiveness by:

- Supporting development and implementation of a new model for optimized data storage and management that will significantly reduce the difficulty in finding, accessing, and using the diverse data products available in the Consortium.
- Creating an integrative software framework that allows researchers to be more effective.

- Enabling Consortium results (data and models) and resources (archives) to be readily accessible to the broader community of environmental scientists, decision makers, students, and the public.
- Providing a coordinated pathway for dissemination of measurements and model results to researchers, educators, and stakeholders that are involved in Track 1 activities related to regional climate change.

3.3 CI Improvement Activity: Using Cyberinfrastructure to Integrate Research with Education (Objective 3)

3.3.1 The Consortium's Cyberinfrastructure Education Challenge

Using CI to address complex scientific and societal challenges will require a new level of technical competence in the 21st century workforce. The Consortium faces three principal challenges in helping to meet the national need. First, there is a need to train graduate students, postdoctoral associates, and faculty with the skills that will enable them to effectively utilize CI to address climate change and other grand scientific challenges. Second, we need to better develop quantitative reasoning, data analysis, and modeling skills in our middle and high school students. Third, we need to improve our outreach to leaders from business and industry in our states, educating them about new CI technologies and associated economic development opportunities. We cannot meet this challenge by simply developing physical cyberinfrastructure (increasing connectivity and computing capacity); we must also build human capacity.

3.3.2 CI Education and Cyberlearning Activities

Using climate change as the underlying theme, we propose three activities that are designed to expand CI awareness, increase use of CI, and better integrate quantitative reasoning, data analysis, and climate change modeling with education (Figure 4). First, a series of training opportunities to develop CI capacity and provide hands-on experience with climate modeling and scientific information systems will be provided for graduate students, postdoctoral associates, and faculty. Second, new cyber-enabled curriculum and education materials will be created and implemented for middle school and high school science education. Third, we will expand CI awareness and promote economic development opportunities by hosting CI Days, with business and industry as a target audience. Details about the three objectives are below.

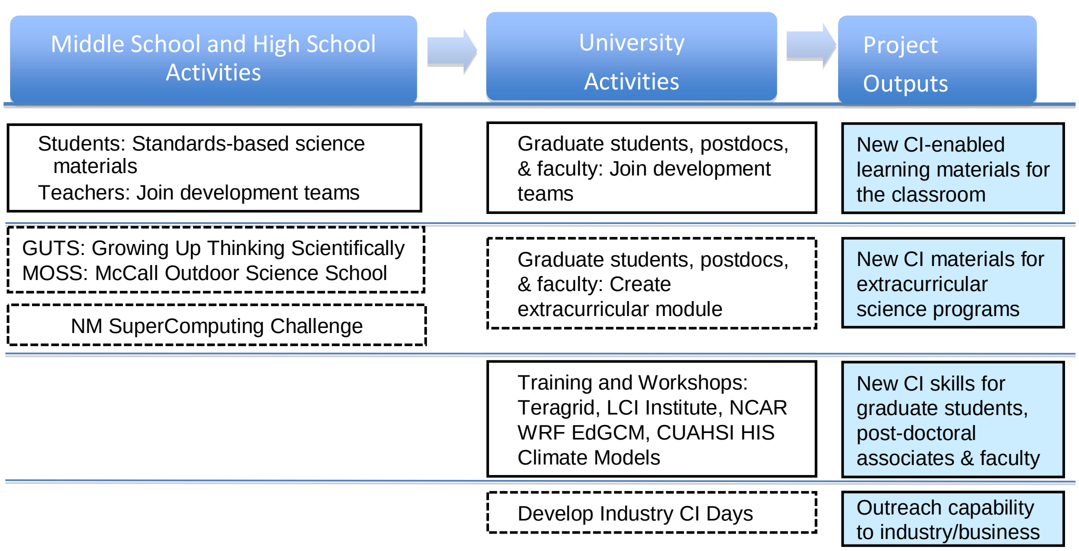

Figure 4: Cyberlearning pipeline: education and outreach activities. Solid-line boxes are Consortium-wide activities. Dashed-line boxes are state-specific or prototype programs.

(1) Training for graduate students, postdoctoral associates, and faculty. The combined faculty of the Consortium states host many students and postdoctoral associates who are or will be involved in Track 1 and 2 hydrology, atmospheric science, computer science, and related disciplines. The Track 2 project provides an opportunity to utilize CI to further integrate their research activities with professional training. We will mentor them in their professional development and provide CI training opportunities. We will leverage existing workshops in cyberinfrastructure and computational science that have been developed by national research laboratories, universities, and professional organizations. The Consortium will sponsor graduate students, postdoctoral associates, and faculty to attend relevant workshops and courses. In addition, customized training workshops in climate modeling and use of scientific information systems will be developed and offered. Specific CI training opportunities will include:

- *Linux Clusters Institute (LCI) Workshop*. The LCI was founded by the UNM Center for High Performance Computing, the National Center for Supercomputing Applications (NCSA), and IBM. It has become a premier international forum to share information on management, administration, and scientific computing techniques for high performance computing. The annual LCI workshop is a four or five-day event offering state-of-the-art, hands-on experiences in high performance clustered computing. The Consortium will sponsor student, postdoctoral associate, and faculty attendance to the annual LCI International Workshops, where they will gain valuable experience in applications, tools, user environments, and administration of large-scale clustered systems.
- *The National Center for Atmospheric Research (NCAR) Advanced Climate Modeling Workshops and Short Courses*. NCAR offers domain-specific training in meteorological and climate modeling. Participants from the Consortium will join scheduled workshops and attend short training sessions customized to meet specific needs. For example, Consortium students may attend a 5-day tutorial offered by the NCAR Mesoscale and Microscale Meteorology lab that provides a comprehensive overview of components of the Weather Research and Forecasting (WRF) modeling system.
- *TeraGrid Workshops*. TeraGrid is an NSF-sponsored open scientific discovery infrastructure that uses high-performance network connections to integrate high-performance computers, data resources and tools, and high-end experimental facilities. We will coordinate delivery of TeraGrid online tutorials and Web-based conferencing for new and novice researchers. Each state lead for education will work in coordination with TeraGrid outreach and education staff to deliver workshops and seminars covering high-performance computing topics relevant to our participants, including scientific workflow tools, an introduction to parallel computing, data applications and management, and portal design.
- *"Introduction to Climate Modeling" developed and conducted by the Consortium Universities*. Introductory climate modeling concepts will be taught in training sessions using EdGCM, an educational climate modeling system developed by Columbia University (http://edcgm.columbia.edu) and supported by NSF. The climate model at the core of EdGCM was developed at NASA's Goddard Space Institute for Space Studies (GISS) and is an updated version of the GISS Model II (Hansen et al., 1983). EdGCM allows students to directly manipulate a general circulation model, and students without extensive theoretical background can execute models and analyze and understand their behavior. In addition, Nevada will take the lead in developing an introductory overview of climate models and a comparison of climate modeling approaches. More advanced workshops will center on atmospheric, hydrological, and climate models in a high performance computing environment. Three major archives of climate model information and results will be introduced with hands-on instruction for: (1) the NCAR Earth System Grid, which integrates supercomputers with large-scale data and analysis servers located at national labs and research centers; (2) Intergovernmental Panel on Climate Change (IPCC) model runs; and (3) the worldwide archive of climate model results on the Lawrence Livermore data base (Program for Climate Model Diagnosis and Intercomparison, PCMDI).
- *"Introduction to the Hydrologic Information System (HIS)" developed by the Consortium of Universities for Advancement of Hydrologic Science (CUAHSI).* Idaho will take the lead in coordinating training for the HIS, an integrated system of Web services, standards, and procedures that provide access to data for hydrologic analysis. Idaho will offer an annual workshop for Consortium participants. The workshop will focus on topics necessary to understand and use the system, such as HIS architecture, uploading data into the system, and application interfaces.

(2) Integrating cyberlearning and climate change science into middle school and high school science education. Consistent with community science concept, a team approach will be used to develop and implement cyberlearning materials for use by teachers in middle school and high school science classes and to create extracurricular hands-on learning experiences. With climate change as a unifying theme, students will gain knowledge about CI and computational science. Understanding the impact of climate change and its future predictions requires understanding science as a modeling process and requires our use of interactive digital tools that support the ability to accurately model the complexity of large systems (Gilbert & Boulter, 2003). Interpreting these models will require "computational literacy" (diSessa, 2001). In addition, extracurricular activities that teach and utilize computational tools and introduce CI topics will be developed and expanded. Specific activities are described below.

- *Development of cyberlearning materials related to computational climate science (ID, NV, NM)*. Teams comprised of faculty, educational materials development experts, teachers, and graduate students in each state will collaborate to develop cyberlearning materials related to computational climate science. Research faculty will provide scientific leadership; education faculty will provide pedagogical leadership; graduate students and postdoctoral associates will learn how to communicate scientific knowledge to a diverse non-expert audience; and teachers will shape the materials to meet student needs and satisfy state educational requirements. All team members will be learning about and using cyberinfrastructure. We propose to fund one team per state each year.

  Educational content will engage learners in the results and findings that emerge from the Track 1 research projects on hydrological, ecological, and socio-economic impacts of climate change through a Web-based delivery and support mechanism that utilizes real-time computational analysis and visualization tools. The teams will define a focused topic in climate change science and specify the audience (grade band) and objectives for cyberlearning materials. Educational materials development will follow the Construct Centered Design (CCD) process, developed by the NSF-supported National Center for Learning and Teaching Nanoscale Science and Engineering (NCLT), which has been demonstrated to be successful for learning materials development (Shin et al., 2008).

  Nevada will lead these efforts and will host a Web site and data portal to facilitate and coordinate curriculum projects. The Web site will be a workspace and resource test bed that will: (1) support communication among the materials development teams, (2) provide access to the data and models applicable to the EPSCoR Track 1 projects; (3) offer a clearinghouse of raw digital materials for project development; and (4) disseminate education materials. The cyberlearning materials developed by the project will utilize open source software environments. To promote wide use, all materials will comply with the Sharable Content Object Reference Model (SCORM). Use of this format ensures that the learning objects can be 'plugged into' commercial courseware products and open source content management systems. In addition, we plan to use existing NSF-supported cyberlearning resources like Interactive Multi-Media Exercises (IMMEX) or the Web-based Inquiry Science Environment (WISE) for the framework and delivery of materials.

- *Middle and high school extracurricular activities that teach and utilize computational tools and introduce CI topics (ID, NM)***.** Opportunities for informal education occurring outside the classroom have been demonstrated to be highly motivational for students and their attitudes toward science and career decisions (Falk, 2001). Idaho and New Mexico have particular interests in investing in extracurricular venues—in addition to classrooms—for utilizing cyber-enabled learning materials. In Idaho, extracurricular programs will be coupled with the development of learning materials teams and products described above. New Mexico will focus on two established extracurricular programs.

  Several extracurricular programs in Idaho have particular relevance to the science theme of the Tracks 1 and 2 projects. These programs include the McCall Outdoor Science School (MOSS), which provides a residential field campus experience with hands-on science activities for students and teachers; Project Water Education for Teachers (WET), which offer teachers accredited workshops providing interdisciplinary water education materials and instruction; the Boise WaterShed Environmental Education Center, which promotes water stewardship by teaching people of all ages how to protect and conserve resources; and the Palouse Discovery Science Center (PDSC), which promotes science, math, and technology literacy through educational programs, exhibits, teaching collections, and activities. Such programs have strong relationships with middle and high school teachers and students. Track 2 investments will enable extracurricular programs such as these to work with several teachers in the co-development of materials. Many other teachers and professionals will be trained to use those materials so that they can incorporate them into their classrooms and education centers.

  New Mexico will utilize two established extracurricular programs: GUTS (Growing Up Thinking Scientifically) and the New Mexico Supercomputing Challenge. The NSF-funded GUTS program for middle school students provides support for teachers who are interested in building after-school science clubs. Students and teachers in the club explore science topics and research methods through modeling and simulation in areas such as ecosystems, epidemiology, and pollution. New Mexico will lead in developing new modeling activities that provide the clubs with simulation datasets and exercises on climate change topics. The New Mexico Supercomputing Challenge involves high school students in team-based activities that develop computationally-based science projects. Track 2 will support the Supercomputing Challenge at additional schools, expanding to locations that have access to the newly installed NMCAC Gateways (Section 1). The Supercomputing Challenge will also be used as a model to recruit teacher and community mentors to help newly-formed teams focus on climate change-based projects.

(3) Improving CI awareness in business and industry. A new "Industry CI Days" aimed at businesses and industry will be piloted in New Mexico. "Campus CI Days" was begun in 2005 by CIDays.org, a partnership of national organizations that assists college and university campuses in strategic planning for cyberinfrastructure development. In 2008, New Mexico Highlands University (NMHU) hosted a very successful Campus CI Days activity for the state. Specific activities include:

- *Creation of a new government and industry-centered outreach effort – Industry CI Days – based on the 2008 NMHU Campus CI Days*. Industry CI Days will bring together state, regional, and national CI project leaders to demonstrate examples of CI-enabled industrial successes and educate businesses and industry about CI opportunities and emerging technologies. This new CI Days approach will be facilitated by the New Mexico Computing Applications Center (NMCAC), which has strong business and industry contacts, and is aligned with state economic development activities.
- *Attendance by Idaho and Nevada representatives at the "Industry CI Days" to determine whether this model has potential to be duplicated in their jurisdictions*.

3.3.3 Deliverables and Milestones

- Graduate student, postdoctoral associate, and faculty training in computation, climate change and CI:
    - Identify participants, national training, and workshops; coordinate attendance (years 1–3).
    - Develop and offer customized training in climate modeling and HIS (year 1 at annual Tri-state CI meeting; years 2–3, centralized or rotated among states).
- Middle and high school educational materials development:
    - Establish development teams and create portal site for education materials (year 1).
    - Develop education materials (years 1–3).
    - Formative evaluation of educational materials (years 2–3).
    - Dissemination of educational materials (years 2–3).
- Middle and high school extracurricular CI activities:
    - Establish development teams and collaborations (year 1).
    - Develop climate change CI activities for partners and fund implementation (years 2–3).
- Industry CI Days:
    - Design, coordinate, advertise, and deliver Industry CI Days program (years 2–3).

3.3.4 Resources Required

All three states will need travel resources for graduate student, postdoctoral associate, and faculty attendance at training sessions and workshops. Additional resources are described below.

Idaho.

- Faculty salary, graduate students, and teacher stipends for educational materials development.
- Summer salary for faculty to coordinate materials development and offer HIS training and workshop.

Nevada.

- Faculty salary, graduate students, and teacher stipends; related expenses for development and implementation of educational materials in classrooms and for extracurricular activities.
- Summer salary for science faculty to develop and offer climate model training and workshop.
- Travel to national educational research conference to disseminate new materials.

New Mexico.

- Salary to develop curriculum and expand extracurricular programs: Education Director, Education Outreach Coordinator, two Masters of Science Teaching graduate students, and teacher stipends.

- Program costs to expand GUTS and NM Supercomputing Challenge: teacher stipends, materials and supplies, in-state travel for participant students.

3.3.5 Outcomes

EPSCoR Track 2 investments in education and training programs will build human resources capacity in our Consortium by increasing awareness, skills, and knowledge in the areas of climate change and cyberinfrastructure. The activities will support a “students in STEM” pipeline approach that begins with middle and high school education, extends to professional training for graduate students and postdoctoral associates, and promotes CI awareness in business and industry. These new investments will complement Track 1 resources that support undergraduate engagement in climate change research.

EPSCoR Track 2 funds will enhance learning and discovery by:

- Supplementing existing degree programs in our states with professional training and workshop opportunities that better prepare graduate students, postdoctoral associates, and faculty, and foster the next generation of CI-literate scientists and engineers able to solve climate change problems.
- Providing teaching tools that will broaden participation in, and understanding of, computational thinking and modeling in general, and climate change science in particular.
- Enabling students to interactively use educational versions of the climate models and test various climate change scenarios.
- Strengthening existing middle and high school extracurricular science education programs, such as MOSS in ID, and GUTS in NM, allowing them to reach more schools, teachers, and students.
- Creating climate change science learning materials for the classroom that meet state science education standards and that will be adopted and used by schools.

4. Diversity Plan

4.1 The Opportunity and the Challenge

The Consortium encompasses a region that is rich in ethnic, cultural, linguistic, socio-economic, and geographic diversity. New Mexico has the highest percentage of people of Hispanic ancestry of any state (44%); the Hispanic population of Nevada (24.5%) is expected to account for the highest population growth in that state in the next few decades; and the Hispanic population in Idaho (9%) is the largest minority in the state, with a growth rate greater than 36% since 2000. Although Native Americans constitute 1% of the national population, they represent 2% of the population in Nevada and Idaho and almost 10% of the population in New Mexico. Nevada has 18 federally recognized tribes, Idaho has 7, and New Mexico has 21 distinct recognized tribal governments.

New Mexico, Idaho, and Nevada are experiencing many complex educational, cultural, and economic challenges. For instance, the three states have large rural areas with attendant problems of rural poverty and a large number of first generation college students. All three states fall below the national average of 24% for persons with a college degree: Idaho at 21%, Nevada at 18%, and New Mexico at 22%.

The Consortium has a unique opportunity and special responsibility to address the national shortages in our S&T workforce by educating a new generation of STEM professionals that includes more of the nation’s underrepresented populations. This responsibility requires tackling racial and gender inequities, and addressing the growing economic disparity between rural and urban population centers.

4.2 Consortium Activities

The Consortium is committed to improving access to cyberinfrastructure for minority populations and geographically disadvantaged populations and to increasing diversity in the future workforce of our states. Our plan is focused on three principal activities that are designed to help us make meaningful progress in achieving diversity goals: (1) invest in the connectivity solutions and human resources that enhance access to CI; (2) maximize geographic, ethnic, cultural, and gender diversity in Track 2 programs; and (3) develop realistic accountability metrics and mechanisms. Close coordination with and leveraging of Track 1 resources are central to our diversity plan.

(1) Investing in Connectivity and Human Resources. The EPSCoR Track 2 CI funds will enable the three states to make major improvements in the inclusiveness of remote areas, rural centers, small colleges and regional universities, Native American tribes and peoples, and persons with disabilities in our nation’s evolving cyber-enabled social and educational structures. Approximately one third of the

Consortium's funding is being applied to improving connectivity. In Idaho, resources will extend connectivity to rural areas by adding a POP and subscription to bandwidth on the IRON network in southern Idaho near Twin Falls; this provides the opportunity for colleges, K-12 schools, and hospitals in the region to obtain affordable high-speed connectivity. In the near term, the UI research facilities will benefit from improved access; in the long term this investment should improve high-speed bandwidth to UI Extension sites in many of Idaho's rural counties via IRON. In New Mexico, $1M of state match will be invested in gateways that provide access and collaboration technologies to four Hispanic Serving Institutions (New Mexico Highlands, Eastern, Northern, and Western Universities) and two Native American-serving campuses (Southwest Indian Polytechnic Institute (SIPI) and Navajo Technical College (NTC)). Nevada, through NevadaNet, will bring connectivity to smaller four-year and satellite campuses as a first step towards a longer-term statewide connectivity implementation for 2-year colleges.

Significant EPSCoR resources are being committed to personnel who will assume responsibility for meeting diversity goals. The Idaho EPSCoR program will have a full time Diversity and Outreach Specialist as part of their RII Track 1 plan. Likewise, Nevada EPSCoR has an Education and Outreach Coordinator, and New Mexico EPSCoR has recently contracted with a Native American education specialist from Taos Pueblo, who will integrate Track 2 CI activities into the larger Track 1 outreach and education plan. These EPSCoR staff will coordinate stakeholder communication in rural areas of their states, and design and implement programs for realizing diversity goals such as those described below.

(2) Maximizing Participation of Underrepresented Groups. Teacher and student program participants will be selected from the applicant pool so as to maximize geographic, ethnic, cultural, and gender diversity. For example, teachers for the materials development teams lead by Nevada will be selected from smaller and rural schools, or schools with a large minority student population. Similarly, the middle and high school extracurricular programs in CI will actively strive to broaden participation. In New Mexico, for instance, the GUTS program will be extended to three tribally-controlled middle schools.

Diversity coordinators in the Consortium will prototype a social networking solution (e.g., using FaceBook) that enables peer-mentoring in order to increase diversity in STEM. Successful minority STEM students will be guided to share experiences and advise freshmen students and others. Mentors can make younger students aware of opportunities and programs. Consortium staff will also network with other programs that encourage diversity, and seek their support, either through funding or expertise, to expand our knowledge base of successful strategies for working with diverse populations. These programs include: NSF AGEP, Louis Stokes AMP, and ADVANCE programs; the NIH Bridges program; and others such as the American Indian Higher Education Consortium (AIHEC), the American Indian Science and Engineering Society (AISES), the Hispanic Association of Colleges and Universities (HACU), and Mathematics Engineering Science Achievement (MESA).

(3) Providing Accountability. The Consortium will establish a Diversity Committee that will meet at the annual joint CI meeting of Track 1 and Track 2. Diversity Committee members will work with the evaluator to create metrics to measure progress and assess performance. The committee will share best practices and provide guidance on improvements that can be made by individual states and institutions.

Each EPSCoR program exists within organizational frameworks that are committed to broadening the participation of underrepresented groups in STEM. These organizations include NSF and higher education systems. For example, Nevada State Higher Education has the Chancellor's Diversity Forum, which brings together community leaders and leaders of higher education to discuss matters of diversity and inclusion; Idaho is developing an NSF EPSCoR-sponsored workshop for a Native American Graduate Research Center at UI; and all higher education institutions in the state of New Mexico participate in the ongoing discussions and working group activities of the New Mexico Higher Education Department Division of Educational Equity and Access (DEEA). Participation by EPSCoR faculty and leadership in these activities is important, encouraged, and financially supported.

5. Dissemination and Communication Plan

The goal of the Dissemination and Communication Plan is to foster scientific literacy and improve educational and research capacity within the Consortium through three dissemination and communication activities: (1) establishing effective internal communications among the Consortium's partners to enable efficient sharing of data and information; (2) creating coordinated mechanisms to communicate project results, benefits, and processes to scientists, citizens, and stakeholders within the Consortium and other EPSCoR jurisdictions; and (3) developing cyberlearning tools for educational outreach.

(1) Establishing effective internal communications among the Consortium's partners to enable efficient sharing of data and information. The Consortium will use cyber-collaboration technologies, including Adobe Connect Pro-video and web conferencing, and teleconferencing. Each state will serve as a host or named organizer for Adobe Connect; other partners (e.g., agencies) can be added as named organizers on an as-needed basis. Project management and document sharing will be facilitated by the web-based tool BaseCamp, which will be hosted by UNM's Earth Data Analysis Center.

A centerpiece for communication is an annual tri-state CI meeting that will be held adjunct to the Track 1 meeting held each spring. Faculty, graduate students, and postdoctoral associates will share ideas and present their work at the meeting, and training workshops may also be offered. The tri-state meetings signify an unprecedented leap in collaboration and information sharing between our states.

(2) Creating coordinated mechanisms to communicate project results, benefits, and processes to scientists, citizens, and stakeholders within the Consortium and other EPSCoR jurisdictions. The external gateway for project information will be Nevada's, Idaho's, and New Mexico's Climate Change Web Portals (Track 1). Each portal will have a common CI Consortium interface. The CI Committee will design and administer mechanisms to manage the flow of CI project information to these web portals.

The Consortium's annual CI meetings will provide a forum for information exchange by encouraging participation from stakeholders, scientists, and NSF EPSCoR Program Managers from the Consortium and other EPSCoR and non-EPSCoR jurisdictions. Quarterly electronic newsletters will keep participants and stakeholders apprised of the Consortium's activities, products, and accomplishments.

(3) Developing cyberlearning tools for education and outreach. Through a strong Cyberlearning component the Consortium will increase scientific and computational literacy and improve educational capacity by: (1) providing access to CI-related workshops and course; (2) creating new educational materials and in-service activities for teachers; and (3) hosting annual workshops on utilizing cyber tools for the development of educational materials. The Consortium's cyberlearning activities will broaden participation in and understanding of computational thinking and climate change science.

6. Evaluation and Assessment Plan

The objectives of the project's mixed-methods (NSF, 1997) formative and summative evaluation processes are to use qualitative and quantitative data to: (1) provide information to refine and improve project implementation at both the state and Consortium levels; (2) measure progress of the project in meeting its goals, objectives, and annual metrics; (3) assess the impact of the project in developing strong inter-jurisdiction collaborations that address regionally relevant and nationally important climate change science and education; and (4) assess the project's impact on enhancing discovery, learning, and economic development through the use of CI. The project's administrative team in collaboration with the external evaluator and the external advisory committee will continuously monitor how well the project is moving toward the anticipated goals as assessed by the annual metrics which will be developed immediately after the grant award. State-level feedback will be collected periodically using existing Track 1 RII infrastructure (including the ~25 metrics reported annually to NSF: numbers of publications, patents, grant awards, etc.) and communicated to the jurisdictional-level administrative team. Implementation and progress monitoring phases of the formative evaluation (NSF, 2002) will be assessed by the external evaluator using targeted surveys, observations, and interviews as well as longitudinal analysis of Tracks 1 and 2 RII data collected by each state. Participant demographics will be disaggregated by gender, race, ethnicity, geography (rural, suburban, urban), and disability. Majors of undergraduate, graduate and postdoctoral participants will be included in the disaggregation of demographics.

The external evaluator, Rose Shaw, Ph.D. in Applied Statistics, is accomplished at working with multiple-site, collaborative projects. She has extensive experience evaluating NSF STEM and infrastructure improvement projects (RII, NUE, GK12, LSC, CETP, IGERT, ITEST, LSAMP Phases I, II, II and BD, ADVANCE, and MSP). She has also evaluated projects funded by the USDOE (Colorado statewide evaluator of Reading First, Title III, Title VII, Upward Bound), and States (Arizona Board of Regents-TQE, Colorado-MSP). She was an invited member of the NSF national site-visit team that evaluated the University of North Carolina-Chapel Hill MSP (2004), and was part of a team that developed an evidenced-based framework for the national evaluation of NSF's EPSCoR program (2007).

The external evaluator will collect concrete, meaningful project data and will present qualitative and quantitative analyses of the data in interim and annual reports to the PI/PD who will disseminate findings to appropriate stakeholders including NSF. The external evaluator will document the extent to which the project meets the anticipated outcomes, measures long-term sustainability, provides sustained development that addresses intra/inter-jurisdictional and national climate change issues, implements internal evaluation components, and effectively uses evaluation feedback. The external evaluator may use the following processes to satisfy the evaluation objectives: interviewing the PI/co-PIs to gain insights into the project planning/implementation and to ascertain the project's anticipated and actual outcomes, on-site observations of project activities, interviews, critiquing the project's internal evaluation processes, and reviewing whether the processes are well-suited for implementation and progress monitoring, identifying project strengths, and making recommendations for improvement. The external evaluator will use some formative evaluation data in the summative evaluation to assess the project's impact.

Formative, process and summative evidence-based evaluation questions will include: In what ways have state and regional high speed network infrastructure and connectivity to multiple institutions improved and enhanced the national networking of research and education enterprises? How have acquisition and support of new computing resources and data handling services resulted in increased scientific competitiveness? In what ways have the modeling and simulation tools established by the project enhanced climate change research? Have the cyberinfrastructure improvement activities resulted in new forms of connectedness, interoperation, and effective participation in national and international projects and virtual organizations? How are the strategy-focused activities contributing to the Consortium's vision for future research and innovation? What significant and measurable value is being added to research capability in S&T areas? What strategies are successfully engaging diverse participation in the STEM enterprise at the state and Consortium levels? What did the annual SWOT (strengths, weaknesses, opportunities, and threats) analysis reveal and how are the weaknesses and threats being addressed with improvements, refinements and proactive changes? What is the evidence of sustainability?

7. Sustainability Plan

Consortium CI development activities will be sustained through three primary mechanisms including: (1) commitments to long-term support by individual states and institutions for Track 2 activities, (2) development of new proposals that make use of and provide continued CI support, and (3) new partnerships. Sustainability efforts are discussed below.

(1) Long-Term State and Institutional Support for Track 2 Activities

Connectivity and bandwidth. Increased connectivity supports the Consortium's efforts to achieve community science, research, and education goals, and adds significant value to each State's existing CI. Consequently, each state plans to maintain and expand upon Track 2 connectivity improvements. In Idaho, connectivity enhancements to the IRON network and the campus LAN improvements are both integral elements of the institutional plans for connectivity and will be maintained by the Idaho institutions and the growing partnerships within the IRON Consortium. Network and video connectivity improvements in Nevada will be sustained by NevadaNet. Likewise, the State of New Mexico will maintain connectivity to the six Tribal colleges and Hispanic-Serving Institutions supported by Track 2 investments.

Model and Data Interoperability Solutions. A key outcome of the Track 2 investments will be the formation of an Idaho Environmental Data Center housed in the Idaho Water Center and sustained by the Idaho Department of Water Resources (IDWR) Information Technology Division. This co-location of the IDWR IT Division and the academic climate change data, HIS data, and Virtual Watershed information from the Idaho Experimental Watershed Network will result in a greater depth of IT support for the state data and will improve communications between state agencies, federal agencies, and the Universities within this Consortium. The state data manager initially funded by Track 2 will be located within the Water Center, and sustained by the University of Idaho. The generic software interoperability framework and other software tools developed in this project will be shared, updated and maintained through the CSDMS model archive (http://csdms.colorado.edu/wiki/index.php/Main_Page). New Mexico data archive enhancements will be integrated into the New Mexico Resource Geographic Information System (RGIS, http://rgis.unm.edu), providing long-term support for the storage and delivery of the developed data products and services via state and USGS funding.

Cyberlearning. Sustainability of cyberlearning components will focus on institutionalization of the activities developed during the project. Collaborative relationships forged during the Track 2 project period will continue, with research teams sponsoring graduate student and postdoctoral associate participation in training workshops and to utilize CI in their collaborations. Consortium institutions will develop CI-enabled training activities that can be adopted into curricula at respective institutions and offered remotely to partner institutions via the Access Grid Network and other CI mechanisms. For example, Nevada (UNR) will develop a graduate level class on Climate Modeling in the Atmospheric Sciences Graduate Program that will be offered to students from partner institutions.

Ensuring sustainability of the cyberlearning materials created for both formal and informal education involves addressing four key issues: (1) producing adaptable, high quality materials; (2) alignment of the materials with the existing science standards; (3) broad availability and dissemination, particularly through web portals; and (4) adoption of resources by schools and school districts. These will be accomplished by connecting materials with schools, initially via the Track 2 teams and extracurricular partnerships, and subsequently by continued use and adaptation by other schools and organizations. All of the Consortium institutions have outreach components through which cyberlearning materials can be distributed. In Nevada, this will involve the Raggio Center for STEM Education on the UNR campus and the Center for Mathematics and Science Education on the UNLV campus. In Idaho, cyberlearning materials can be distributed by programs like Project WET, BoiseWatershed, MOSS, and science centers, as well as through NSF-funded GK-12 partnerships with school districts and the Idaho Teachers Association. Outreach programs in New Mexico include the New Mexico Public Education Department, the Earth's Birthday Project, Santa Fe Institute's GUTS Program, the New Mexico Supercomputing Challenge, and programs associated with the New Mexico Computing Application Center.

(2) Proposal Development and Enhancing Future Competitiveness

Combined, Track 2 investments will enable Consortium participants to partner with each other and with scientists beyond the three states to compete for additional external funding from NSF and other agencies. For example, collaborators develop proposals for funding from NSF's Office for Cyberinfrastructure and various Directorates including the Biological Sciences, Geosciences, Computer and Information Science and Engineering, as well as Cross-cutting Programs. Because the climate change theme also encompasses social and economic impacts, collaborators will also be able to expand their grant-seeking into programs such as Coupled Human and Natural Systems and to submit proposals on Complexity Science and Large-scale Interdisciplinary Research to the Directorate of Social, Behavioral, and Economic Sciences. In addition to NSF, teams will be competitive for NASA's Research Opportunities in Space and Earth Sciences, and the Department of Defense's Broad Agency Announcements for basic and applied research in Environmental Sciences (in particular, Atmospheric Sciences) and Computing and Information Sciences (in particular, Software and Intelligent Systems). Track 2 investments will enable Consortium participants to use CI for education and training. This will enable collaborators to become more competitive in proposals to education-oriented programs, such as the NSF IGERT and GK-12 programs, Scholarships for STEM, and STEM Talent Expansion Programs.

(3) New Partnerships

Sustainability will be fostered by creation of new partnerships and collaborations (e.g., CSDMS, NCAR, National Laboratories, state, and federal agencies) that result from the project activities. CI investments will also facilitate growing collaborations with researchers at the Pacific Northwest Laboratory, University of Washington Climate Impacts Group, and Washington State University Laboratory for Atmospheric Research, all of which are working on climate change in the Pacific Northwest. The proposed hydrologic information systems (HIS) servers and databases for point observations will make the Consortium states among the first members of the new CUASHI Water Data Federation. This relationship with the NSF-sponsored CUAHSI will serve to help facilitate long term use and advancement of the system.

Milestones for Sustainability. By the end of the project these key milestones will be met:

- All proposed connectivity and bandwidth improvements will maintained by identified state entities.
- The Idaho Environmental Data Center will be situated in and maintained by the IDWR.
- The Idaho State Data Manager will be fully funded and institutionalized by the UI.
- The software interoperability framework and other software tools will be shared, updated, and maintained by CSDMS.

- The NM data archive enhancements will be integrated into the NM RGIS.
- All states will incorporate sponsorship of graduate students and postdoctoral associates in CI training and utilization.
- All states will develop CI-enabled training activities for use in curricula
- UNR will develop a graduate level class on Climate Modeling.
- Cyberlearning materials developed will be distributed through existing state outreach mechanisms.
- Collaborative proposals will be submitted to NSF and other funding agencies.
- New partnerships will begin in year 1, and firmly in place by the end of the project.

8. Management and Coordination Plan

The Consortium's management and coordination plan draws on the strengths of each state's EPSCoR program structure. There are four primary elements of the Consortium's CI management structure: (1) State Committees, (2) EPSCoR offices and Management Team, (3) CI Component Teams, and (4) evaluation and assessment (Figure 5). The Consortium management and coordination plan also includes a postdoctoral mentoring plan and coordination mechanisms.

8.1 Project Management Structure and Functional Roles of Components

State EPSCoR Committees. A State Committee that includes members from community, government, private, and academic sectors from all regions of their respective states oversees each state's EPSCoR program. State Committees are a catalyst for integrating academic research capacity with state S&T plans and priorities.

Idaho's 18-member State Committee establishes policies, criteria, and procedures necessary to ensure that EPSCoR goals and objectives are met including to (1) guide and coordinate the state effort under federal-wide EPSCoR; (2) exercise quality control through the use of external reviewers; and (3) ensure that research supported under EPSCoR is consistent with state economic, human resource development, and S&T strategies. It also oversees the business of the Idaho EPSCoR office and monitors the selection, progress, and implementation of the EPSCoR-like programs in the State.

Nevada's 12-member EPSCoR Advisory Committee advises the State EPSCoR Director on strategic directions for sustained health and growth of Nevada's EPSCoR programs; connects science and technology advancements to an educated workforce, and ensures economic development and diversification; supports and assists in the development of science and technology in the State of Nevada, including education, research, and technology transfer; and informs legislators, businesses, committees, associations, and other interested parties about the importance of EPSCoR in Nevada and the critical role science and technology play in economic development.

New Mexico's EPSCoR Committee is the primary governing body for NM EPSCoR. It recommends the focus areas for NM EPSCoR; assists EPSCoR in enhancing the state's research infrastructure through partnerships with universities, national laboratories, and industry; promotes research and collaboration among the NM universities; increases opportunities for K-graduate education and training; helps develop the state workforce of scientists and engineers; and promotes economic development.

State EPSCoR Offices and Management Team. A strong basis for effective management of the Consortium is rooted in the collaboration created in 2008 by ID, NV, and NM in their RII Track 1 climate change programs. The Track 2 Management Team will be led by the three state Project Directors: Dr. Greg Bohach (ID), Dr. Gayle Dana (NV), and Dr. William Michener (NM), with administrative coordination and outreach assistance from their state EPSCoR office staff. Because Nevada is the lead organization, Dr. Dana will be the Lead PI and primary Consortium liaison with NSF. The PIs will be responsible for overall project management, budgetary and reporting oversight, and ensuring evaluation and assessment requirements are met. One PI/Co-PI will Chair the Management Team, with the Chair rotating annually. The Chair will ensure that interjurisdictional meetings and activities are scheduled and implemented. EPSCoR office staff of each state will provide web, editing, and communications support for the project.

CI Component Teams. Each project component has an overall faculty lead to ensure component goals and objectives are met: Dr. Fred Harris (NV) for Connectivity/Bandwidth; Dr. Karl Benedict (NM) for Model/Data Interoperability; and Dr. Katherine Mitchell (NM) for Cyberlearning. State faculty leads are also identified to oversee state-specific component activities. Each state will assign an individual to serve as a CI program coordinator and assist with the day-to-day management of the Consortium's activities.

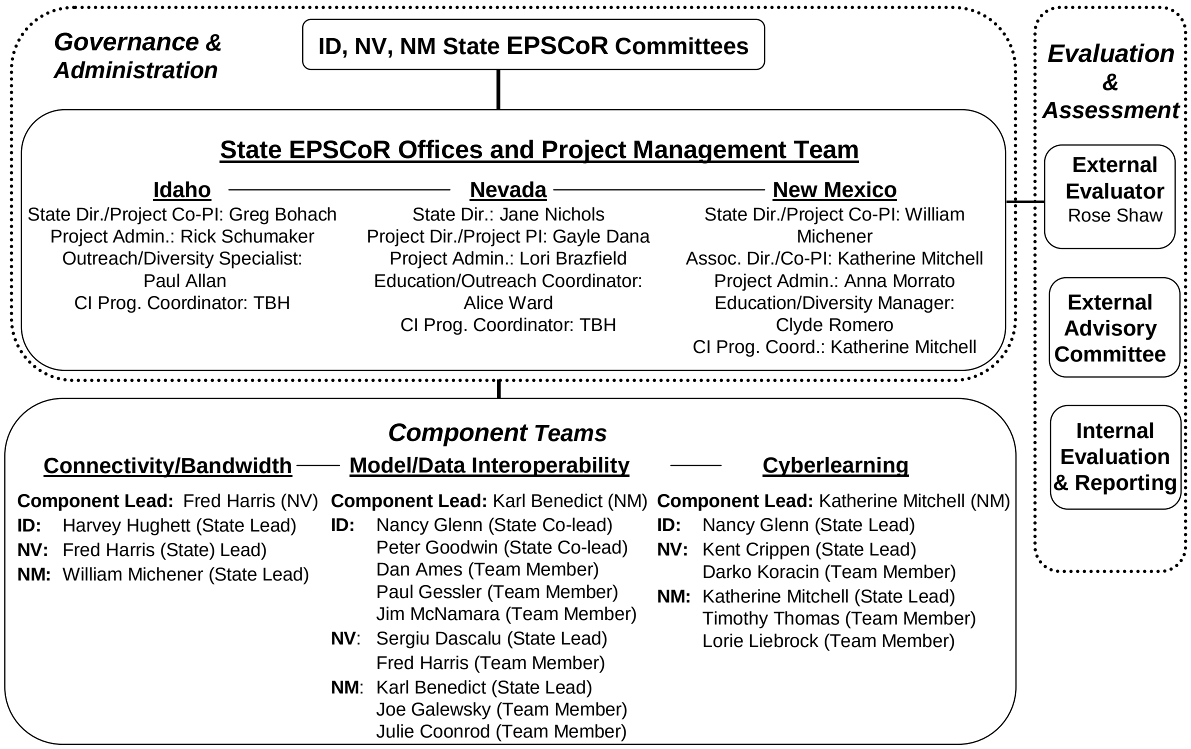

Figure 5: Organizational Chart

Evaluation and Assessment. The Management team will work in concert with the External Evaluator (Dr. Rose Shaw), an External Advisory Committee, and Internal Evaluation to monitor how well the project is moving towards its goals. The External Advisory Committee (EAC) and External Evaluator will interact with researchers and their coworkers as well as the Management Team by attending the annual meeting held in rotating state locations. The EAC will (1) review progress toward achieving outcomes of the projects; (2) make constructive suggestions for improving and/or changing the direction of the work underway; and (3) advise the Management Team. Committee members have been selected to ensure that internationally and nationally recognized experts will review the subject areas.

Western Consortium External Advisory Committee Members

Dr. Francine Berman	University of California, San Diego
Dr. Kelvin Droegemeier	University of Oklahoma
Dr. Jordan Powers	National Center for Atmospheric Research
Dr. Robert Sherwood	Indiana University, Bloomington
Dr. Henry Neeman	University of Oklahoma
Dr. David Tarboton	Utah State University
Dr. Janice Gobert	Worchester Polytechnic Institute
Dr. Alan Hevner	University of South Florida

Postdoctoral Mentoring Plan. The Consortium has adopted a theme of inclusion and engagement for mentoring of postdoctoral associates. Mentoring will include early career development such as cultivating professional networks, guidance on teaching, engagement in outreach, and participation in learning materials development. They will also receive training in grantsmanship, manuscript preparation, and responsible conduct of research. In particular, Consortium postdoctoral associates will participate in the annual week-long New Mexico Faculty Leadership Program where they will learn project management, leadership, communication, and related skills from internationally recognized experts. Climate change science and CI cross many disciplines; therefore, postdoctoral associates will be integrated into the CI and climate change teams, where they will learn interdisciplinary collaboration via active engagement with professionals from other disciplines.

Under the guidance of senior faculty members, postdoctoral associates will also be involved in organizing scientific forums (conferences, workshops, and/or symposia) and reviewing related research work submitted to these forums. In addition, the postdoctoral associates will work jointly with their advisors to publish research papers and will deliver presentations at national conferences. Postdoctoral associates will also be trained by faculty members to mentor graduate students involved in the project.

8.2 Coordination Mechanisms

Integration of cross-jurisdictional and cross-disciplinary science will be coordinated via several mechanisms that are described in more detail in the Dissemination and Communication Plan. These mechanisms include collaboration enabled by annual tri-state CI meetings, BaseCamp, and Adobe Connect Professional online meetings. The Management Team will review the progress of the project semiannually. With the advice of the EAC, the Management Team will take corrective actions as necessary to ensure successful attainment of the project's goals. The lead PIs will also meet several times a year at the NSF EPSCoR Project Director and National meetings. Lead PIs will meet monthly via Adobe Connect to discuss project management and progress. Project coordinators will participate in bi-weekly online video and/or teleconferences to ensure effective coordination of project details.

Management and coordination mechanisms appear in the budget as travel costs for participants, and material and supply costs for the state hosting the annual CI Consortium meetings; travel and honoraria for External Advisory Committee annual site visits; and Adobe Connect service costs for NV. BaseCamp is provided by UNM's Earth Data Analysis Center at no cost to the Consortium. Travel costs for the PDs to attend NSF EPSCoR PD and National EPSCoR meetings are covered in each state's Track 1 budget.

9. Conclusion: Intellectual Merit and Broader Impacts

9.1 Intellectual Merit. In the Western U.S., climate change impacts may be especially pronounced due to the tight coupling between climate and regional hydrology, and its ramifications for the water supply, disturbance regimes (e.g., fire, drought), the region's economy, and quality of life. The proposed cyberinfrastructure developments will enable atmospheric scientists, climatologists, hydrologists, engineers, social scientists, economists, and others to more effectively share standardized and interoperable data and models, and to more easily develop regionally coupled atmosphere-land surface-hydrology-socioeconomic models. Enhanced connectivity to research universities, Tribal colleges, regional universities, field stations, and other academic organizations will have broad-ranging impact on research and education enterprises throughout the Consortium. Our institutions and states will be linked to more than 200 other Internet2 universities, government research laboratories, companies, and many research facilities throughout the world, facilitating data-intensive research, collaborative development, distributed experiments, grid-based data analysis, and experimentation using high performance networking, social networking, and cyber-enabled learning. Community science will be enabled by the shared capabilities for model interoperability, data assimilation, analysis, and visualization that will be developed by the Consortium. Most importantly, the combined improvements in connectivity and enhanced interoperability and accessibility of data and models will enable the Consortium to realize its community science objectives, and to participate in national and international virtual organizations that work to solve problems associated with global climate change.

9.2 Broader Impacts. From its inception, the proposed CI investments in the Consortium were designed to achieve broad impact and to add value by leveraging existing resources and infrastructure within the institutions, jurisdictions, and regions. The institutions that will benefit from increased connectivity include rural institutions and those that serve Hispanic and Native American students and faculty. Open access to the data and models developed within the Consortium and made available through the data archive and the model interoperability framework ensure that scientific products can be broadly disseminated and readily used by scientists, engineers, and students throughout the world. Moreover, the project will make usable high-quality environmental data, information, and models available for STEM education and outreach, including classroom and laboratory use and student research. The Consortium's education programs will have far-reaching impact by: (1) developing new CI skills and climate modeling expertise for students, postdoctoral associates, and faculty; (2) integrating cyberlearning and climate change science into middle and high school education, especially targeting rural schools and schools that reach large numbers of Hispanic and Native American students; and (3) developing an Industry CI Days Program that increases awareness of emerging CI technologies among business and industry representatives.