Report of the NSF EPSCoR Tri-State Cyberinfrastructure Project (Track 2) External Advisory Committee (EAC)

Year 3 Review
Conducted February 23, 2012
Inn and Spa at Loretto, Santa Fe, New Mexico

Introduction and General Findings/Recommendations

The External Advisory Committee (EAC) for the NSF EPSCoR Tri-State Cyberinfrastructure Project (Track 2) (TSCP) met on February 23, 2012 with project leaders and participants to review the effort. The meeting was held in the Inn and Spa at Loretto in Santa Fe, NM and was hosted by the New Mexico EPSCoR office. The EAC appreciates the opportunity to improve the project by providing feedback on its activities and directions. Through this report, the EAC offers its comments on, questions of, and recommendations to the Tri-State Cyberinfrastructure Project (Track 2). This summary begins with general findings, then addresses the three areas of the TSCP activity: (1) connectivity, (2) model and data interoperability, and (3) cyberlearning. TSCP personnel provided updates on each area in their EAC review meeting presentations. The presentations concluded with the plans to sustain project efforts after current EPSCoR funding ends in 2012.

The EAC first notes that the level of activity that the TSCP has stimulated to date is impressive. The three states, Idaho, Nevada, and New Mexico, have benefited greatly from the project, and the effort has been effective in leveraging Track 1 and other sources of funding. The project has excellent leadership and organization. As has been seen in previous years, the production of the review meeting and the presentations are clear evidence of this.

Immediately below are general recommendations of the EAC, applying across all three of the TSCP activity areas. The sections that follow address the focus areas individually.

1) Track 2 Final Year Wrap-Up

The TSCP is in the final year of its funded activities. It will be important for the project to bring its varied activities to clear conclusions with well-defined and tangible deliverables. Recommendations on how best to complete various project activities and deliverables will be provided in each of the three sections below. The EAC encourages the TSCP to consider another Track 2 application if and when the NSF again funds this initiative.

2) New External Evaluator

The EAC was impressed with the value added to the project by the change of the external evaluator, Lisa Kohne. The new measurement design and instruments have provided both structure and a formalized timescale for gathering important metrics that the project had been previously lacking. The new evaluator has clearly helped the TSCP leadership clarify desired project outcomes and put into place mechanisms for measuring progress toward them. The Track 2 EPSCoR Logic Model shows the goals, inputs, outputs, and outcomes of the project clearly

presented on a single page. We also note that the "Example Impacts Response" in Lisa's presentation, responds exactly to the committee's recommendations last year about gathering evidence of impact.

The four quarterly evaluation reports provided to the EAC are extensive and include well-defined data collection activities for all three areas of the project. Current and future evaluation plans and metrics are in place to track progress toward the completion of the project.

3) Intellectual Merit Results

The original Track 2 proposal made claims to develop a three-state cyberinfrastructure that would enable new collaborative research on climate. The proposal discussed linking atmosphere, surface, hydro, and socio-economic models into an integrated research platform. However, the committee questions whether this has been accomplished fully. It does recognize that the research results of the project are hard to quantify. Also, it is difficult to separate the research results in the related Track 1 and Track 2 projects. The committee presented research in progress towards these goals at the advisory board meeting (via graduate theses, etc.), and the group should include details about the various research projects in their final report.

The latest data on research publications and proposals are found in the June 2011 TSCP Year 2 Annual Report, which is not fully up-to-date for the EAC's current review. The EAC recommends that an effort be made to clearly report and justify the research contributions (intellectual merit) of the three-year TSCP Track 2 project.

> **Response:** We will pay particular attention to detailing the intellectual merit of the Track 2 project in the upcoming annual report to NSF.

4) Broader Impact Results

The EAC recognizes the significant efforts over the past year to demonstrate the impacts of the project to the broader communities of researchers, educators, and the general public. The new evaluation design focuses on both quantitative and qualitative data gathered from the users of the cyberinfrastructure, the modeling interfaces, and the educational programs. A side benefit of TSCP's efforts to collect data on impact is that it is encouraging the project clientele to think more broadly and take a longer-term view about their own aspirations.

In particular, survey instruments are being used to collect evidence on the impact of project activities. Additionally, qualitative data is being gathered in the form of quotations from program participants and success stories of use of the cyberinfrastructure platforms and educational programs. Current and future uses of outreach platforms, such as the videos being produced at UNLV, hold promise for sustaining the momentum of the project.

In the previous report, the EAC praised and encouraged the use of Innovation Working Groups (IWGs). During the past year, the project sponsored several successful IWGs. In particular, the EAC notes the Increasing the Diversity of the Western Tri-State Consortium IWG, which has led to a Tri-State diversity strategic plan and standing committee on diversity issues.

5) Awareness of Project Resources

The project has produced a significant set of resources for researchers, educators, and other potential users. The EAC believes that users should be made more aware of these resources and that use measures should be defined. One idea, for example, would be to develop a portal with Likert scale questions to have people enter data on usage. Some useful, but easy, open-ended questions can also be provided. The project PIs, for example, can send an email to all project members asking them to fill this questionnaire out 3–4 times per year. The resulting use statistics will demonstrate what resources are being used and by whom. These data would be very useful and could potentially seed other proposals. For example, say a particular visualization tool is being widely used: it might lead to a new proposal involving that tool. The project should keep track of new adopters, and possibly develop a login process for this. It would also be good to track use data on new adopters.

> **Response**: The evaluator has been working with the interoperability team members and developed a user survey, which is posted on the Nevada, New Mexico, and Idaho Data Portal webpages. Users are encouraged to complete this survey after they access Data Portal resources. Additionally, the data portals will be introduced to Tri-state Consortium participants. Data Portal developers will conduct a workshop in which participants use a data portal and complete the user survey. The evaluator will compile and analyze the results and report them to the data portal developers.

The EAC feels that that the involved universities should do some basic advertising to be sure research administrators, current faculty, new faculty, etc., know about the portals and what they offer. The TSCP universities really do have a vested interest in informing/reminding their faculty about this, pointing to capabilities that have been developed, thanks to NSF EPSCoR funding, to make the states more competitive.

> **Response**: The Tri-State CI Team will develop a coordinated plan to perform outreach within each of our respective states to better advertise the capabilities for data management, discovery, and access that have been developed under the auspices of the EPSCoR Track 1 and 2 programs. This plan will include both the content to be delivered, the methods of communication, and identified target communities for the information. A key component of this plan will be data portal training for potential users, including targeted training sessions throughout the remainder of the Track 2 project, also looking at opportunities for high-impact training through the end of the Track 1 project.

6) Sustainability of Track 2 Activities

TSCP leadership has, rightly, turned its focus to the long-term sustainability of the EPSCOR investment. The EAC believes that the project has a strong plan for sustaining its programs and cyberinfrastructure (CI) across the three states after the project winds down this year. Sustainability efforts are being planned for the TSCP areas of connectivity, model and data interoperability, and cyberlearning. On the aim of project sustainability, the EAC comments as follows:

- There is no doubt that the project has been successful in forging new collaborations in the three states. The EAC commends the TSCP for proactively addressing the challenge of

maintaining these partnerships and activities. The idea of charging individual groups (e.g., the interdisciplinary modeling course) to develop models for sustaining their own activities is particularly creative.

- One significant advance from the TSCP is a new transparency and coordination of state-level EPSCoR efforts. Examples are the development of the "academic/political landscapes" charts showing each state's organization of its activities, the plans to continue tri-state IWGs and diversity planning, and the development of a new, more coordinated approach on Track 1 proposals.

- It is a positive that NM opened slots in their Junior Faculty Leadership program to other states. In addition to enhancing the skillsets of junior faculty and helping them understand what is needed to build a successful research program, this creates new opportunities for developing inter-state collaborations.

- The annual Tri-State Meetings have become a notable success, with over 200 participants anticipated for the April 2012 meeting. The EAC believes that this meeting has momentum and will continue.

- It is promising that some of the Track 2 activities will be incorporated in Track 1 projects by the states.

- The potential of a collaborative Track 1 proposal is intriguing.

- Discussions with other Western states for future collaboration in areas of the areas of interoperability and cyberlearning are encouraged.

Connectivity

The TSCP has yielded substantial improvements in connectivity for all three states, varying in scale from individual sites to statewide. The TSCP team reported that all of the connectivity components have now been deployed. In the previous (Year 2) EAC report only two sites remained (Hagerman and Kimberly), and these have now been completed.

The EAC was pleased to see that the project's agenda was structured to frontload the connectivity deployments and that this is now complete and is serving the connectivity needs of the tri-state users. In some cases use has already exceeded former capacities. The focus of connectivity activities is centered on documenting the use and impact of improved connectivity in enhancing productivity. While it is easy to document use (i.e., "If you build it, they will come"), it is more challenging to quantify the long-term scientific outcomes. It is encouraging to see the team focusing on this, although the answers are not yet clear.

The Year 2 EAC report stated:

> "Now that the connectivity improvements are in place, the central task for physical CI is to establish its value to the tri-state STEM research enterprise. Doing so will require identifying metrics that clearly depict not only how the physical CI has improved research productivity, but especially, how it has given rise to new research capabilities and outcomes that were not possible before this deployment. For example, traditional network usage statistics are not particularly compelling as metrics for this project. Knowing aggregate data transfer rates before and after deployment is not necessarily a useful indicator of better science being enabled. The TSCP team should develop metrics that are more clearly related to the program goals of enabling research and of the integration of research into education."

The EAC applauds the accomplishments of the TSCP team with respect to collecting qualitative data in the form of specific use cases of the physical CI and the impact of the CI on those specific research and education endeavors. These use cases complement connectivity consumption data, which by itself is of limited value.

The EAC recommends pursuing additional forms of quantitative data to feature alongside the consumption and use case data. Possibilities are subnet analysis, measures of usage of specific connectivity-enabled capabilities (e.g., videoconferencing between specific sites), and impact headcounts (e.g., numbers of undergraduates, graduate students, postdocs, faculty, staff, K-12 teachers/students, etc., who have participated in the activities enabled by the physical CI).

> **Response:** The connectivity leads will meet with systems administrators to brainstorm ideas for pursuing additional forms of data. The evaluator will work with the connectivity lead to develop metrics and provide headcount data.

The project team should continue to clarify the broader impacts of the connectivity in all three states. The Year 2 EAC report stated:

> "A potentially useful approach would be for the team to request at least a few sites (e.g., the McCall site) to log the events where the CI was used for specific group activities, as opposed to general access to the Internet for individual use. The sites should be encouraged to provide testimonials of usage, such as: "We couldn't have gotten specialist X to participate in the workshop without the new CI capabilities.", or "This helped me carry out task Y, which previously I couldn't do." Do this longitudinally: for relevant STEM research and/or education teams, get near term responses at the event— What might you accomplish?— and then follow up a year or two later to see what they actually accomplished."

The accomplishments noted in the connectivity presentation were much in this spirit. The EAC was pleased to see this.

The Year 2 EAC report suggested:

> "At the TSCP annual meeting, conduct a CI usage survey to identify which groups and individual researchers are exploiting the CI, how they're exploiting it, and to what effect. To improve the response rate, withhold swag until they submit their completed survey."

The EAC did not see information on whether this had been done. The committee thus encourages the TSCP to use opportunities at upcoming meetings to gather survey information on CI usage and needs that may help identify worthwhile future CI capabilities to pursue.

> **Response:** The evaluator will work with the connectivity lead to develop this survey, which will be conducted at the Tri-state Consortium. The evaluator will include questions to assess additional cyberinfrastructure, connectivity, and interoperability needs.

The Year 2 EAC report also asked:

> "First, how sustainable is this effort? Will the infrastructure be supportable after the project with known funding or planned efforts to get sustaining funding? Second, is additional capability (e.g., bandwidth) already needed and/or anticipated?"

The EAC was pleased to see that the connectivity infrastructure seems to be on a sustainable path in that it has been assimilated into existing facilities. The committee reminds the TSCP to be aware, however, that network demand will increase. Thus, there is an ongoing need to look ahead to fill these needs and to gather data to support the requests to facilitate this.

Model and Data Interoperability

The EAC commends the TSCP on incorporating widespread standards for catalog services, metadata, data, map images, and web services. This not only facilitates current research and educational use of the data, but also gives the three states a strong foundation for smoothing transitions as new standards emerge (as one would expect a straightforward path from today's to tomorrow's standards).

> **Response:** The Tri-State interoperabilty plan continues to expand its plans to integrate appropriate interoperable protocols and standards into the published web services as appropriate. In addition to the highlighted OGC standards that have provided the interoperable core of the project, there are ongoing development efforts to develop or expand robust CUAHSI HIS services for some data being generated by the Tri-State consortium, and DataOne member nodes in ID and NM.

The ISO metadata standard is used to identify collections that might merit special treatment. The committee understands that the intent is to replicate metadata in the three states to improve search performance or, possibly, to mirror data in particularly high demand. The standard is also used to record and manage multiple versions of data. (In general, previous versions of a data object are maintained intact, in part to support reproducibility.) The idea of selective replication is a good one.

Response: Yes, the committee's understanding is correct. The intent is for full metadata replication between all three states, with the plan for data replication focusing on specific targeted data products that are identified by each state. When data are replicated between states, the developed ISO metadata model will allow for the maintenance of an authoritative metadata record that remains with the associated source data product, while the replicating states will host ISO metadata components that provide supplementary information about the replicas relating to replica contact information, available service, and download options. The master metadata record will include (by reference) the ISO metadata components hosted by the replicating states. With this model, a fully resolved metadata record may be generated based upon the master record and the linked components.

The committee understands the desire to develop graphical tools to couple models, but it questions the approach taken. One question concerns building yet another coupler when other, developed capabilities exist that have support groups and user bases. Coupling software capable of linking WRF to other models includes MCEL (Model Coupling Environmental Laboratory), MCT (Model Coupling Toolkit), and the ESMF (Earth System Modeling Framework). The committee questions why extant packages such as these have not been used. It seems a dubious use of limited NSF money to re-invent this software, which the public has, to varying extents, already paid for. If the "graphical" element is a distinction, why is that aspect critical? Have the user communities of WRF and the other candidate models been surveyed to determine the need for new coupling software, and if so, have user community requirements for this been gathered? If a new coupler is developed, how will the case be made to potential users that the framework is more efficient, or robust, or otherwise better than ones that have received substantial resources over many years?

A further question on the new capability is how it will be kept vibrant and up-to-date as the component models and computing environments (e.g., compilers, hardware) evolve. This encompasses, in part, a committee concern with how an effort based on the work of a student will be supported long-term. While the committee understands that it's important for CS grad students to do something new and different, that doesn't make it the best path in terms of the interests of the future user community or of the consumption of EPSCoR funds.

Response: Regarding the EAC's concern about re-inventing existing software for model coupling, our approach has been not to rewrite solutions already completed elsewhere but to extend them and provide new capabilities and features that they do not currently offer. Having examined the more prominent model coupling software systems, including MCT and ESMF, some of their limitations have been identified. In particular, most of these coupling systems are API-based, lack user interfaces to simplify user interaction, require writing code in specific programming languages, and have limited or no web-enabled development capabilities. In our approach we aim at providing software with user-friendly graphical interfaces and more flexible web-enabled data structuring and processing capabilities (while also allowing more advanced users to integrate their own scripts in their modeling and data processing scenarios). To some extent, our software is not a traditional model coupling framework, as it incorporates functions that can be used by scientists from various domains to perform data-related activities not necessarily pertaining to model coupling.

The graphical aspects of the user interface are indeed important to us. As indicated in the proposal submitted to NSF in 2009, we planned to design and implement software solutions focused on user-interface and human-computer interaction aspects. A major reason for this is that a graphical user interface significantly increases the number of users that can utilize a system over a command-line or code-based control system (mainly because less specialized computer knowledge is required) and, in general, can speed up the process of configuring and running a software application. Such interfaces reduce the learning time and help prevent and correct user errors. This, in turn, can increase the productivity of the users by allowing them to focus on the scientific aspects of their work rather than on coding.
To identify requirements for our software we have conferred with potential users and consulted partners from the Tri-State Western Consortium. The bulk of the requirements, however, have been developed by surveying the field of model coupling software frameworks and noting their strengths and weaknesses (and trying to address some of the latter). Certainly, we have taken notice of the EAC's specific comments on this point and will extend collecting requirements from the user community and incorporate them in our solutions. We have started a series of workshops focused on Tri-State data portals in which we will include demos of the newly developed software. Furthermore, we will include a user survey on our portal and will ask user community members to provide feedback on our work. Presentations at conferences will also be made to disseminate our results and elicit additional feedback.

We also have taken notice of the EAC's other remarks and we will demonstrate that the framework, which is also part of a PhD student's work, has additional or better capabilities than existing software systems. This will be done through comparisons with existing frameworks that will include feature-based evaluations and user testing and feedback.

To keep the software developed up-to-date we will document it properly and make it open source, allowing developers and users to contribute to it and improve it over the years. The software will also be deployed on the Nevada Climate Change Portal and made available to the community of users. Furthermore, we have communicated with CSDMS and plan to contribute our software to their repository.

The committee was a bit surprised that there is no requirement for the climate researchers funded under the TSCP to make their data available through the data portal. We encourage the TSCP leadership to "turn up the heat" on these groups to do so. It will look much better for them and the TSCP to show a clear connection: to show that a key aspect of the effort is really helping science. The committee also suggests including such requirements as part of future proposals.

Response: The direct data ingest model adopted by Nevada in developing their instrumentation transects has proven very effective in minimizing the delay in transferring obtained from those system. New Mexico and Idaho's current models of working with the researchers to integrate the data into the respective data portals is making slow, but measurable progress, and lessons learned from the current project will be captured and integrated into planning for the development of future data management and access CI.

Cyberlearning

As has been mentioned in the general comments of this report, the new evaluator has provided the project greater focus with regard to measuring perceived outcomes at university-level workshops, seminars, and conferences. Written instruments have made use of Likert scales that generally showed positive results in terms of the usefulness and effectiveness of the activities. The extended list of open-ended question responses was useful to provide additional information about the activities.

The pre-college activities continue to mature at different rates in the three states. The approach to evaluate the results of these projects was reasonably designed, focusing again on perceived effectiveness of the curricular materials and/or activities.

When the TSCP prepares its annual report, the EAC suggests that the following items be included or addressed:

- Gather data from workshop attendees with questions such as: "What has this allowed you to do that you could not do before? Be specific."

  Response: This question is already being included in all evaluation instruments.

- In the development of educational materials, describe how construct-centered design was used.

  Response: Construct-centered design was not explicitly used in the development of the educational materials. The development groups used a variety of pedagogical approaches. For example, NV C4D used a single pedagogical structure (5 DIE) as the foundation of their educational materials, which employed innovative uses of various technologies to highlight regional impacts of climate change. The 5-DIE format is inquiry-centered, rather than construct (or concept)-centered. In NM, GUTS is grounded in research on how simulations and computer modeling promote understanding of patterns and processes (key constructs) and develops higher order thinking and problem-solving skills. Similar to NV, GUTS has applied innovative technologies (agent-based modeling) to climate science. The MST teachers employ various approaches, based on their experience and understanding of pedagogical principles developed in their undergraduate work. The focus of the MST program is on developing science understanding, not developing specific pedagogical approaches or structures. In summary, we've been focused on addressing the Track 2 objective "to utilize cyberinfrastructure to integrate research with education to improve learning" without constriction of one pedagogical model. Furthermore, our group feels strongly the importance of continuing to follow the model that was designed as a way of thinking about science inquiry. It aligns with our goals and how instruction is delivered.

  With that said, there are many similarities between what we used and the construct-centered approach. As one example, the 5-DIE framework formalizes both the student experience as well as the teachers' development of materials. Although this approach is still under investigation, the framework has been developed as a result of an extensive review of the literature on scientific inquiry (Carroll, Crippen, Kern, & Ebert, in preparation). Further, curriculum development within 5-DIE is sequential and roughly

follows the steps outlined in the construct-centered approach. Overall, the materials are delivered from the following features:

Big Question:
1) Your initial ideas
2) Explore the evidence
3) Your scientific claims
4) The science related to the big question
5) Research council (share ideas)

For informational purposes, the evaluator provided the Cyberlearning lead with a short summary and design process of construct-centered design (http://assessment-ws.wikispaces.com/file/view/CCD_summary.pdf). The evaluator encourages all curriculum developers to identify and utilize a research-based design process that incorporates construct centered design methods.

- Make a list of the materials that have been developed, their target knowledge and skills, and their audiences (e.g., middle school, high school, undergraduate education, graduate education, or research resources, tools, etc.). In terms of usage, please gather precise data here and report it.

  Response: Creating a comprehensive list of developed materials with details specified above is an excellent idea and will be included in the final report.

- For *each* objective listed in the summary slide, be sure to address exactly what progress has been toward each objective (as it is a bit difficult to map some deliverables onto objectives).

  Response: This information will be provided in the final report. As clarification, as of February 2012, all objectives (Offer and support CI training in computation and climate change; Develop and disseminate educational materials for middle/high school; Develop and support extracurricular CI activities; Design/coordinate/advertise/deliver Industry CI Days Program) are nearly complete. For the remaining 6 months of the project, we are focusing on sustainability and cross-state collaborations for many of these activities.

Summary

The EAC commends the TSCP leaders and personnel on a good, productive effort to date. The project has continued to stimulate a great deal of activity, to generate capabilities, and to yield advancements for the partner states. All of this appears to make the three states more competitive, as per the overall EPSCoR goals. The EAC finds the broader impacts of the project to be significant in all three focus areas. The connectivity aims of the project have materialized, and will support elements of the other program areas. The data component has a solid foundation and tangible developments in the portals created to date, while the modeling component would benefit from a bit of clarification and from the actual realization of the proposed capabilities and consequent research. Cyberlearning is benefiting from the investment and, over the past year, the capacity to evaluate the impacts has been improved. The research (intellectual merit) achievements of the project should be more clearly presented and justified as the project nears a

conclusion. The EAC thanks the TSCP and EPSCoR for the opportunity to guide and improve the effort for the most efficient and productive use of NSF funds.

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