Review and Guidance to the Utah Experimental Program to Stimulate Competitive Research (UT EPSCoR)

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Executive Summary

This report includes the findings and recommendations by a review panel convened by the American Association for the Advancement of Science (AAAS). The AAAS Research Competitiveness Program was requested by the Utah Experimental Program to Stimulate Competitive Research (Utah EPSCoR or "innovative Urban Transitions and Arid-region Hydrosustainability – iUTAH") to provide review and guidance on its Research Infrastructure Improvement (RII-Track 1) award from the NSF. The Track 1 award is a $20 million, five-year cooperative agreement (2013 – 2018) with the National Science Foundation.

iUTAH's broader program goals are to improve water-related science and technology infrastructure in Utah; improve the state's research competitiveness; and further develop the workforce in areas of research, education, and practice – thereby promoting sustainable economic development. This effort consists of a state-wide collaboration with nine Utah institutions of higher education and involves faculty, students, and staff as well as professionals from State agencies and non-profit organizations.

It is clear to the panel that iUTAH has generated very positive initial results and that considerable momentum is being built. There are ample opportunities for synthesis across program elements that can lead to demonstrable impacts in research competitiveness and broader societal relevance in the following three Research Focus Areas: (RFA 1) Improve Utah's capacity to monitor and understand the ecohydrologic system of the Wasatch Range Metropolitan Area, (RFA 2) Improve the capacity of Utah's science community to gather and analyze social and engineering system data on coupled water systems, and (RFA 3) Describe the water system as a whole, by defining and including the linkages between biophysical and social dynamics, using results from RFAs 1 and 2.

The AAAS panel offers the following recommendations to build on the program's momentum and to enable maximal success:

- With the imminent departure of the PI and the State EPSCoR director, the transition to new leadership potentially exposes iUTAH to potential loss of program momentum and important and useful contacts at the State level and at NSF, inter-campus rivalries, and decreased stakeholder engagement. The leadership structure could be made more transparent, and with less conflicting management reporting and accountability lines. The specific roles of the Project Director, the Project Manager, the Leadership Team and the Management Team should be redefined to reflect current and forward-looking management plans. The proposed new Project Director should be relieved of other major leadership positions in the focus areas to allow the time and energy needed to take on program-level responsibilities.

- The panel recommends that the RFA1 team estimate the annual cost of maintaining the GAMUT (Gradients Along Mountain to Urban Transitions) system after the Track I EPSCoR funding ends. This would include the cost of field staff and equipment and the costs of maintaining the database and web portals that make the data available. It also includes the cost of implementing QA/QC procedures. Identifying this total annual cost is the first step to planning for sustainability and looking for funding sources.

- A decision should be made soon on whether or not to build the GIRF (Green Infrastructure Research Facility) and if so, for what specific purposes. The question is in part a budget issue. The GIRN (Green Infrastructure Research Network), which has considerable potential, may require resources that could be given up by the GIRF. Some thought has been given to the potential relationship between the GIRF and GIRN, but the relationship is still not clear to the panel. Moreover, it is difficult to recommend whether or not to build the GIRF and/or the GIRN based on the information received to date.

- The panel agrees that the high-tech "Situation Room" does not appear to be the best investment for stakeholder engagement. This is because 1) it does not allow flexibility of location; 2) it would

incorporate a level of technology that will likely far exceed the need of the types of interactive decision-making that are planned for this project; 3) there is not a plan for continued use and maintenance of the room after the first 5-years, and 4) there appear to be more cost-effective alternatives. There is value of having group visualization sessions with stakeholders to explore scenarios because the group dynamic adds to the benefits obtained from the scenario exploration process. This could be accomplished using sharable laptops or other mobile devices coupled with an inexpensive data projector that can be used for improving the effectiveness of collaborative processes at any location.

- To obtain the potential benefits associated with the use of visualization technology, users of this technology should have some basic skills. iUTAH may need to assess (and if appropriate offer some training in) stakeholder visual literacy and cognitive processes, multiple-user visualization design process, visualization tool expertise, applying these tools to achieve effective visualization products, and publishing with an iterative feedback cycle when appropriate. Having those skills will help build professional competence and confidence in hardware and software tools acquisition. As opportunities for pursuing improved visualization processes are identified, iUTAH should continue to evolve the conceptual model they have already developed, as a process that documents the system framework, suggests meaningful linkages, and generates hypotheses worthy of scientific exploration.

- The panel recommends that consideration be given to redirecting some cyber-infrastructure resources in the coming years to developing successful visualization tools.

- And finally, EOD activities that began in the summer of 2013 should be intensified (ensuring greater participation) and extended (developing additional activities). The summer institute (high school) and REU (undergrad) should be geared towards directly contributing to RFA 1, 2, and 3. EOD should not be standalone activities, but better integrated, articulated and strengthened.

Contents

I. Introduction

This report includes the findings and recommendations by a review panel convened by the American Association for the Advancement of Science (AAAS). The Utah Experimental Program to Stimulate Competitive Research (Utah EPSCoR or "innovative Urban Transitions and Arid-region Hydrosustainability – iUTAH") asked the AAAS Research Competitiveness Program to review and offer guidance on its Research Infrastructure Improvement (RII-Track 1) award[1]. The Track 1 award is a $20 million, five-year cooperative agreement (2013 – 2018) with the National Science Foundation.

iUTAH's broader program goals are to improve water-related science and technology infrastructure in Utah; improve the state's research competitiveness; and further develop the workforce in areas of research, education, and practice – thereby promoting sustainable economic development. It aims to meet these goals by water-quality and water-quantity monitoring and modeling in three watersheds, extend and support cyber-infrastructure, develop human-capital diversity, and engage with decision-making and policy processes at the state level and beyond. This effort consists of a state-wide collaboration with nine Utah institutions of higher education[2]. Utah State University (USU), University of Utah (UU), and Brigham Young University (BYU) are the co-leads for the three research focus areas (RFAs) of the program, each having multi-faceted aims:

> RFA1: Improve Utah's capacity to monitor and understand the ecologic/climatic/hydrologic (ecohydrologic) system of the Wasatch Range Metropolitan Area (WRMA). This goal will be achieved by improving watershed-scale measurement capacities. This instrumentation will be used to conduct research aimed at gaining a better understanding of the biophysical processes that influence Utah's water resources.
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> RFA 2: Improve the capacity of Utah's science community to gather and analyze social and engineering system data on coupled water systems. Additionally, understand the interactions between urban form, environmental change, built water infrastructure, and decision-making in terms of water use; and also model the impact of alternative infrastructure designs and policy options on water use behaviors, the water cycle, water quality, and interconnected social and environmental systems.
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> RFA 3: Describe the water system as a whole, by defining and including the linkages between biophysical and social dynamics, using results from RFAs 1 and 2. Finally, facilitate interactions with stakeholders and linkages among disparate datasets and models to improve capacity to study the complexity of local water issues.

The charge to the AAAS panel was to review progress made to date and advise on future plans to enable maximal success. In addition, iUTAH requested specific feedback on the following areas: visualization and communication of water and climate change data to stakeholders (RFA3) and how to prioritize decision making for a proposed green infrastructure research facility (RFA2). To address these issues, a panel was recruited having collective expertise in water resources and climate change science, engineering, decision support, and visualization. The panel was led by an AAAS staff director experienced in program evaluation. Panelists and their affiliations are provided on the cover page. Background materials[3] were provided prior to the site visit and over the course of 2 ½ days, the panel

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[1] Utah EPSCoR has previously been awarded an NSF EPSCoR RII-Track 2 award and NSF EPSCoR C-2 cyberinfrastructure award. The current report is focused solely on Track 1 activities.

[2] The following partners comprise iUTAH, representing a range of institutions: University of Utah (UU) and Utah State University (USU) - public PhD-granting research universities; Utah Valley University, Southern Utah University, Weber State University, Dixie State College - metro-regional universities; Snow and Salt Lake Community Colleges; USU regional campuses (Roosevelt, Vernal, Tooele, Brigham City, USU Eastern-Price, USU Eastern-Blanding). Brigham Young University (BYU) is the state's only private, PhD-granting university and Westminster College is the only private liberal arts college.

[3] Background materials provided to the panel include: iUTAH Track 1 research proposal, strategic plans, progress reports (annual and NSF RSV), External Advisory Board report, and education evaluation report (iFellows).

interviewed iUTAH participants and visited a field site (the full agenda is provided in Appendix A). The panel then debriefed the iUTAH leadership team with its initial findings. This report reflects a refinement of those views, starting with the overall iUTAH project management, which is going through a major transition. This is followed by a discussion of each of the RFAs and cross-cutting features including visualization, cyberinfrastructure, and education/outreach/diversity.

II. Project Management and Leadership

In one and a half short years since the Track 1 grant began, iUTAH leadership has built a dynamic program involving faculty, students, and staff of the partner academic institutions as well as professionals from State agencies and non-profit organizations. The iUTAH program is highly relevant to the State's needs, as evidenced by engagement with the Governor's water task force, which is represented on the iUTAH management team. It is clear to the panel that initial results are positive and that considerable momentum is being built. There are substantial opportunities for synthesis across program elements that can lead to demonstrable impacts in research competitiveness and broader societal relevance. Just as important, the environment for collaboration has been strengthened, evidenced by over 30 joint research proposals submitted (and some accepted), where collaborations are reported to have been few prior to the RII Track-1 project.

Project leadership has been exceptional. During its site visit, the panel was informed, however, of the imminent departure of the PI and the State EPSCoR director. In spite of the "succession plan" built into the project management up to this point, the panel feels that the transition exposes iUTAH to several risks, including potential loss of program momentum and important and useful contacts at the State level and at NSF, inter-campus rivalries, and decreased stakeholder engagement. This could diminish the project's ability to secure continued State funding for iUTAH beyond 5 years. The new program leadership will have to be aware of these risks and work towards their reduction. The panel feels that the current leadership structure could be made more transparent, and with less conflicting management reporting and accountability lines. In particular, the specific roles of the Project Director, the Project Manager, the Leadership Team and the Management Team should be redefined again to reflect current and forward looking management plans. The new Project Director should not be given other major leadership positions in the focus areas to allow the time and energy needed to take on the program-level responsibilities.

In addition, the RFA leads appear to be over-committed particularly with the imminent leadership transition (see below). Also potentially serious is the low level of resources committed to several RFA activities. Given Utah's ineligibility for continued EPSCoR support beyond the current 5-year phase, the sustainability plan beyond 5 years of current funding is especially important. While the panel appreciates that the program leadership has considered future external funding, it would be wise to consider alternative plans, including the use of the universities' own resources where applicable, to sustain the sensor and information technology infrastructure, and the needed human resources that account for the majority of the iUTAH investment.

In summary, the panel believes that the success of the entire program will depend on iUTAH's overall leadership and management to actively address these critical issues.

III. Research Focus Areas (RFAs)

a. Research Focus Area 1: Biophysical Ecohydrologic System

The overarching goals for RFA1 is to provide long-term research opportunities for university faculty, staff, and students interested in better understanding and predicting the processes that take place, and that influence, ecologic/climatic/hydrologic (ecohydrologic) systems.

Strengths and Areas For Further Momentum:

This group is well into their installation of watershed-scale measurement instrumentation that will give researchers improved opportunities to collect and analyze data needed for scientific studies of ecohydrologic processes.

The design and implementation of the ecohydrologic observatory called Gradients Along Mountain to Urban Transitions (GAMUT) seem to be progressing well. Standard operating procedures (SOPs) for instrument operation have been developed and the needed technicians have been hired.

There was considerable enthusiasm among various researchers looking forward to using the data obtained from GAMUT, and their writing of new grant proposals based on the availability of these data. Graduate students have been involved in the development of watershed instrumentation plans. The GAMUT infrastructure has provided research (REU-like) opportunities for undergraduate and even high-school students during the summer as well as for more substantial research in watershed hydrobiogeochemistry.

The panel applauds the fact that GAMUT is designed to complement existing measurement networks in the three watersheds as well as the new NEON observatories in Red Butte Canyon and the Salt Lake Valley. This will help fill critical gaps in the data useful for hydrologic, climate, and land surface modeling.

The panel also applauds the efforts being made at this early stage of the project to identify possible sources of additional funding needed to ensure that GAMUT and GIRF (Green Infrastructure Research Facility) facilities will provide important place-based infrastructure for research and education beyond the duration of this grant.

Challenges and Opportunities for Improvement:

It wasn't clear to the panel what criteria were used to select the types of sensors being installed in the three test watersheds. Is there a plan on how the collected data will be used, or who might be interested in using it at the local and state governmental levels?

It also wasn't clear how RFA1 activities are to link to and support RFA2 and RFA3. Are there predictable actions of stakeholders (including public agencies) – the social system – to undesirable ecohydrologic conditions that are designed to reduce those undesirable conditions? Are there sensors that can provide useful information on social system behavior (e.g., changes in regulations and governance) that impact, say, water supplies and qualities?

Project documentation states that uncertainty in regional climate models will be reduced by down scaling model outputs at the Wasatch Range scale. Will not the downscaled flows be as uncertain as the climate model that produced the data they came from?

Other considerations:

Over time, GAMUT will need to be maintained and upgraded as new technology and demands for new types of data are made. This will certainly result in a long-term funding challenge. The panel notes that the project investigators believe having the GAMUT infrastructure in place will make it easier for them or their successors to obtain future grants for research that will benefit from the existence of GAMUT. The panel recommends that the RFA1 team estimate the annual cost of maintaining the GAMUT (Gradients Along Mountain to Urban Transitions) system after the Track I EPSCoR funding ends. This would include the cost of field staff and equipment and the costs of maintaining the database and web portals that make the data available. It also includes the cost of implementing QA/QC procedures. Identifying this total annual cost is the first step to planning ahead and looking for funding sources. The investment in this system is significant and its long-term viability would be one of the main metrics for the success of the iUTAH Track 1 project.

b. Research Focus Area 2 – Social and Engineered Systems

The main objectives of this focus area are to improve the capacity of Utah's science community to gather and analyze social and engineering system data on coupled water systems; and to understand the interactions between urban development / form and water use/availability and water management policies. A goal is to model the impacts of alternative infrastructure designs and policy options on water use behaviors and interconnected social and environmental systems. A facility, the Green Infrastructure Research Facility (GIRF) was originally proposed. In addition, a Green Infrastructure Research Network (GIRN) has been newly proposed.

Strengths and Areas For Further Momentum

This focus area already deeply integrates social and engineered systems. The principal leads on both engineering and sociology areas seem to be leading interdisciplinary, collaborative efforts. Also, new faculty and graduate students all have highly interdisciplinary research activities, focusing on the human dimensions of water systems. This focus area also involves stakeholder participation. Faculty and graduate student efforts dedicated to stakeholder involvement are under way.

Significant progress has been made in developing the research infrastructure, including: collection of social data associated with the GAMUT and built infrastructure data, development of partnerships with local water system managers in the study areas to coordinate data sharing, creation of a model of scales of analysis, instrumentation of green and built infrastructure, and development of initial models for relating human and built systems.

The proposed facility (GIRF) has been designed at a conceptual level. Additionally a network (GIRN) was conceived of and designed with the intention of complimenting the GIRF. This network will collect data from a number of in situ experiments for testing green infrastructure effectiveness and impacts. The panel heard some initial ideas for the role that GIRF and GIRN could play in addressing RFA2 research questions.

Overall, the efforts associated with this RFA have already made significant progress towards building capacity for undertaking research in the area of social and infrastructure coupled systems. Additionally, the Green Infrastructure focus provides tools for research on the relationship between sustainable infrastructure and water use and policies.

Challenges and Opportunities for Improvement:

The watersheds included in this study have significant agricultural activity that impacts water quantity and quality. However, agricultural water use does not seem to receive significant attention in iUTAH. A stronger integration of agricultural water use into the research is recommended.

Although there is a good data infrastructure that includes GAMUT from RFA1, social data and green infrastructure data, the panel had not seen nor heard of a specific plan for integrating these in a way that is useful to broader iUTAH objectives. For example, is social system behavior in response to ecohydrologic conditions predictable? If so, how can these coupled responses best be observed and predicted? If not, is this effort limited to informing stakeholders and the public on what is going on in nature and reacting based on their response, if any? Many models or types of models are possible. The work could be focused on addressing some key specific questions in order to guide the efforts toward delivering specific demonstrable results. The questions can be linked to data, models and analysis that would address the questions. Specific stakeholders may be associated with specific questions. This would tie in closely with RFA3.

The interdisciplinarity of iUTAH is somewhat limited to social systems and built infrastructure (both green and conventional). There may be opportunities to integrate with other disciplines such as economics, biology (e.g., riparian health), and agriculture.

Other Considerations

A decision should be made soon – in the coming 6 months – on whether or not to build the GIRF and if so, for what specific purposes. The question is in part a budget issue. The GIRN, which has considerable potential, may require resources that could be given up by the GIRF. Some thought has been given to the potential relationship between the GIRF and GIRN, but the relationship is still not clear to the panel. Moreover, it is difficult to recommend whether or not to build the GIRF and/or the GIRN based on the information received to date. The decision should be made by the Management Team based on cost (including facilities maintenance), current and future research value, and staffing resources.

There is a concern that development of both the GIRF and GIRN may be quite ambitious and could strain the overall project resources. Each of these should be considered alone in terms of capital cost and personnel and their potential research contribution (e.g., what questions can be answered or models developed, and how easily could the data or experiments be related to other project outcomes?). Another important consideration is the future use of these in research and the maintenance costs after the 5-year iUTAH funding ends. A decision to implement only one, either GIRN or GIRF, should be based on similar criteria. It is most likely that construction and maintenance of a GIRF facility, on the one hand, would not be feasible along with the simultaneous development of a GIRN network.

c. Research Focus Area 3 – The Coupled Human-Natural System

The main objectives of RFA3 are to integrate the results of RFAs 1 and 2 in order to describe the coupled system and to facilitate interactions with stakeholders and linkages among disparate datasets and models all aimed at improving researchers' capacity to study the complexity of local water issues. Five main activities associated with RFA3 include: 1) collecting data from RFAs 1 and 2 and storing them in a centralized database; 2) from these data, inferring linkages between the human and natural systems; 3) developing interdisciplinary models to quantify or illustrate the linkages, integrate models and datasets into a participatory modeling and visualization platform that can inform researchers, stakeholders and decision-makers; 4) developing appropriate visualization techniques to facilitate common understanding and stakeholder collaboration; and finally, 5) engaging researchers, stakeholders and decision-makers in exercises of scenario planning, research results dissemination, and decision-making.

The original proposal envisioned a "Situation Room" with state-of-the-art video displays and capacity to accommodate up to 50 participants. The current thinking is not to build this expensive facility and to identify other opportunities for a flexible, dynamic approach for communicating with stakeholders (see section on Visualization)

Strengths and Areas For Further Momentum

This effort benefits from leveraging the interdisciplinary aspects of RFA2 in which human system-natural system relationships are being explored. RFA2 will result in models that can be integrated by RFA3 into the scenario exploration suite that describes the coupled system.

The research team associated with RFA3 is highly qualified and experienced in modeling, connecting models and stakeholder engagement. The development of a conceptual framework was a team effort that resulted in identification of the system components, their organization and linkages across different scales, and provides a roadmap for the evolution of this framework. The application of this framework to a specific case – that of Green Infrastructure – was also demonstrated. This framework can be used to guide the generation of questions and models for other elements of the research. The process of converting components of this conceptual framework to specific elements and relationships should be underway.

The stakeholder engagement effort has made a good start. A stakeholder database is being developed with contacts and interests, and protocols for interaction. The very important connection with the water management community began in a meeting in the first year of the project. A Year 2 milestone is to

"assess stakeholder needs for visualization and research products." In addition to identifying needs, the stakeholders could provide information about what aspects of the coupled system they would find interesting or useful and what management or policy issues around water are particularly challenging.

The results of RFAs 1 and 2 will likely include some new discoveries about the relationships between the natural and human systems, especially involving green infrastructure. These discoveries could expand the solution space of existing problems in unanticipated ways. The model/data/scenario/visualization exploration should give stakeholders new ideas in addition to responding to specific needs that they may already have identified.

Challenges and Opportunities for Improvement:

RFA3 faces some significant challenges including 1) needing to identify and link models and data, 2) creating scenarios that respond to stakeholder interests, 3) developing visualizations that can communicate useful information about the nature of the coupled systems, and engaging researchers, stakeholders and decision-makers in exploring the scenarios by way of the visualizations. In spite of having expert and experienced research participants, it is difficult to produce usable "end products" even at the demonstration level. Some expertise in the technological aspects of visualization may be missing. Moreover, the effort is minimally funded compared with the other research areas. One RFA3 lead feels that this focus area is unacceptably lacking in funding and also identified the distance between campuses (separation of key researchers) as a challenge. The discussions revealed that the scope of this work is not yet well defined. The panel encourages the RFA leaders and technical experts to develop a detailed plan commensurate with the budget and possibly shift funding to insure there is an adequate budget to implement the plan. Furthermore, the main researchers at the two campuses need an agreed-upon procedure for collaboration.

A possible approach to defining a relatively detailed scope would be to consider existing models and newly discovered relationships and identify questions these tools can address. For example, propose a number of very specific scenarios that reflect the conceptual system model and use the data that are or will be collected and models that are or will be developed, and that respond in some way to interests of stakeholders, decision-makers or other researchers. Target a small number of these for initial development and begin to design in detail the integration and outputs from these. Let the questions drive the visualization needs.

Regarding the "end product" of this RFA, it is not realistic to expect that all the information about the coupled system will be available in the scenarios; there are inadequate time and resources to do more than a few example cases. However, these examples should be well thought out and well executed in order to convince potential future funding sources of the value of the approach and work. The key aspects of success will be novelty – giving people new information and insights about the coupled system discovered by the project; relevancy – addresses possible solutions to existing or future problems; and effectiveness of the scenario exploration process. Again, a few good implementations will accomplish the iUTAH goals more than many less well thought out or irrelevant ones.

Successful scenario exploration is facilitated by visualization tools (see below). The RFA3 team has identified Envision Tomorrow as a potential tool. This software appears to be suited to urban planning problems and could be useful to illustrate the benefits of green infrastructure but will not cover the range of models and scenarios that will characterize the coupled system. Other available software such as Tableau can be used to develop highly interactive visualizations to explore spatial or multi-dimensional relationships.

Other Considerations

The panel agrees that the high-tech "Situation Room" does not appear to be the best investment for stakeholder engagement. This is because 1) it does not allow flexibility of location; 2) it would incorporate a level of technology that will likely far exceed the need of the types of interactive decision-making that are planned for this project; and 3) there is not a plan for continued use and maintenance of the room

after the 5-year project and 4) there appear to be more cost-effective alternatives. For example, there is value of having group visualization sessions with stakeholders to explore scenarios because the group dynamic adds to the benefits obtained from the scenario exploration process. This could be accomplished using sharable laptops or other mobile devices coupled with an inexpensive data projector that can be used for improving the effectiveness of collaborative processes at any location. Ideally the funding for this would be re-programmed within RFA3.

IV. Visualization

The iUTAH program has stated goals of involving all internal and external stakeholders in a visually supportive environment. The iUTAH program asked this panel to offer specific suggestions regarding visualization alternatives and opportunities. The remainder of this report focuses on this request.

Ideal visualization processes aim to build cohesiveness through visual tools supporting organizational knowledge retention. Iterative knowledge discovery and situation awareness processes are particularly well-supported by visualization techniques. Ideal tools promote efficient iteration of current understanding in support of gaining insight and consensus for current and future activities. Visual assets (imagery, video, multimedia, interactive applications, etc.) that come out of the use of visualization tools are then available for use in publications, websites, presentations, lectures, and grant proposals.

Strengths and Areas For Further Momentum

iUTAH has already demonstrated a competent example of a meaningful visualization process. Starting with a visual collaborative white-boarding process, RFA3 researchers created a visual conceptual model of how stakeholders interrelate as a coherent system to pursue activities that will accomplish the iUTAH mission. The visual system framework suggests linkages between groups of people performing critical tasks and the knowledge bases they attain to perform those tasks competently. Each of those linkages suggests opportunities where collaboration and better cause-effect knowledge can be pursued to improve system behavior for better water quantity and quality management.

iUTAH is building a database of internal and external stakeholders that maps roles, individuals, and organizations to components in the model. Visualization provides an opportunity to efficiently connect people to system model for visual communication of responsibility and accountability. Identifying roles helps suggest redundancy and deficiency for staff planning purposes. Mapping external stakeholders to those roles suggests priorities for stakeholder engagement.

Mapping and plotting services have been developed for situation awareness GAMUT and sense-making neighborhood behavior analyses using appropriate visualization tools – demonstrating that skills exist within iUTAH personnel for iterating upon visual techniques for better understanding and insight. Discussions with Envision Utah team participants suggested visualization ranked high on the list of activities being pursued to support state water strategic goals. Student poster visual components suggested visualization was important to their communication effectiveness.

By deciding against using project resources for a state-of-the-art decision theater, iUTAH allows the opportunity to direct more resources towards developing visualization skills and implementing a more mobile and flexible stakeholder involvement process.

Challenges and Opportunities for Improvement:

The iUTAH enterprise has a fantastic opportunity to build visualization skills through the nature of all the data and systems considerations that are a by-product of iUTAH activities. Those skills can be developed among iUTAH researchers by considering other internal stakeholders – the research team – and attempting visualization processes for their benefit. In particular, providing “user-centric” visualization tools in which data exploration responds to a multitude of needs and preferences of users, could be of

great benefit to the team. Communicating knowledge across system linkages should strengthen collaborative activities and visualization has proven to be an effective tool for shared knowledge pursuit. The skills gained by improving visualization processes internally would pay off when performing visualization processes to inform and benefit external stakeholders.

To become expert visualization developers, the skill acquisition process requires time and focus be devoted to that aim. Much of the art of visualization comes through experience, not all of which is easily gained through existing case studies. The skill is likely highly relevant to any researcher going forward in the information age and is likely to pay off in furthering their professional career – similar to how a grant-writing skill supports their career currently. Examples of visualization 'core competencies' that iUTAH may want to develop, and existing models to support these efforts, are provided in Appendix B (Visualization Tools and Resources).

Alternatively, visualization process skills can be acquired via external personnel as consultants or contractors to the iUTAH team. Immediate benefits might come from gaining access to others who already have the skills and time to perform visualization design. Through working with the users, those outside consultants and contractors can end up with new knowledge that is best retained within the team as it sheds light on future services for the user and overall perspectives of the iUTAH system. The iUTAH enterprise itself is an important user of the data and knowledge produced, and can serve to make sure information is recorded and available as part of organizational knowledge. iUTAH researchers can gain experience with development of user-centric design by acting as the user participant; they would simultaneously gain skills in the use of tools that are being created to support the process. Use of external consultants must be carefully considered with respect to the budgets. (In other words, good ones are not cheap.)

The visualization design process for a specific use case aims to incorporate the full scope of relevant data and presentation needs. The use case considers user visual literacy and cognitive abilities so that visuals can best map to user abilities or assistance can be provided in acquiring those skills. The full scope then suggests what hardware and software solutions are worth investing in to be able to support visualization. Once a use case has suggested the acquisition of such hardware and software those assets can be considered valuable to meet the needs of other visualization use cases.

iUTAH is wise to suggest physical spaces can be natural environments to spur collaboration and mutual support of individual goals. Decision theaters contain components that can be used for watching motivational videos and real-time symposiums/conferences, etc. that are relevant to the iUTAH mission. Today a data projector and a white wall can enhance a meaningful shared space until other hardware has been deemed necessary for a visualization process goal. The projector can be a mobile asset maximized in value through use with stakeholders at their location. Add an always-available shared laptop or mobile mini-computer to provide a more complete portable solution.

The panel recommends that iUTAH pursue developing a good foundation in visualization skills in order to be more effective and efficient in communicating organizational mission as well as key discoveries about the coupled system and possible scenarios for iterative insight and consensus building. Once those skills reach a critical mass, visualization will become a more frequent component to meetings and discussions that aim to capture activities asynchronously for the benefit of others who have not attended.

Those skills will also build professional competence and confidence in hardware and software tools acquisition. As opportunities for pursuing visualization processes are identified, iUTAH should continue to evolve the conceptual model they have already developed, as a process that documents the system framework, suggests meaningful linkages, and generates hypotheses worthy of scientific exploration.

V. Cyberinfrastructure/Data & Modeling Federation

The cyberinfrastructure goal of iUTAH is to build on Utah's existing strengths in hydrologic modeling and

cyber-infrastructure from the CIWATER (Track-II) and cyber-infrastructure (C-2) NSF EPSCoR awards. Activities include increasing capacity for data collection, data organization, data management, data sharing, and synthesis to higher-level products and increase capacity for integration of data and models. Data visualization to assist in determining significance, relevance and uncertainty has also been pursued to date.

Strengths and Areas For Further Momentum

The panel was very impressed with the C-I team and progress made to date. iUTAH has identified the requirements for cyber-infrastructure support and has been competently providing solutions to meet those requirements. As iUTAH consists of a wide range of stakeholders, the C-I team has pursued important policies and processes that will better support the collaborative nature of hydrologic modeling contribution to a larger water quality management system process.

The data policy and meta-data decisions have been made with the right considerations in mind and have thoughtfully considered time and size which are often at odds with each other. User experience has been identified as a benchmark through which effective services are being gauged. Expectations for C-I services have been mapped to both research focus areas and potential external collaborator needs.

Back-end virtualization infrastructure seems ideally suited to the support of varied system needs identified in the conceptual model. Modeling integration skills are coming on board via an experienced new member of the C-I team. Internal cloud facilities can mitigate the risk of exposure that full external cloud facilities may pose. The presentation of trade-offs is well thought-out for arriving at an internal cloud decision. Upon reviewing the work processes and solutions provided by the C-I team to date, the panel expects the C-I team will continue to do a great job of virtualization, model integration, and cloud development – three areas of C-I that traditionally require significant effort in development and maintenance.

The excellent and comprehensive cyber-infrastructure and data management plan is readily shared with those dependent on it and C-I implementers have proven competent to consider any need identified by iUTAH personnel. The team is working hard to share iUTAH assets through website services that use reasonable technical choices where many options exist. Real-time data from GAMUT sensors are made available in both raw and scrubbed versions. Error and uncertainty issues are forefront to C-I concerns when confronting trade-offs between accessibility and validity. The panel is confident the C-I team will continue to iterate on the solutions they provide as they have been iterating to date.

The C-I team supports a culture of open-source software in sharing their code for five key solutions developed to support the iUTAH mission. These code bases are provided through the most popular means (github repository). The C-I team appears to be looking outwards for other open source efforts that provide code of use to the iUTAH mission as well. The open-source focus is likely to help with fostering collaboration among all the competent programming teams at member institutions.

The open-source skills being refined through coding solutions are parallel to open-source skills that can be refined through visualization process skill development. The C-I team seems to have skills that could be very valuable in supporting and facilitating user-centric visualization processes – specifically for the visualization products included within the C-I solutions provided but also for visualization products for a wider range of stakeholders.

Opportunities for Improvement:

The C-I enterprise is extensive and requires much maintenance. It has been a major focus of efforts in the first and second years and has been highly successful in laying the foundation for continued development and maintenance. It is not clear whether the C-I team will have time to focus on a wider visualization responsibility. The panel recommends that consideration be given to redirecting some C-I resources in the coming years to developing a similarly successful visualization tool effort.

The panel did not identify any weaknesses in the C-I structure or methods, and offers the following suggestions for the iUTAH C-I to be a collaborative enterprise to ensure that user needs are continually addressed.

The user needs and user experience of C-I services has been effectively studied and supported through a competent top-down process. The needs of collaborators who are pursuing new areas of research are often partially unaware of their needs when mapping out collaborative activities. As the C-I team is implementing and maintaining identified services, the panel suggests that it could be beneficial to spend some minimal time building a more community/distributive involvement for system and data requirements. This could serve to adjust the products to new needs as they arise, and in addition, would demonstrate a culture in which everyone is responsible for proper and effective use of C-I assets. Hopefully, it also would provide a process by which use of C-I assets can be identified more smartly through a shared experience of users (appropriateness of shared data sets to tasks, for example). This could be accomplished by taking advantage of annotation services within C-I resources. If collaborators don't engage in using available on-line asynchronous tools, synchronous facilities (in person or on-line) could be targeted to identify those needs explicitly. From a time and cost-perspective, asynchronous can provide significant savings if a strong culture of optimal group behavior is attained. A crowd-source model may be particularly relevant for the iUtah given its collaborative mission and goals and the geographical distance among partner institutions.

The Web services gold rush is on as people are rapidly developing skills for mash-ups and infographics and the back-end infrastructure is becoming standardized in efficient ways to manage and distribute data sources. Web-based processes are available for fostering collaboration and stakeholder engagement. iUTAH still needs to determine what interactive capabilities are of interest to potential users and how those interactions will be facilitated through C-I. A user-centric process for visualization development will also identify user requirements of C-I to support visualizations.

VI. Education, Outreach and Diversity (EOD)

iUTAH's Diversity Enhancement (DE) goal is to "increase the individual, disciplinary, institutional, and geographic diversity of the STEM enterprise in Utah to address the water sustainability issues facing Utah and the Mountain West". By extension, the Workforce Development goal is to "enhance the STEM workforce in Utah by developing programs for a diverse range of learners that inspire students to choose STEM careers by promoting the retention of students in STEM degrees and enhancing the success of faculty in STEM disciplines".

Strengths and Areas For Further Momentum

The panel appreciated the iUTAH's clear recognition of the needs and opportunities for EOD. The program has developed effective outreach to PUIs for this purpose. Programmatically, EOD activities were off to a dynamic start in the summer of 2013 even though the plan only called for this to start in 2014. Early and successful activities including outreach to diverse students and public, collaborative activities with the Leonardo Museum, the Summer Institute for K-12 students and teachers, and the undergraduate research fellows program indicate the energy and talent that iUTAH has brought to this effort. To achieve EOD goals, iUTAH has a dedicated staff member in a cross-campus position who will help facilitate program-wide activities.

Challenges and Opportunities for Improvement :

The panel has commended the provisional start to EOD activities in the summer of 2013, and these efforts will need to be intensified (ensuring greater participation) and extended (developing additional activities). It is somewhat unclear how the summer institute (high school) and REU (undergrad) directly contribute to RFA 1, 2, and 3. In other words, EOD cannot be standalone activities, but must be better integrated, articulated and strengthened.

Appendix A

iUTAH AAAS Review Agenda
February 19th – 21st, 2014

February 19th, Wednesday – Salt Lake City, UT

Meeting Space
Alpine Room at the University of Utah Guest House
110 South Fort Douglas Boulevard,
Salt Lake City, UT 84113-5036
http://www.universityguesthouse.com/
(Parking has been prepaid for all iUTAH attendees at Utah Guest House lot, so park anywhere around building.)

8:00am *Light refreshments and informal networking*

8:30am **Opening Session**

- Welcome and introductions
  - Review Team
  - AAAS staff
  - iUTAH attendees
- Agenda overview

9:00am **iUTAH Overview and Conceptual Framework**

- Overview – T. Crowl
- Conceptual Framework – R. Hale

9:45am *break*

10:00am **iUTAH Project Management** – R. Teutonico, T. Crowl

- Utah EPSCOR Executive Committee
- iUTAH Management Team

10:30am **iUTAH Research Focus Areas (RFAs) & Facilities** – Team leads

- RFA 1 & GAMUT – M. Baker, Z. Aanderud
- RFA 2 & GIRF – D. Jackson-Smith, C. Pomeroy
- RFA 3 – D. Pataki, *S. Null*

11:30pm *lunch*

Poster session – UU & BYU postdoctoral associates & graduate students

February 19th, Wednesday (cont'd)

1:00pm **Small group meeting – RFA 1**
- Faculty/researchers
- Postdoctoral associates
- Students – graduate and undergraduate

Go-to-meeting link: https://www4.gotomeeting.com/join/580743343

2:00pm **Stakeholder Engagement** – S. Hinners, C. Keleher

3:00pm Tour of Red Butte watershed – D. Eiriksson
(Bring sturdy shoes/boots)

5:30pm Dinner with iUTAH Management Team – plans for Day Two
Squatters Restaurant
147 W Broadway, Salt Lake City, UT

7:00pm Review Team travel to Logan, UT

February 20th, Thursday – Logan, UT

Meeting Space
USU Innovation Campus, USTAR BioInnovations Center 650
Conference room 158
650 E. Grand Avenue, North Logan, UT 84341
http://ustar.usu.edu/htm/bioinnovations-center

8:00am *Light refreshments and informal networking*

8:30am Tour of EPSCoR offices and labs (Suite 305 B/C/D)

9:00am **Small group meeting – RFA 2**
- Faculty/researchers
- Postdoctoral associates
- Students – graduate and undergraduate

Go-to-meeting link: https://www4.gotomeeting.com/join/580743343
UU room available: INSCC 345

10:00am **Small group meeting – RFA 2**
- Faculty/researchers
- Postdoctoral associates
- Students – graduate and undergraduate

Go-to-meeting link: https://www4.gotomeeting.com/join/580743343
UU room available: INSCC 345

February 20th, Thursday – Logan, UT (cont'd)

11:00am **iUTAH Data & Modeling Federation** – J. Horsburgh, A. Jones

11:30pm *lunch*

Poster session – USU postdoctoral associates & graduate students

1:00pm **Integration of Research with Education, Outreach and Diversity (EOD) – R. Teutonico, E. Burns**

- Overall EOD goals
- Workforce Development
- External Engagement
- Diversity Enhancement
- Adding new partners – EOD proposals

2:00pm Meeting with iUTAH Leadership Team

3:00pm Tour of Water Lab and Logan River Watershed – C. Cox

5:30pm Review Team working dinner (closed)

February 21st, Friday – Logan, UT
8am to 1pm

Meeting Space
USU Innovation Campus, USTAR BioInnovations Center 650
Conference room 158
650 E. Grand Avenue
North Logan, UT 84341
http://ustar.usu.edu/htm/bioinnovations-center

8:30am *Light refreshments and informal networking*

9:00am Review Team Executive Session (closed)

12:00pm **Debrief with iUTAH Leadership Team**

1:00pm Meeting adjourns – Review team travels to Salt Lake City airport

Appendix B: Visualization Tools and Resources

Performing a user-centric process for generating visualization products is a skill that builds competence through experience – similar to skills gained in reading, writing, and arithmetic. There are organizations that have performed and studied the process to gain advanced skills and share those experiences. iUTAH can develop competency through discussion of those organizations' activities and the visual products they have produced to demonstrate meeting user-centric visualization needs:

The Center for Environmental Visualization at the University of Washington has been creating visual ocean and watershed products for client users as a core competency since 1997. Each of the visualizations shared at www.cev.washington.edu has a user-centric design process behind the development of visual products.

The GeoVISTA Center at Penn State University has been developing geo-information representation, spatial analysis, cartography and visual analytics products for client users for well over a decade (see www.geovista.psu.edu).

The Stanford Visualization Group (see vis.stanford.edu) has been developing visualization tools and processes to support big organizational needs in order for those organizations to become competent at user-centric visualization design. These tools often investigate the opportunity that interactive exploration of visualizations leads to more effective insight and understanding. They identify the differences individual users have when using such tools and provide alternative packaging of visual components to better facilitate individual learning styles.

Individual developers like Chris Weaver at the University of Oklahoma attempt to build rapid prototyping tools for support of user-centric visual exploration of data (see www.cs.ou.edu/~weaver/improvise/examples.html). Team software development and bottom-up, example-based, library communities attempt to help support user-centric visualization process competency for individuals and organizations (see http://www.tableausoftware.com/ and github.com/mbostock/d3/wiki/Gallery respectively).