Strategies for Sustainability of Biological Infrastructure: Workshop Report

Introduction

Two of the major goals of the Ecological Society of America (ESA) are to promote the continued development of ecological science and increase the resources available to conduct ecological science. As part of this effort, with support from the National Science Foundation (NSF) and in partnership with the Meridian Institute, ESA hosted a workshop on Strategies for Sustainability of Biological Infrastructure. The workshop was held at the Ronald Reagan Building and International Trade Center in Washington, D.C. on 29 and 30 November 2010, and brought together 15 managers of various infrastructure forms, including databases, field stations, and collections.

Background and Workshop Objectives

Biological science increasingly depends on a wide array of infrastructure forms, which in turn have evolved from primarily buildings, single instruments, and printed materials toward complex instrumented sites, databases and software, and collections of living or preserved organisms. With these changes have come concerns about how to provide for the long-term maintenance and operations of this infrastructure.

The NSF Committee of Visitors for the Division of Biological Infrastructure has already observed that infrastructure needs are growing more quickly than the capacity to provide long-term maintenance and operations for an entire class of resources (DBI COV 2007, DEB COV 2006). To enable the long-term sustainability of these resources, it is imperative to develop a strategic approach that involves resource managers, developers, and users across multiple projects.

This workshop initiated that process by bringing together managers of existing critical resources in a range of infrastructure forms to clearly define the problem and identify further steps in crafting a strategic approach to sustainability. Specifically, the workshop objectives were to:

- define the problem
- identify approaches and issues of common concern among the organizations represented
- explore applications and limitations of existing sustainability models
- identify key ingredients for infrastructure sustainability
- recommend next steps

This is intended as the beginning of a series of conversations aimed at providing guidance for funders, managers, and users of biological infrastructure to ensure long-term sustainability. Such an effort is critical to the ultimate goal of sustaining the infrastructure required for biological research and supporting continued development of the scientific community.

Current Approaches to Infrastructure Sustainability: Defining the Problem and Identifying Common Concerns

<u>NSF Perspective</u>

This workshop was developed in response to several challenges identified in previous National Science Board and Committee of Visitor reports (NSB 2005, DEB COV 2006, DBI COV 2007) regarding NSF's growing responsibilities for digital collections and other infrastructure. Invited NSF representatives

helped to define the problem, emphasizing that although they want to sustain biological infrastructure, they face growing pressure and less money. This workshop was designed for members of the science community to begin discussing other options and funding models for sustaining these important resources. There is also a genuine need to involve the users in these discussions, since they are served by research infrastructure and any decisions about alternative funding models affect their work and research. The science community, including NSF, needs to know more about who the users are and how they value these resources, bearing in mind that infrastructure is needed to support scientific innovation, a key aspect of NSF's mandate. Infrastructure leaders and NSF also would benefit from a better understanding of the real costs of long term operations and of how separable costs are from each other.

Defining Infrastructure and Sustainability

In order to help frame the breakout group discussions later in the day, participants developed consensus working definitions of infrastructure and sustainability as a group.

> *Infrastructure is: the resources required to enable scientific research, education, and decision-making for a broad community of users over a long period of time.*
>
> *Sustainability is: the capacity to preserve content and services, and increase their value to the user community over time.*

There were some important, overarching ideas the participants wanted to convey in the infrastructure definition. First, it establishes infrastructure as a process that enables science. The definition implies a plan and purpose; infrastructure doesn't happen randomly. Finally, infrastructure serves many different kinds of users and groups.

The participants started with a sustainability definition adapted from the Ithaka report on Sustaining Digital Resources: "the ability to generate or gain access to the resources – financial or otherwise – needed to protect and increase the content's value for users" (Maron 2009: 11). Important aspects of the sustainability working definition include its temporal element and its emphasis on value. Constant innovation, implied in increasing value, to keep infrastructure relevant and useful is vital to sustainability. Other important elements include resource accessibility on a long-term basis, and ensuring that users know how to make use of the resource.

Invited Presentations: Current Approaches to Sustainability

Three workshop participants gave presentations on their organizations' current approaches to sustainability. Detailed funding models were presented for two database projects and one field station. Below are some of the key approaches these presenters highlighted:

- **Spreading costs across institutions or a member network.** This can reduce overall expenses, particularly if all members are invested and truly value the common infrastructure.
- **Positioning data as something new and/or creating software or services.** Users are more receptive to fees that are built into a product or service. This increases value as well, so users are willing to pay more.
- **Including infrastructure costs explicitly in all grants and contracts to the program.**
- **Engaging the user community at all levels.** One project includes users at the decision-making level, solicits ideas from them, and uses them to help advertise and create support for new

initiatives. Users help develop ideas that can lead to more successful proposals. Thinking like a user and being in contact with them helps ensure you are providing what they need.
- **Building relationships with partner institutions and state governments** to ensure the infrastructure is relevant. Partners can help take up slack if needed, particularly if the project is important to their own work, and reaching out to state institutions can help justify the project's importance and need for state funding.
- **Beginning initial efforts at creating endowments.** This can be challenging in the current economic climate and is a long-term effort, but one with significant potential for long-term, stable funding.
- **Charging more for commercial clients, so academic users can pay less.**
- **Creating economies of scale.** Sometimes increasing products and lowering prices can be financially advantageous. Associating infrastructure with an existing institution or university can help reduce some overhead costs.
- **Charging membership fees.** One project uses membership fees to help subsidize other programs.

Some key challenges their projects encounter are:

- When using a diverse funding portfolio, revenue streams may be unpredictable, making long-term planning, expansion, and improvement of infrastructure value and facilities a challenge.
- In cases where revenue is being used to subsidize multiple projects, keeping track of these subsidies when revenues change can be challenging.
- User communities can be averse to fee structures.

<u>Common Concerns and Successes</u>
Clifford Duke highlighted some of the commonalities apparent in a pre-workshop survey that participants were asked to complete:

- Personnel and overhead costs dominate most project budgets.
- Organizations employ diverse methods for cost management and revenue generation, depending on their size and type. Almost all projects rely primarily on grants and contracts for funding, but almost all are also trying to diversify their revenue streams.
- Organizations have many metrics to measure their success, but the most common ones included the number and diversity of users, literature citations, number of data/tool requests, and website traffic statistics.
- It was apparent that diverse fundraising requires a lot of time, management, and skill.
- Managers have different definitions of sustainability and success. Success could be as simple as "keeping the doors open," or involve more complex factors, such as having satisfied users, a well-served community, and being valued within the user community.
- One core challenge for everyone was that many funders don't see infrastructure sustainability as a priority; they tend to prefer funding new initiatives, rather than maintaining something that already exists.
- Everyone agreed that simple maintenance versus being able to adapt, add value, and grow are two very different trajectories with significant implications for managing costs and developing budgets.

In the ensuing discussions, one of the most common challenges that participants identified was the user community's aversion to fee structures. When exploring funding models that do not rely entirely on

grant funding, many organizations have at least investigated some type of user fee. Depending on the resource and the user community, these discussions can result in serious backlash. In communities where free access to infrastructure is typical, significant cultural change may be necessary for a user-pays model to be successful. Participants identified several broad factors that would be important to this cultural change:

1. Each project needs to analyze its own user community to determine how to implement user fees effectively. Important questions to answer include:
    a. What do the users value the most?
    b. What are they willing to pay for, and how much? For example, most users are currently more receptive to charges for software and services than they are to data access fees.
    c. What level of cost would be prohibitive?
    d. How can we make services personally useful, important, and enjoyable, so that users are willing to donate to keep the system going?
2. There is a need to involve agencies and the international community. If there are other related projects out there providing free access, competition will render any user fee model ineffective.
3. It is important to get advice from independent, external experts who are not wrapped up in the day-to-day use of the resource.

One participant described how they successfully implemented a user fee for their project:

> *Because our Governing Board was initially comprised entirely of scientists, they had the same strong resistance to implementing user fees to build a sustainable funding model. There was a conflict of interest, so we brought in members from the non-profit world to help rethink our funding model; some distance between the users and decisions about usage fees was needed. Our rate structure started out very low – the only way we were able to figure out what people were willing to pay was to charge a fee and monitor its impact on use. As it turned out, our rate structure was low. We have been able to increase our fees without seeing a drop in use, while simultaneously increasing the value and demand of our services.*

Obviously, what works for one project and user community won't necessarily work elsewhere, but the above factors could be a useful starting point when considering usage fee implementation. It is clear that biological infrastructure needs to reach a new phase in terms of funding portfolios in order for resources to be sustainable. Developing interim solutions and moving gradually towards a user-pays model while considering the factors above may help projects be more successful in this endeavor.

Breakout Group Discussions: Exploring the Applications and Limitations of Sustainability Models

Participants separated into three breakout groups according to infrastructure type, to enable more specific discussion and planning. They were asked to identify key elements to a sustainable business model and their top three challenges and opportunities when considering their organization's sustainability. Throughout the conversations and presentations, the overlap between challenges and opportunities became apparent; some opportunities could also present new challenges, and vice-versa. Though there was significant variety among projects within each breakout group, participants were asked to find general commonalities and trends.

Below is a table that summarizes the key opportunities and challenges from each breakout group.

Sustaining Biological Infrastructure: Opportunities and Challenges, by Infrastructure Type

	Key Opportunities	Key Challenges
Group 1: Databases	1. Engaging stakeholders in shared resources (including funders) 2. Establishing community information and metadata standards 3. Creating distributed strategic (global) partnerships 4. Establishing new linkages across disciplines to boost infrastructure value proposition	1. Cultural resistance to costing models 2. Securing interagency/international support for interagency and international resources 3. Looming federal, state, university, library, and museum deficits
Group 2: Field Stations	1. Technological changes are creating new opportunities for research, data collection, and outreach (but also constraining others) 2. Environmental change will increase demand 3. Developing flexible, adaptable processes 4. Value of data will increase over time	1. Lack of strategic control of the discipline 2. Declining federal funding available 3. Excitement decay of the science 4. Transparent cost structure is often lacking
Group 3: Collections	1. Creating a subscription-based collection organization that would assume some of the costs/functions of individual institutions 2. Determining the monetary value of collections, including costs for maintaining and improving them 3. Developing data use fees and partnerships with income-generating organizations	1. There is no existing successful organization that meets the needs of collections. 2. Lack of knowledge and appreciation for the value of collections 3. Depending on NSF funds that are not specific to the needs of collections; this creates unnecessary competition.

<u>Group 1: Databases</u>

This group identified one of the most important elements of a sustainable business model, and a significant opportunity for infrastructure sustainability, as thorough and constant analysis of key stakeholders. Stakeholders encompass those who deposit and use data, and other partners such as independent organizations, international institutions, professional societies, and private companies. Identifying who stakeholders are and what they want is a key step to meeting user needs and keeping infrastructure relevant. Stakeholder input can also help create ideas for new products or services, leading to more diverse revenue streams. Another opportunity the group identified is establishing community information and metadata standards, which can help users discover resources across disciplines and conduct analyses more efficiently, again increasing the data's relevance, importance, and value. Building partnerships with other organizations, including international ones, can open up new

sources of funding. Creating links with other disciplines can enhance data's value and allow project managers to take advantage of exciting science that is progressing rapidly in new areas.

The most significant challenge identified was cultural resistance of user communities to usage fees, which was also highlighted in the previous discussion of common concerns and successes. Many database projects provide resources valuable to national and international communities. In such cases, it can be challenging to obtain support for these resources from the community they serve. Looming deficits and funding cuts are currently affecting federal and state government, universities, and libraries, which will significantly affect the funding available for infrastructure.

Discussing the challenges and opportunities identified by this group brought out some important points for data sharing and establishing community data standards. Various government agencies have different rules for data sharing and fees; some will not link to data unless it is shared for free. This lack of coordination poses significant challenges to certain funding models for biological infrastructure, and is particularly challenging to projects that relate to multiple disciplines and receive funding from multiple agencies. In terms of creating standards, there are very broad practices that are not standardized across the biological sciences community. Science is becoming increasingly dependent on large volumes of data, and it is clear that more coordination is needed. There should be an incentive for developing standards and curating data effectively, particularly in communities with historical resistance to setting standards and sharing data, and especially because most standardization practices currently benefit data users, rather than providers. Incorporating coordination and standardization of data into technical applications and needs can make science more productive, help us tackle many more questions, and help ensure that there is no needless arguing over fine semantics of concepts that are never used. All these ideas relate to making infrastructure, and databases in particular, more usable and relevant, and hopefully more sustainable in the future.

In summary, this group also identified four key aspects of a sustainable business model that would be relevant to their projects:

1. Engage all stakeholders at all levels, including governance, particularly at the outset.
2. Data curation is an essential function.
3. Plan for and support ongoing innovation.
4. Plan for and support collaboration.

<u>Group 2: Field Stations</u>

This group identified technological change as an important opportunity for creating sustainable field stations. Advancing technology will greatly expand capabilities for collecting data in the field, which can also create new ways for scientists to collaborate with each other and new avenues for citizen science through remote technology. Technology changes could, however, present new challenges to field stations, potentially reducing the need to physically visit them. Scientists would also need to develop additional skills in order to collaborate effectively in new, innovative ways. Environmental change, and the need to monitor it, is another opportunity for field stations; it can increase the importance of field stations and increase the value of their data over time. The longer that stations are collecting data, and the more kinds of overlapping research they foster, the more valuable they become if well maintained. Stations also have an opportunity to develop flexible, adaptable processes that will position them broadly and prepare them for future cutting edge science.

A serious challenge for field stations is the lack of strategic control of biology as a discipline. Biologists have not had a huge need to work together in the past, have not needed to agree on standards, and are not always well-trained in the skills needed to develop and maintain infrastructure. Declining federal funds available for infrastructure support are worrying, along with the presence of "excitement decay." New projects are exciting, while funding to maintain an existing project can be difficult to obtain. Furthermore, field stations need new users, so they need to position themselves at the cutting edge of science to garner the next generation's understanding and appreciation. The lack of transparent cost structures for field stations is another challenge. Many stations do not have detailed financial information, and do not know their true costs. This issue needs to be addressed for stations to recover costs effectively and be financially sustainable.

In terms of developing a sustainable business model, the following are important:

- Strategic planning. Biology as a discipline should come together and establish some critical issues for investigation — essentially developing a core message and strategic plan that determines scientific priorities. This could help create several larger projects, rather than lots of smaller, competing projects. This strategic plan was likened to astronomy decadal plans, which make medium-scale recommendations for the discipline's research priorities and are developed by a high-level group (e.g., National Research Council committees). Shifting to a more top-down science could be challenging, but strategic planning to guide decision-making in biology could be positive.
- Providing incentives to encourage collaboration and information sharing among scientists collecting data at field stations. For example, standardized protocols for data collection would facilitate use of data to answer broader questions posed by other scientists and unanticipated in the original study.
- Developing new ways to generate income (such as ecotourism).
- Strengthening networks to spread out costs and create new partnerships.
- Creating a transparent pricing structure to facilitate understanding and charging of full costs.
- More effective communication to the general public. This group determined that infrastructure sustainability depends very much on a steady stream of compelling cases in leading edge science that are supported by the infrastructure. Better communication can help convey the importance of these stations, how the data are being used, and the data's potential significance for the future.

<u>Group 3: Collections</u>

The opportunities and challenges this group identified overlap significantly; many of the opportunities are ways to address what the participants view as the biggest challenges to sustaining collections. There were significant differences between the living and non-living collection communities, but the group attempted to address the needs of both. Something that emerged as a challenge and an opportunity was the lack of organization in the non-living collection community. There is currently no successful national organization that meets the needs of collections, offers coordination, and provides the community with ideas and platforms for sustainability. Participants in this breakout group proposed creating a national, subscription-based organization to coordinate how collections operate. This organization, composed of collections leaders, would take on some of the issues collections deal with and help them accomplish their work more effectively. The organization could help with publicity, track collection use, provide data storage and hardware upgrades, and would generally assume some of the member collections' costs and functions. It could also help with data digitization, and an essential function would be to compile catalogs and map out where collections are and what they contain – a tool

that could be used to communicate with the general public. There could be guidelines establishing what happens if a collection becomes financially unsustainable, so that it could be absorbed by a partner collection and continue to exist. A first step in this process could be reaching out to and assessing all collections, regardless of the state of curation, which would identify needs and justify forming a large coordinating organization.

As for living collections, they often have more established guidelines and known cost and value structures, but there is still a need to diversify funding sources. Commercializing collections could create significant revenue opportunities, but possible negative outcomes on the collections themselves have to be identified and considered.

The lack of knowledge of and appreciation for the value of collections is another significant challenge. This could be addressed by determining the monetary value of collections, including the costs for maintaining and improving them, as a way to document the services they provide and their value to users. That valuation could become the basis for determining user fees, which have not been used widely in the natural history community, and justify funding proposals. This relates to the final opportunity the group identified: developing data use fees and investigating the best way to implement them. Partnering with income generating organizations and university libraries, using subscription and licensing schemes, or developing in-kind charges for specimen identification, are all potential options. Quantifying the value of collections and implementing user fees could help institutions receive proper credit for these resources.

Finally, collections are currently very dependent on NSF funding that is not specific to the needs of the collections themselves. Thus, there is unnecessary competition for funding, and this can hinder the development of better, sustainable business models. Overall, this group identified the first key step in developing alternative funding for living and nonliving collections as determining value, and using this to justify funding, more national coordination, and new sustainable business models.

Outcomes: Key Elements for Sustainable Infrastructure and their Importance

On day two of the workshop after the breakout group presentations, participants developed the following list of key elements for sustainable biological infrastructure in a plenary discussion.

<u>Standardization and Coordination</u>
Organization at a higher level would greatly enhance infrastructure sustainability. Increased coordination can create economies of scale by distributing costs among multiple organizations and projects. Higher levels of coordination can also contribute to establishing priorities and creating some strategic directions for biology, as well as creating new levels of investigation. Standardization will enable more communication and analysis between and among infrastructure projects. More organization and coordination will help engage stakeholders by making communication more effective.

<u>Understanding and Assessing Costs</u>
This is crucial to projecting and planning for the future, and is linked to defining the value proposition (below). Understanding costs helps create transparency to the user community and funders. Linking costs more directly to the activities they support is helpful for decision-making. A thorough analysis of both ongoing, daily costs and riskier innovative costs is vital for managers and infrastructure leaders to make informed decisions that enhance sustainability.

Public Outreach, Communication, and Reaching New Users

These are all key to increasing support for and use of infrastructure. Effective outreach and communication helps articulate the resource's public benefit and convey the project's value proposition. Reaching new, diverse users can help generate new ideas and revenue streams. All these efforts will ultimately increase the infrastructure's value and relevance.

Diverse Revenue Streams

Having various sources of revenue helps create more stability; if one source declines, other sources may help compensate. Infrastructure can no longer rely completely on grants and contracts, and in terms of long-term sustainability, it cannot rely on only one source of funding, particularly in the current economic climate.

Clear Value Proposition

A value proposition is more dynamic than a mission statement; it very clearly explains an organization's value, and it changes as the needs of the user community change. A single project can have more than one value proposition, and these can be tailored for different audiences (e.g., you may have one value proposition tailored for the general public, and another targeted at the scientific community). A clear value proposition defines who benefits from infrastructure, how they benefit, and how much. It can be used to justify why the resource is worth what it costs and provide some level of quantification. This statement can help define infrastructure products and services. It can be a way to deal with excitement decay, and convey how infrastructure addresses and supports exciting developments in the field.

Ongoing, Sustained Stakeholder Engagement

This is critical to a sustainable business plan, though engaging stakeholders continually can be costly, time intensive, and difficult to fund. Different stakeholders need to be engaged in different ways and require different incentives. Finding a balance and ensuring that no stakeholders are alienated is incredibly important. Stakeholder input can contribute to new ideas and services, and their effort and support can increase infrastructure's value and importance.

Next Steps: Continuing the Sustainable Biological Infrastructure Conversation

In the workshop's final session, participants endeavored to plan out next steps for advancing this conversation and making biological infrastructure more sustainable.

Who should be involved?

The workshop participants currently receive funding from a variety of sources and agencies. Though NSF plays a significant role in most of their projects, there seems to be a genuine need to involve more government agencies in future conversations. Important agencies identified in addition to NSF were: the National Institutes of Health and its various institutions, the Department of Energy, the Department of Defense, the Department of Agriculture, the Environmental Protection Agency, and the US Geological Survey. Important issues for these agencies to address could include how they serve the scientific community, what could happen if infrastructure ceases to exist, and how that could affect different stakeholders. Participants generally agreed that a large meeting with all agencies would not be effective. Instead, they proposed a series of conversations involving different agencies and stakeholders.

It also became clear, especially when planning strategic partnerships, creating new projects, and communicating messages and value, that other sectors need to be involved. Private companies, the business community in general, and business programs at educational institutions should be involved in

future efforts. They have expertise in marketing, business planning, and finance that would be invaluable to this conversation.

Recommendations

There will be a gap between needed and available resources. This workshop can help define a way forward, but in order for infrastructure to become less reliant on grant funding, and on single agency funding in particular, some level of initial financial and strategic support is needed. Finding the time and resources to investigate new business models, reach out to others who can help, and plan for the future is time intensive and may require interim funding.

For example, a useful first step could be to develop funding sources to help organizations create their own sustainable business plans, with the collaboration of experienced professionals. Another mechanism is additional workshops like this one to help identify strategies for success, and/or for research funders to support data archiving in all research grants in the same way that publication costs are funded.

How do we move forward?

The biological community is diverse, as is the infrastructure that supports it. Projects serve a variety of audiences, provide different services, and have funding from diverse sources. A vital question is how to effectively move this conversation forward despite these nuanced differences. The ideas below were introduced by various participants, and are listed in no particular order:

- **Determining scale is important.** We need to decide, in terms of next steps, what can be accomplished by individual projects and what needs more overarching coordination among the scientific community as a whole.

- **Future meetings to help projects develop their business models, communications, products, and services.** Communication is key, and getting marketing input from the commercial world would help. Projects could benefit from experts who could create a framework for approaching separate stakeholders and conveying messages effectively. Consultants with marketing experience, business skills, and basic scientific knowledge would be ideal to help with this endeavor, as would experts in product development.

- **Define the discipline.** There are a lot of directorates and programs emerging in the biological sciences. We could hold a workshop with case studies to determine which fields are doing well and begin to pull biology in those directions. Highlighting what is working well and how individual projects fit into the trend (and how they are different) can help reach new users. This effort could also be pulled into the case studies workshop or a workshop on how infrastructure impacts science, mentioned below.

- **Case studies and lessons learned workshop.** This workshop would involve many infrastructure project managers to discuss and present case studies. Examining the history of successful projects, how they have evolved, and the lessons learned could be useful and bring new information and sustainability approaches to the fore. Involving a Masters of Business Administration program with a nonprofit focus could help participants define business models and provide expertise that would make this meeting practical and productive.

- **Large workshop on how infrastructure impacts science.** This workshop could highlight success stories, lessons learned, and compare past, present, and potential future infrastructure endeavors. The workshop could include cutting edge science from different domains and infrastructure resource providers, with a goal of demonstrating the role of infrastructure in supporting the biological sciences. In order for infrastructure to continue enabling science, it needs to have the capacity to help address bigger questions. This workshop could help identify next steps: how to make infrastructure more valuable now, and how to transform it so we can be innovative in the future.

- **Workshop on archival issues.** This workshop would attempt to address barriers to digital archival storage and present potential solutions to ensure data is accessible and consistent. The workshop could also inform infrastructure project managers of best practices in terms of storing data efficiently. Increasing commitment from agencies and the scientific community to archival issues, and the ability to put more data into data.gov, would be invaluable.

- **Direct and in-depth meetings with agencies.** As mentioned above, there is a need to involve more agencies in this conversation. The most productive way to do this is likely to have a series of smaller conversations based on which agencies impact, use, and/or fund projects. Some participants questioned whether this would be a truly useful step, or if future efforts should be focused solely on opening up existing budget pools to new sources and ideas.

As a final next step, workshop participants are encouraged to continue this conversation and share ideas and this report with their colleagues and other infrastructure projects. This workshop has helped to define the problem and outline some possible strategies for sustainability of biological infrastructure. This is only a first step; more effort and coordination is needed in order to fully address the issue of infrastructure sustainability and ensure these valuable resources are available in the future to continue supporting the biological sciences and fostering innovation.

Appendix I: (Literature Cited)

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Appendix II: (Related Resources)

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Appendix III: (List of Workshop Participants)

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Appendix IV: (Pre-Workshop Survey Questions)

Definitions:

a) How do you define infrastructure?

b) How do you define sustainability? One definition: "sustainability is the ability to generate or gain access to the resources – financial or otherwise – needed to protect and increase the content's value for users." Is this a good definition? Please explain why it is or is not.

Background:

c) What types of costs (overhead, personnel, etc) are associated with sustaining research infrastructure? Please express as approximate percentages of your program's budget.

d) How are these costs tracked or monitored?

e) What are the key metrics for success in terms of the use of the research infrastructure in your program? How do you measure your impact – number of registered users, website hits, downloads, students trained, etc?

Managing for current and future sustainability:

f) What steps have you taken to develop revenue generating and/or cost management strategies?

g) How do these align with the program's mission (i.e., how are the metrics described in your response to (e) tied into assuring the long-term sustainability for the viability and utility of the research infrastructure in your program)?

h) To what extent are you successful in the revenue generating and/or cost management strategies and how do you define success?

i) Are you engaged in establishing a diverse portfolio of funding for the research infrastructure in your program? Are there effective partnerships you are involved in that could serve as models?
    1. Public-private partnerships?
    2. Multiple agency support?
    3. Where are the problems?