2012 Annual Report
Advanced Biomedical Information Technology Core

FY 2011/2012

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RESEARCH TECHNOLOGIES
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1. Executive summary

The Advanced Biomedical Information Technology Core (ABITC) is simultaneously a management unit of the Research Technologies (RT) division of University Information Technology Services (UITS) and a certified core of the IU School of Medicine (IUSM). ABITC is focused on providing information technology services and cyberinfrastructure facilities to support the demanding, and sometimes unique, requirements of researchers in the IU School of Medicine and allied health schools. As a management unit, it is part of the Science Community Tools group, whose focus is to provide software application development, development of virtual science organization and collaboration tools, access to national high throughput computing grids, support for genomics research, and operational support centers for research communities. As a certified core of the IU School of Medicine and the Indiana Clinical and Translational Sciences Institute (CTSI), the ABITC provides consulting and programming services for biomedical, translational, and clinical health researchers and also serves as a front door to all services provided by the Research Technologies division of UITS. These additional services include data storage, supercomputing, visualization and analytical support, and collaboration and engagement support. ABITC includes a total of 9.3 FTEs, of which 3.8 are base funded. Overall, more than 82 FTEs within the Research Technologies division provide services directly or indirectly that aid IUSM research and research education.

Indiana University (IU) offers two primary storage systems: the Scientific Data Archive, offering secure, replicated storage of data over long periods of time on tape; and the Data Capacitor, which offers large amounts of disk-based storage and extremely fast input / output for analysis of large and complicated data sets. As with other RT services, these systems are aligned with HIPAA – at the request of researchers from IUSM – so that IUSM researchers may store and analyze data on these systems including identifying references in electronic protected health information (ePHI). ABITC is responsible for maintaining alignment with the Health Insurance Portability and Accountability Act (HIPAA) for the storage of ePHI data. A unique aspect of IU's research storage systems is that data stored in the Scientific Data Archive are copied in duplicate – once to a tape library in Indianapolis, and a second time to a tape library in Bloomington. IU is the only university research computing center in the US to provide this capability. Five of the top 10 users of ABITC/RT storage services are within IUSM. Overall, data stored by IUSM researchers constitutes one-eighth (12.5%) of the total data stored by IU researchers.

Research Technologies provides, and ABITC supports, the use of several supercomputers to IU and IUSM. Overall, IUSM researchers used 6.3% of all of the supercomputer CPU (processor) hours used by researchers at IU. Two of the top 25 users of Big Red, three of the top 25 users of Mason, and one of the top 25 users of Quarry were IUSM researchers.

Computing centers tend to be good at counting things like terabytes used and teraflops of computing power consumed. Operational metrics, like number of databases supported, number of records in databases, and number of collaborations and studies enabled are often as or more important to researchers in the IU School of Medicine, but more difficult to count. Databases managed by ABITC hold hundreds of thousands of records and documents used in collaborative research led by the IU School of Medicine.

The Research Technologies Division Advanced Visualization Lab (AVL) provided critical assistance to the IU School of Medicine in several key areas. AVL continued its ongoing and integral involvement in the Collaborative Initiative on Fetal Alcohol Spectrum Disorders (CIFASD) Imaging Core. AVL staff are helping Neuroimaging Center staff acquire and install an IQ-Station, an interactive and immersive stereoscopic visualization environment. The IQ-Station was designed by the AVL as part of the Lab's effort to more widely distribute visualization resources throughout the IU campuses and state of Indiana. This system is being paid for by the Center for Neuroimaging, and because the Center is using an IU-designed system they are getting state-of-the art visualization capabilities at a fraction of the cost they would pay for a commercially provided system. AVL is also aiding allied health researchers in the Schools of Nursing and Dentistry.

ABITC provided extensive consulting help for IUSM researchers. During FY 11/12, the Advanced Biomedical Information Technology core in particular greatly increased its support for key IUSM research initiatives and for IUSM research generally. The ABITC concluded a total of handled a total of 64 extended consultations – consulting and programming projects that take from four hours to months of person effort. This is up significantly from a total of 27 extended consultations completed in FY 10/11. Another 23 extended consultations are ongoing into FY 2012/2013.

Critical grant-related projects taken on during FY 11/12 include the following – many of which are directly related to support of the Indiana CTSI project and the Indiana Biobank, including:

- The Indiana CTSI HUB. ABITC staff manage the Indiana CTSI HUB, which provides the central portal for translational research for the state of Indiana. ABITC staff have developed key service components on this HUB including federated identity support for trusted access, clinical trials listings, INResearch for volunteer trials recruitment, a grants management system for administering Indiana CTSI grant applications and awards, and i2iConnect – a national technology transfer service for licensing inventions. This HUB serves over 3,600 registered users across the state.
- REDCap (Research Electronic Data Capture) - ABITC has expanded its support for REDCap software, used to by researchers to quickly design and start small surveys and/or clinical studies in a HIPAA-aligned environment. This service supports over 900 research and administrative data management projects.
- Alfresco Share. ABITC has also expanded is support and services related to Alfresco Share an online collaboration tool that allows researchers to collaborate easily with colleagues from external institutions preparing reports, articles for publication, or grant proposals. This service shares over 34,000 documents for over 1,100 users.
- The new Indiana Biobank system. ABITC has been asked by the Indiana CTSI to oversee the implementation of the new Indiana Biobank that will provide specimen management as well as the ability to integrate with electronic medical records and genomic data to support the IUSM research program. A contract has been signed with Remedy Informatics for this system, and implementation is currently underway.
- Clinical Registry service implementation. ABITC has been asked by the Indiana CTSI to implement a Clinical Registry System to manage data from IU Health, Regenstrief's Indiana Network for Patient Care (INPC), and other local and national data providers to create cohort- or disease-based research registries. ABITC is currently involved in vendor selection and data integration planning, and expects to deploy the new system in 2013.
- Supporting Epidemiological Research. The ABITC was asked by the Regenstrief Institute to house a copy of the INPC database on its research database cluster and to provide access to its Quarry supercomputer to Observational Medical Outcomes Partnership (OMOP) program.
- Hosting Regenstrief Systems. The ABITC is playing an active role in the collaboration between UITS and Regenstrief that will result in hosting their systems in UITS facilities. Many of these systems will support access to clinical data for research and integration with biospecimen data.

The Collaboration and Engagement Support Group of Research Technologies supported the preparation of five grant proposals that resulted in awards to IUSM researchers during the current reporting period for a total of $3,793,034 in new awards to IUSM researchers. ABITC and RT generally supported a total of six ongoing grants led by IUSM faculty that were awarded prior to the current reporting period and remained active during the reporting period. New and continuing awards to IU Medical School researchers totaled $29,385,594 in awards to IU, supported by $615,000 in direct match from ABITC / IUSM. Three grants led by ABITC / RT staff totaling $6,082,815 directly aid research by IUSM faculty. In sum, activities of the Advanced Bioinformatics IT core and the Research Technologies division of UITS supported or led grant awards totaling $35,468,409 that aid the mission of the IU School of Medicine.

The annual UITS customer satisfaction survey provides an overall view of the IU community's satisfaction and usage of UITS services. This survey measures satisfaction on 1-5 Likert scale where 1 is "not at all satisfied" and 5 is "highly satisfied." The average satisfaction score for ABITC was 3.97 (±0.1). Just over 90% of the respondents gave a rating of 3 or higher – this is referred to as the "satisfaction %." Just over 5% of all IUSM researchers who responded to the survey used ABITC services directly (more use them indirectly via the Indiana CTSI portal). (Faculty, staff, and graduate students totaling 28.1% of IUSM researchers responded to the 2012 annual survey. This represents the responses of 133 individuals. The response rate was comparable to IUPUI overall – 30.0%). Other services used by IUSM researchers, including IU's supercomputers, the Scholarly Data Archive data storage system, and AVL all had average scores of greater than 4, and satisfaction % of greater than 90. Fifteen percent of respondents indicated that they used Research Technologies supercomputers, and twelve percent indicated that they use the Scholarly Data Archive. When asked *Overall, how satisfied are you with the UITS research technology services available at IUPUI?* IUSM researchers gave an average rating of 4.40, with a satisfaction rate of 95.6%. The percentage of IUSM researchers who indicated that they used some aspect of the services and support provided by ABITC and the Research Technologies division of UITS was 15.4%

Overall, during FY2012, ABITC provided critical services in support of IUSM – particularly in support of Indiana CTSI – that were well used and well liked by IUSM researchers. In several cases, ABITC and RT provided resources and services that are unique, or provided by at most one or two other universities to their medical schools as general resources. ABITC services have provided critical direct and indirect benefits to the research and research education missions of IUSM, particularly in support of some of IUSM's high priority grant-funded projects such as the Indiana Clinical and Translational Studies Institute. During this reporting period, ABITC and Research Technologies were in the process of acquiring major new supercomputer and disk storage facilities which will create new and greater opportunities to provide services to IUSM during FY2013 and beyond.

2. History of the Advanced Biomedical Information Technology Core

The Indiana University School of Medicine has a long and storied history of important contributions to medical research and medical treatment – fundamental discoveries about alcoholism and a critical role in locating the genes for Huntington's disease on human chromosomes are two of the most well-known contributions of one of the largest and best medical schools in the world. Indiana University also has a storied history in advanced computing in support of research, including critical contributions to compiler, language, and grid computing development. IUSM's history is primarily on the Indiana University – Purdue University Indianapolis (IUPUI) campus. IU's history in advanced computing was made mostly on the Bloomington (IUB) campus. These histories and critical accomplishments proceeded largely independently until late 1999. During the fall of 1999 IUSM led the preparation of a historic grant proposal to the Lilly Endowment for $105M in support of the Indiana Genomics Initiative (INGEN). The opportunity to submit this proposal was based on historic progress toward the sequencing of the human genome by the Human Genome Project and in part by IU's early success with the Lilly Endowment grant to IU for the Indiana Pervasive Computing Research (IPCRES) initiative, which helped create the Pervasive Technology Labs. Staff of University Information Technology Services and the Office of the Vice President for Information Technology played a critical role in writing the INGEN proposal, and it included significant funding for advanced information technology services and facilities in support of biomedical research. Prior to the advent of the INGEN grant, IUSM used few if any of the research facilities offered by the central IT organization of IUPUI or IU as a whole (after the 1997 reorganization of central IT functions at IUPUI and IUB into University Information Technology Services). Believing the basic information technology (IT) infrastructure within IUSM to be in excellent condition in both systems and support, the computing staff participating in the INGEN grant proposal development focused on advanced IT capabilities and next-generation, supercomputer-aided biomedical research. UITS

involvement in INGEN provided early headlines and tangible progress at times when not all parts of the project were moving quickly. The INGEN IT Core, as ABITC was known then, provided very deep expertise and extensive consulting to a few researchers at IUSM who were in a position to take advantage of those capabilities. This core became the first core facility ever certified by IUSM as an IUSM core but outside the organizational umbrella of IUSM. However, at a very fundamental level there was a mismatch between the services the INGEN proposal called for UITS to provide and the service most IUSM researchers needed in 2000. From 2000 through 2003 there was steady and significant improvement in the matching of IT services and IUSM needs under the direct leadership of Craig Stewart – then Director of Research and Academic Computing and a member of the INGEN Operations Committee. Faculty recruiting by IUSM, some of which was funded by INGEN, resulted in new faculty arriving at IU with more sophisticated and extensive computer needs. Starting in 2003, a reorganization of UITS leadership positions (stemming from what was ultimately a terminal illness suffered by one of the leaders and a reallocation of Stewart's time away from IUSM) resulted in a significant setback in the UITS – IUSM research information technology relationship. A subsequent reorganization assigned Dr. Eric Wernert (now a Research Technologies director) to manage and improve this relationship. It was under Dr. Wernert that UITS first began efforts to align with HIPAA so that ePHI could be stored and analyzed on UITS research IT systems. Some early history of these efforts is described in publications by ABITC staff [1-5].

In 2007, Dr. William K. Barnett was hired as Senior Manager for Life Sciences. Dr. Barnett and the rest of the Research Technologies leadership have been working since then to continue to improve services and expand collaborations, and disseminate knowledge of both, throughout IUSM. In 2011 Dr. Barnett was promoted to Director of Research Technologies (Science Community Tools) in the Research Technologies division of UITS. The INGEN IT Core was renamed the Advanced Biomedical Information Technology Core (ABITC).

At present, the following are both fair assessments of the services that ABITC offers to the IU School of Medicine:

- ABITC, the Research Technologies division of UITS, and UITS generally provide excellent services to IUSM – many of which are without parallel at other medical schools.
- The group of IUSM researchers who know about ABITC, have needs that match ABITC services, and make use of ABITC services is still smaller than it could be and smaller than it should be for IUSM to achieve the strategic goals it has set for itself.

In this report, we provide information on services provided by ABITC and the Research Technologies division of UITS to the IU School of Medicine and the uses of those services to achieve new advances in biomedical and clinical/translational research.

3. Description of services provided by the ABITC and Research Technologies to the IU School of Medicine

3.1. Service summary descriptions

As a research core of the IU School of Medicine and a management unit of the Research Technologies division of UITS, the goal of the Core is to provide information technology solutions to problems confronted by health care research labs, partner in innovative approaches to medical research through consulting and programming staff of the Core, and enable researchers in IUSM and allied health fields to make use of the full capability and breadth of IU's advanced cyberinfrastructure. Critical services provided by ABITC and RT include:

- Storage of critical research data

- Central storage of working data that can be made visible on computers distributed around the lab or campus. All data are backed up daily.
- Free archival storage of up to 10 terabytes of data per project. All data are replicated between Bloomington and Indianapolis.

- High performance computing
  - Supercomputers for computational and data-intensive analyses such as BLAST, image analysis, and gene or protein analyses, as well as large memory supercomputers supporting sequence assembly using data from next-generation sequencers.
- Visualization
  - Equipment, software, and technical expertise to display medical information in two, three, and four dimensions.
- Virtual servers
  - Virtual servers housed, maintained, and backed up by UITS, with a 99.99% uptime guarantee, over which a department or group has complete control.
- Management, analysis, and dissemination of research data
  - Creation of information workflows that allow easy, standards-based data entry, management, analysis, and dissemination of research data through web environments. These environments can grow with projects as researchers bring in national or international collaborators.
- Access to national computational grid environments
  - Active participation in the TeraGrid and other national cyberinfrastructure facilities; a doorway to the use of these as either a resource provider or consumer.
- Strategic partnering in grant solicitation
  - ABITC has an established record of making research more competitive and productive, and bringing to bear the advantages of a major university technology program to provide an advantage.

The IU School of Medicine has a number of units that supply information technology services and support, such as Information Services and Technology Management (ISTM), the Bioinformatics Core within the Center for Computational Biology and Bioinformatics, the Biostatistics Core in the Division of Biostatistics, and individual departmental or research groups. Many of these groups have deep, world-class expertise in particular algorithms and software. ABITC has the capacity to implement these and other advanced information technology services at scale. ABITC and Research Technologies provide IUSM with HIPAA-aligned storage in amounts without comparison at any other medical school in the US. ABITC can also implement and deliver advanced computational services via the largest university-owned, university-funded supercomputer in the US. ABITC delivers visualization capabilities that match the most sophisticated capabilities at any medical school of sensitive government agency in the US.

3.2. Changes in organizational structure during FY 2011/2012

During FY 2011/2012 there were changes in the name and structure of the Advanced Biomedical IT Core and in the structure and activities of the Research Technologies division of UITS in support of the research of IUSM and IU's allied health schools.

RT was significantly reorganized. It is now subdivided into four components, all of which deliver services to IUSM:

- Science Community Tools (led by Director Dr. William K. Barnett, also Director of ABITC)
- Research Systems (led by Director Matthew Link)
- Visualization and Analytics (led by Director Eric Wernert)
- Collaboration and Engagement Support (led by Therese Miller)

The management groups within Research Technologies that specifically serve IUSM and biomedical / life sciences research are as follows:

- The Advanced Biomedical Information Technology Core (https://pti.iu.edu/rtl/aitc), led by manager Ganesh Shankar. This group is funded by a variety of sources, most particularly IU general funds; subcontracts from and administrative supplements to the Indiana CTSI grant award; and a variety of other grant awards to IUSM (with subcontracts to ABITC) or led by UITS. ABITC is the point of contact for all RT services related to clinical research, translational research, and support geared toward researchers funded by the National Institutes of Health. The Advanced Biomedical Information Technology Core was renamed to clarify that the advanced IT services provided were specifically in support of biomedical research – not just "advanced" in any number of ways that IT services could be advanced.
- The National Center for Genome Analysis Support (NCGAS – http://ncgas.org) is largely funded by a grant award from the National Science Foundation (NSF) to provide genome analysis services to the US national research community, particularly NSF-funded researchers. With IU general funds, NCGAS also provides support to healthcare researchers at IU.
- The Collaboration and Engagement Support group routinely supports grant proposal development and writing by researchers of IUSM and allied health fields.

Because ABITC serves both as a consulting / service / programming organization for IUSM and other health-related schools at IU, and as a front door to other services RT offers, we describe both aspects of our services in this report. In the following sections, we describe consulting / programming services provided to IUSM directly via ABITC; computational, storage, and visualization resources; support for grant proposal development; and evaluation of ABITC services.

3.3. Highlights of ABITC consulting and programming activities during FY2011/2012

One of the critical and most visible services offered by ABITC to IUSM and to the state of Indiana is delivery of the online collaborative home of the Indiana CTSI. ABITC took over the delivery of the web portal for the Indiana CTSI project in 2007. What was originally referred to as the web portal in the original grant proposal documents has now been named the Indiana CTSI HUB (http://www.indianactsi.org/). This online hub serves as the central online collaboration framework for all of the partners in the Indiana CTSI project – at Indiana University, Purdue University, and the University of Notre Dame. The Indiana CTSI project is now the clear leader in delivery of online collaboration and translational research workflow tools in support of the National Institutes of Health (NIH) Clinical and Translational Science Award (CTSA) program, and the CTSI HUB represents the state of the art in information technology systems that support collaboration and operation of a CTSA-funded project.

The "hub" in the CTSI HUB name derives from the underlying software used to power this collaboration tool – called HUBzero (http://hubzero.org). HUBzero is an open source software suite created and supported by a not-for-profit foundation. The HUBzero Foundation is led principally by Purdue University, with IU as a charter member. IU has played a particularly important role within this foundation to ensure that the software is properly licensed as open source software, that it is well maintained, and that in any event IU retains the rights and capabilities to continue using HUBzero no matter what becomes of the HUBzero Foundation in the future. This involvement in the software production and the organization that supports HUBzero is a critical aspect of ABITC's ability to support CTSI in ways that are convenient to the researcher. For example, when a researcher wishes to access the CTSI HUB, s/he goes to a login screen and is taken to the online authentication (login) screen for his or her own home institution. This means that researchers using the CTSI HUB do not need to remember a separate username and password for it. It also means that security is extremely high – as people are added to or leave a partner institution, their ability to access the CTSI HUB changes automatically with their status at their home institution. The software that implements this important ease-of-use capability was developed and implemented by ABITC programmers and is the most extensive of any CTSA program in the nation, supporting 20 institutions including the NIH and IU Health. (Within IT circles, this is termed

federated identity management, and complies with important directions set for IT services generally by the NIH.)

Less obviously visible, but also critical, ABITC manages HIPAA compliance activities for all research services and infrastructure offered by UITS and used by IUSM and other health researchers. IU was the first supercomputer center in the US to have the ability to manage and analyze ePHI in alignment with HIPAA on its supercomputers. This review and certification process was done in response to requests from IUSM researchers, and was completed and approved by University Counsel in January 2010. Today, there are only two supercomputer centers in the US with this capability (the other is the San Diego Supercomputer Center at University of California San Diego).

IU's services in support of management and analysis of ePHI have been expanded and support increased during the past year in several ways. Most particularly, during the past year, we have expanded the HIPAA-aligned services available through CTSI as follows:

- **REDCap (Research Electronic Data Capture** - http://redcap.uits.iu.edu). ABITC has expanded its support for REDCap software. As its name implies, REDCap enables researchers to quickly design and start small surveys and/or clinical studies in a HIPAA-aligned environment. Using the REDCap service allows an investigator to decrease the time, effort, and cost of starting a clinical study and is particularly valuable in exploratory or early phase studies. REDCap software (http://project-redcap.org) is supported by a consortium of more than 500 institutions, with a license from its originators at Vanderbilt University to IU (as a REDCap foundation member) that allows us to use the software in perpetuity. To date 907 projects have been conducted using REDCap, with 491 of them initiated by IUSM researchers in FY 11/12.
- **Alfresco Share.** ABITC has also expanded is support and services related to Alfresco Share (http://alfresco.uits.iu.edu), an online collaboration tool. Alfresco Share software (http://alfresco.com) allows researchers to collaborate easily with colleagues from external institutions preparing reports, articles for publication, or grant proposals. Using the CTSI HUB's federated authentication mechanism, users from over twenty organizations can log in using their institutional identity. Alfresco Share allows for the creation of group collaboration spaces and sharing of documents. Alfresco Share currently houses 34,793 documents including 23,516 word processing documents, 4,182 spreadsheet, and 7,096 PDF files. It has been used by 1,125 users in support of grant proposal writing.
- **HIPAA security plan and documentation updates.** HIPAA requires that security documentation and alignment plans are constantly updated as services change, and are comprehensively updated every six months through review of all technical, physical, and administrative controls for each service. During 2011-2012, ABITC began coordinating HIPAA alignment for three new clinical research systems: the Indiana Biobank, the CTSI Clinical Trials Management System, and the CTSI registry system. ABITC is also coordinating alignment among all UITS systems that manage HIPAA implicated data and will be coordinating the same support for the Regenstrief Institute as they move their systems into UITS data centers.
- **The Indiana Biobank.** ABITC has been asked by the Indiana CTSI to oversee the implementation of the new Indiana Biobank that will provide specimen management as well as the ability to integrate with electronic medical records and genomic data to support the IUSM research program. A contract has been signed with Remedy Informatics for this system, and implementation is currently underway.
- **Clinical Registry service implementation.** ABITC has been asked by the Indiana CTSI to implement a Clinical Registry System to retrieve data from IU Health, Regenstrief's Indiana Network for Patient Care (INPC), and other local and national data providers. This is an especially exciting development of IU health-related research and medical care because these registries are critical to patient cohort or disease-based prospective studies and for subsequent clinical research project data management. IU Health has expressed interest in using them for quality studies that are

important for demonstrating meaningful use. ABITC is currently involved in vendor selection and data integration planning, and expects to deploy a new system in 2013.

- **Supporting Epidemiological Research.** The ABITC was asked by the Regenstrief Institute to house a copy of the INPC database on its research database cluster and to provide access to its Quarry supercomputer to run experiments (SAS routines) as part of the Observational Medical Outcomes Partnership (OMOP) program. The ability to manage and analyze this 26-terabyte data set put Regenstrief Institute in a position to effectively partner in this national effort.

Other service improvements related to the Indiana CTSI project include:

- **ABITC improved the CTSI Grants Management System** in September 2012. This system allows the CTSI to manage and administer grants it sponsors by enabling the grant administrator, reviewers, and applicants to interact in an organized fashion during the application and award process. During the current reporting period, the functionality of this software was improved by enabling reviewers to collaborate with each other and administrators to more closely monitor the review process. The software was also enhanced with advanced reporting capabilities that help the CTSI administrators create multiple reports within and across multiple grants. This is a unique software tool that will be contributed back to the Clinical and Translational Science Awards (CTSA) community as an open source release. During the 2011-2012 year, the grant system managed a total of 522 applications for 29 CTSI grant awards. It has managed 1,648 since its inception in 2009.

The above services represent the predominant informatics contributions of the Indiana CTSI since its inception in 2007, in addition to national leadership provided by the ABITC director, Dr. Barnett, in the Informatics and Communications Key Function Committees. Without this leadership and these activities, the Indiana CTSI would not be competitively positioned for renewal this year.

Major improvements in general services and capabilities include:

- **ABITC has adopted use of a ticket tracking system** to manage client contacts and research collaborations. Researchers and students requesting help can send email to rtls@iu.edu, or to hubsupport@indianactsi.org for Indiana CTSI support issues. Contacts, problems, consultations, and collaborations are subdivided into short-term and long-term consultations. In either case, a person sending a request for help receives an automated reply almost immediately and a follow-up email or phone call within 24 hours.

  Short-term consultations are relatively straightforward questions or problems that can be resolved in a matter of less than about four hours of staff time and within one to three days. While a problem is being worked on status information is relayed to the scientist or student with the problem at least once every three days. Long-term consultations are often requests for new features or requests for research collaborations that go on for weeks or months. Use of the trouble ticket system ensures consistency and enables a team-based approach to such collaborative activities.

The Indiana CTSI will adopt this customer problem / trouble ticket system across all Indiana CTSI programs and service cores in 2013 as part of its improved tracking and evaluation effort. This will provide Indiana CTSI with a consistent and integrated system for tracking and evaluating its activities.

- **Major upgrade to IU supercomputing and storage resources.** Indiana University recently reached a major milestone in a project that has been going on for 18 months – major upgrades to IU's supercomputer and storage resources. IU announced a major upgrade to its research cyberinfrastructure with the acquisition of Big Red II, a 1 petaflops Cray supercomputer; and the Data Capacitor II, an extremely fast data storage system holding a total of five petabytes of data. Big Red II will be the first university-owned, university-funded supercomputer capable of more than a petaflops of calculating capability – that is, one thousand trillion mathematical operations per second. To put this in context, if a person were to perform one mathematical operation per second

with a hand calculator, it would take more than 20 trillion years to do what Big Red II will be able to do in one second.

The Data Capacitor II disk storage system will be a major upgrade to IU's storage infrastructure. It will be put into production in early 2013. Data Direct Networks will provide the hardware and partner with IU to implement this system, which will be operated with the Lustre® open source parallel file system. This will increase the ability of IU storage systems to read and write data up to 50GB/s – two and a half times the speed of the existing Data Capacitor system. DDN will also provide a new file system for home directories that will be geographically replicated and fault tolerant – if a researcher accidentally deletes a file that they need, it will be possible to recover that file for a period of a few hours to 30 days.

These systems were implemented based on extensive analysis of the needs and research requirements of the IU community generally, including IU School of Medicine faculty. Among the people who offered opinions about the new system were Dean Brater and Dr. Andrew Saykin:

- *D. Craig Brater, dean, IU School of Medicine* – **"**Having been involved in the evolution of IU's advanced computing environment since the beginning of INGEN in 2000, I have seen how advanced computing has become more and more critical to medical research and innovation, and watched as the IU computational resources have been deployed in ways that are more and more valuable to IU medical research. Big Red II will be a critical and strategic aid to accelerating new medical breakthroughs and enabling research that will improve human health."
- *Andrew J. Saykin, Raymond C. Beeler Professor of Radiology* – **"**Data sets of unprecedented scope can facilitate new discoveries regarding the brain, genome, disease and therapies but computational power has become a major bottleneck to scientific progress. To analyze the entire human genome in relation to longitudinal changes on brain MRI and PET scans in over 800 individuals we need an order of magnitude more computing power than available today. The new [supercomputer] is an exciting development that will undoubtedly enable new discoveries my many investigators at IU and beyond."

A critical aspect of the new Big Red II Cray supercomputer and Data Capacitor II is that they will be implemented in ways that enable researchers to analyze larger data sets than ever before, in ways that are easier for the researcher than ever before. These new systems will be of particularly dramatic value to IUSM bioinformaticians, radiologists, brain scientists, and neurologists as well as in support of the IUSM Biobank initiative, which will use UITS storage for managing genomics data linked to specimens and Big Red II and Mason for the analysis of gene sequence data.

3.4. National Center for Genome Analysis and Support activities, METACyt, high throughput computing, and services delivered to IUSM

To help address the scientific challenges of understanding this new wealth of gene sequence information, the National Science Foundation awarded Indiana University a $1.5-million grant (NSF Award #1062432 - *ABI Development: National Center for Genome Analysis Support*) to establish NCGAS. Through IU funding, NCGAS also offers support for all researchers within the IU community, including IUSM. As mentioned above, NCGAS is a Research Technologies management unit that offers services to IUSM researchers, with ABITC serving as a point of contact for IUSM and a source of information and help for IUSM researchers regarding these services.

NCGAS is just completing its first year of activities. This first year has been primarily a year of building services, with several new services implemented during the past year. These are not yet widely used by IUSM researchers, but ABITC and NCGAS plan to promote them heavily during FY 12/13. These new services include:

- The new Mason cluster is a large memory cluster with 16 nodes, each with 512 TB of RAM (random access memory). While the processing power is modest (3 teraflops), this system provides exactly the sort of computing environment needed to do genome assembly with next generation sequencers.
- To make the Mason system easier for researchers to use, IU is implementing a web-based genome analysis workflow tool called Galaxy (http://galaxyproject.org). Galaxy is widely regarded as the state of the art in user-friendly interfaces for genome analysis and bioinformatics. IU's web interface for Galaxy is online at http://galaxy.indiana.edu. This new interface was implemented with partial funding support from the Indiana Metabolomics and Cytomics (METACyt) Initiative and is an important example of a METACyt-funded service that will benefit IUSM. A screen shot of IU's Galaxy interface is shown below in Figure 1.

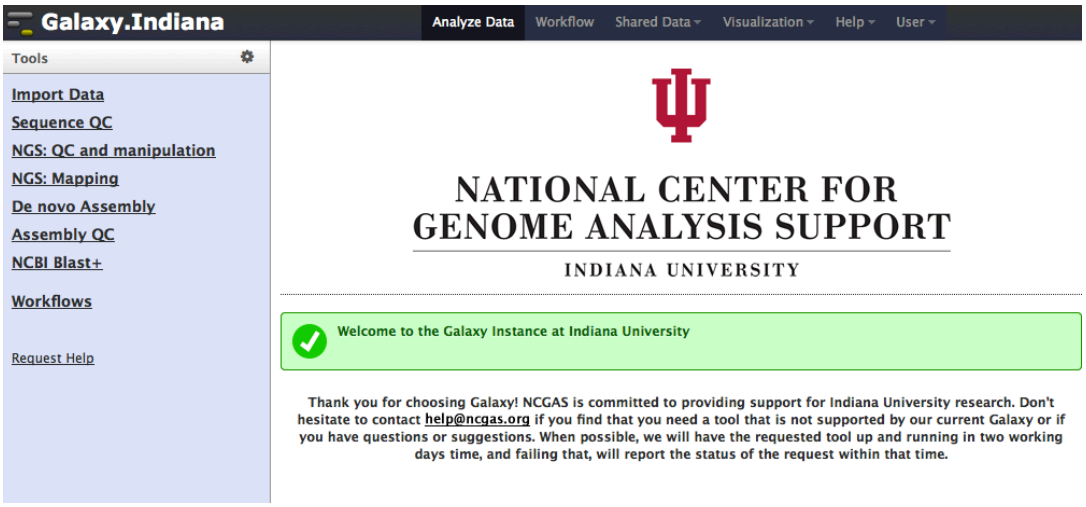

Figure 1. Web-based graphical user interface implemented by NCGAS, to make access to IU's Mason cluster for genomic and bioinformatics research easier for the practicing biomedical researcher.

- Rob Quick, manager of RT's High Throughput Computing group, has been working to create an easy-to-use computational "back end" for Dr. Samy Meroueh's SPLINTER (Structural Protein-Ligand Interactome) service. The web portal for the SPLINTER service (http://www.biodrugscreen.org/) is shown in Figure 2. Mr. Quick has created a transparent job manager that executes computations on behalf of users of SPLINTER on Mason and other servers operated by Research Technologies, so that researchers can perform protein analyses without needing to manage the details of what computer systems are used to perform the analyses. This service was been implemented as a prototype during the current reporting period, and RT expects to convert it to a production service in FY 12/13.

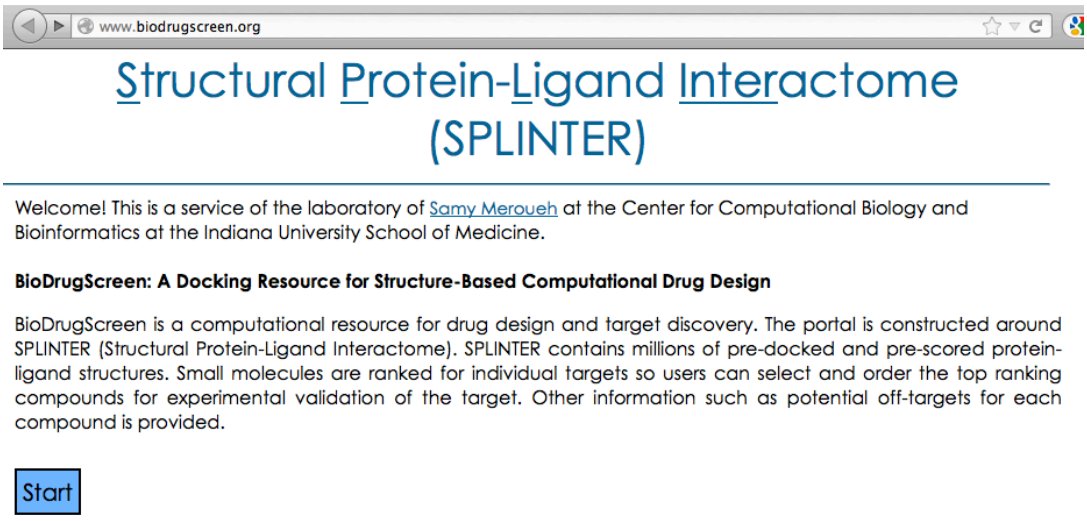

Figure 2. Web-based interface to Dr. Samy Meroueh's SPLINTER service.

NCGAS has had a particularly significant early accomplishment in support of IUSM researchers with Dr. Andrew Saykin. Dr. Saykin is a national leader in the Alzheimer's Disease Neuroimaging Initiative (ADNI). ADNI will store the full human genomes of 808 people, and use this genomic data in conjunction with brain imaging data and behavioral assessments to identify linkages between genome variations and Alzheimer's disease. Thanks to Dr. Saykin's leadership, and NCGAS and RT's ability to provide resources, IU will be one of the three national data repositories for ADNI. This means that IU's high performance and robust storage system will enhance the national infrastructure of ADNI. In addition, Dr. Saykin and other IU researchers will have particularly good capability to analyze these valuable data because they will be stored at IU, on IU computer systems. Being a national genomics repository also positions IU strategically for future genomics research collaborations.

4. ABITC / Research Technologies service use metrics

The IU School of Medicine is a major user of the overall services provided by the Research Technologies division of UITS to Indiana University as a whole.

4.1. Storage resource use

Indiana University offers two primary storage systems: the Scientific Data Archive, offering secure, replicated storage of data over long periods of time on tape; and the Data Capacitor, which offers large amounts of disk-based storage and extremely fast input / output for analysis of large and complicated data sets. As with other Research Technologies services, these systems are aligned with HIPAA – at the request of researchers from IUSM – so that IUSM researchers may store and analyze data on these systems including identifying references in ePHI. IU was the first institution in the US with high performance storage systems and supercomputers that are aligned with HIPAA, allowing analyses of ePHI without the encumbrance of having to de-identify these data. To the best of our knowledge, we remain one of just two public institutions in the US with this capability.

A unique aspect of IU's research storage systems is that data stored in the Scientific Data Archive are copied in duplicate – once to a tape library in Indianapolis, and a second time to a tape library in Bloomington. IU is the only university research computing center in the US to provide this capability. These storage systems are described in more detail in section 8.4.

Overall, data stored by IUSM researchers constitutes one-eighth (12.5%) of the total data stored by IU researchers. Five of the top 10 users and seven of the top twenty-five users of ABITC/RT storage services are within IUSM. During the past year, there has been continued growth in use of UITS Research

Technologies storage systems by IUSM researchers. Table 1 shows IUSM usage and overall usage of the Scientific Data Archive. Table 2 shows the representation of IUSM researchers among the top 25 users of the Scientific Data Archive.

System	Total storage capacity	PB currently in use overall	PB of data stored by IUSM researchers	% of total storage used by IUSM researchers
Scientific Data Archive (tape storage)	15.0	9.0	1.20	13.0%
Data Capacitor (spinning disk storage)	1.5	.9	.037	2.4%
Aggregate storage use (tape + disk)	**16.5**	**9.9**	**1.237**	**12.5%**

Table 1. Usage of IU storage systems for FY 2011/2012, showing usage by IUSM. (*A petabyte (PB) is a trillion bytes – a stack of CDs containing a PB of data would be more than a mile.high)

	Top users of Scientific Data Archive as ranked by amount of data stored		
	Campus/School	**Dept.**	**TB in use**
1	IUB-nonIUSM	Chemistry	1258
2	IUB-nonIUSM	Library & Information Sciences	1187
3	IUB-nonIUSM	Astronomy	937
4	IUB-nonIUSM	Genomics and Bioinformatics	842
5	**IUPUI-IUSM**	**Dept of Biostatistics**	**616**
6	**IUPUI-IUSM**	**Public Health**	**406**
7	IUB-nonIUSM	Vice Pres Information Technology	399
8	**IUPUI-IUSM**	**The Center for Bioinformatics**	**212**
9	**IUPUI-IUSM**	**Radiology and Imaging Sciences**	**200**
10	**IUPUI-IUSM**	**Medical and Molecular Genetics**	**190**
11	IUB-nonIUSM	Geology	186
12	IUB-nonIUSM	Music	134
13	IUB-nonIUSM	Computer Science	108
14	IUB-nonIUSM	Libraries	198
15	IUB-nonIUSM	Dentistry Admin Services	80
16	**IUPUI-IUSM**	**Information Services Technology**	**73**
17	External	Grant funded	73
18	**IUPUI-IUSM**	**Biochemistry/Molecular Biology**	**69**
19	IUB-nonIUSM	Archives of Traditional Music	65
20	IUB-nonIUSM	Education	64
21	IUB-nonIUSM	Physics	55
22	IUB-nonIUSM	Indiana University Press	54
23	IUB-nonIUSM	Biology	54
24	IUB-nonIUSM	Informatics	46
26	IUB-nonIUSM	Sociology	40

Table 2. Top users of IU storage systems for FY 2011/2012, showing usage by IUSM. IUSM researchers vs. other are indicated in bold.

4.2. Computational resources and usage

Indiana University offers a variety of important major computing systems supported and delivered to the university community as a whole, including the Big Red supercomputer, the Quarry cluster, and the Mason large memory cluster. These systems are described in more detail in section 8.3. During the past year, there has been continued growth in use of UITS Research Technologies supercomputers and clusters by researchers in the IU School of Medicine. Table 3 below shows IUSM usage and overall usage of IU's main supercomputers. The three tables that follow show the representation of IUSM researchers among the top 25 users of Big Red, Mason, and Quarry.

IUSM researchers consumed more than 7% of the CPU hours utilized on Big Red. Overall, IUSM researchers used 6.3% of all of the supercomputer CPU (processor) hours used by researchers at IU. Two of the top 25 users of Big Red, three of the top 25 users of Mason, and one of the top 25 users of Quarry

were IUSM researchers. (This matches utility to IUSM, with Quarry being the system least well matched to IUSM needs and at the same time most heavily used by physicists and chemists).

System	Processing capability (teraflops*)	CPU hours used IU overall	CPU hours used by IUSM researchers	% of CPU utilization by IUSM researchers	Total number of jobs run IU overall	Number of Jobs run by IUSM researchers	% of jobs run by IUSM researchers
Big Red	40	26,598,400	1,918,920	7.21%	571,690	40,817	7.14%
Quarry	26	13,337,400	613,088	4.59%	1,505,721	21,127	1.40%
Mason	4	1,000,490	47,901	4.79%	27,800	1,109	3.99%
Aggregate Overall	70	40,936,290	2,579,909	6.3%	2,105,211	63,053	3.00%

Table 3. Usage of IU supercomputer clusters for FY 2011/2012, showing usage by IUSM. (*One teraflops is a trillion floating point operations per second.)

Overall, IUSM researchers made relatively greater use of Big Red than Quarry or Mason. The primary causes of this are as follows:

- The overall architecture of Big Red is better suited to the types of high performance computing tasks done by IUSM researchers than the Quarry cluster (which is used heavily by physical scientists).
- Mason is a large memory cluster and was purchased in association with an NSF award supporting genome assembly. Most of the current Mason nodes are dedicated to use by NSF-funded researchers as a result. However, the architecture of Mason is potentially very useful to a segment of the IUSM research community and we are pursuing NIH funding to expand this system in support of NIH-funded researchers.
-

	Top users of Big Red (as ranked by CPU utilization)		
	Campus / School	**Department**	**CPU hours used**
1	IUB-nonIUSM	Chemistry	3,816,482
2	IUB-nonIUSM	Chemistry	2,635,452
3	External to IU (grant funded)		2,630,722
4	IUB-nonIUSM	Chemistry	2,278,189
5	IUPUI-nonIUSM	Engineering & Technology	1,985,547
6	IUPUI-nonIUSM	Chemistry	1,915,769
7	IUB-nonIUSM	Chemistry	1,284,456
8	**IUPUI-IUSM**	**Biochemistry/Molecular Biology**	**1,033,028**
9	IUPUI-nonIUSM	Chemistry	747,403
10	**IUPUI-IUSM**	**The Center for Bioinformatics**	**721,577**
11	IUB-nonIUSM	Chemistry	540,466
12	IUB-nonIUSM	Physics	537,921
13	IUB-nonIUSM	Physics	528,653
14	IUB-nonIUSM	Chemistry	520,544
15	IUB-nonIUSM	Chemistry	440,307
16	IUB-nonIUSM	Chemistry	333,005
17	IUB-nonIUSM	Informatics	303,166
18	External to IU (grant funded)		287,598
19	IUB-nonIUSM	Public & Environmental Affairs	282,452
20	External to IU (grant funded)		276,541
21	IUB-nonIUSM	Chemistry	265,013
22	IUB-nonIUSM	Chemistry	259,309
23	IUPUI-nonIUSM	Mechanical Engineering	236,378
24	IUB-nonIUSM	Chemistry	227,576
25	IUB-nonIUSM	Chemistry	207,597

Table 4. Top 25 users of CPU hours on Big Red for FY 2011/12. IUSM researchers are indicated in bold.

	Top users of Mason (as ranked by CPU utilization)		
	Campus / School	**Dept.**	**CPU hours used**
1	IUB-nonIUSM	Biology	157,731
2	IUB-nonIUSM	Office of VP for Info Tech	140,386
3	IUB-nonIUSM	Informatics	86,688
4	IUB-nonIUSM	Genomics and Bioinformatics	71,392
5	IUB-nonIUSM	Biology	68,502
6	IUB-nonIUSM	Genomics and Bioinformatics	51,044
7	IUB-nonIUSM	Office of VP for Info Tech	46,826
8	IUPUI-nonIUSM	Mathematics	41,452
9	IUB-nonIUSM	Office of VP for Info Tech	35,451
10	IUB-nonIUSM	Physics	35,143
11	IUB-nonIUSM	Office of VP for Info Tech	31,384
12	IUB-nonIUSM	Office of VP for Info Tech	23,590
13	IUB-nonIUSM	Office of VP for Info Tech	22,665
14	IUB-nonIUSM	Genomics and Bioinformatics	22,599
15	IUB-nonIUSM	Biology	21,693
16	**IUPUI-IUSM**	**Medical & Molecular Genetics**	**17,062**
17	**IUPUI-IUSM**	**Medical & Molecular Genetics**	**16,235**
18	IUB-nonIUSM	Informatics	11,541
19	IUB-nonIUSM	Office of VP for Info Tech	10,395
20	IUPUI-nonIUSM	Office of VP for Info Tech	9,831
21	IUB-nonIUSM	Office of VP for Info Tech	8,403
22	**IUPUI-IUSM**	**Medical & Molecular Genetics**	**8,140**
23	IUB-nonIUSM	Center for Exploration of Energy & Matter	7,985
24	IUB-nonIUSM	Office of VP for Info Tech	7,287
25	IUB-nonIUSM	Genomics and Bioinformatics	6,276

Table 5. Top 25 users of CPU hours on Mason for FY 2011/12. IUSM researchers are indicated in bold.

	Top users of Quarry (as ranked by CPU utilization)		
	Campus / School	**Dept.**	**CPU hours used**
1	IUB-nonIUSM	Informatics	2,667,373
2	IUB-nonIUSM	Informatics	2,185,031
3	IUB-nonIUSM	Biology	518,461
4	IUB-nonIUSM	Office of VP for Info Tech	501,996
5	IUB-nonIUSM	Chemistry	345,274
6	IUB-nonIUSM	Informatics	340,772
7	IUB-nonIUSM	Biology	333,928
8	IUB-nonIUSM	Chemistry	325,431
9	IUB-nonIUSM	Chemistry	308,592
10	IUB-nonIUSM	Chemistry	297,015
11	IUB-nonIUSM	Center for Exploration of Energy & Matter	283,018
12	IUB-nonIUSM	Chemistry	245,121
13	IUB-nonIUSM	Physics	231,723
14	IUB-nonIUSM	Chemistry	222,566
15	IUB-nonIUSM	Statistics	193,675
16	IUB-nonIUSM	Chemistry	179,736
17	IUB-nonIUSM	Chemistry	150,763
18	IUPUI-nonIUSM	Chemistry	148,294
19	IUB-nonIUSM	Informatics	140,715
20	**IUPUI-IUSM**	**Radiology & Imaging Sciences**	**139,122**
21	IUB-nonIUSM	Informatics	137,109
22	IUB-nonIUSM	Informatics	119,760
23	IUB-nonIUSM	Chemistry	115,975
24	IUPUI-nonIUSM	Chemistry	115,662
25	IUB-nonIUSM	Chemistry	111,375

Table 6. Top 25 users of CPU hours on Quarry for FY 2011/12. IUSM researchers are indicated in bold.

4.3. Databases and collaboration systems supported

Computing centers tend to be good at counting things like terabytes used and teraflops of computing power consumed. Operational metrics, like number of databases supported, number of records in databases, and number of collaborations and studies enabled are often as or more important to researchers in the IU School of Medicine. In this section we present such metrics for the operational services provided by ABITC and Research Technologies to researchers in IUSM.

Service	Services delivered	
	Number of units	Unit
Data repository for Collaborative Initiative on Fetal Alcohol Spectrum Disorder	2,462	Number of distinct subjects (people)
	41,938	Total number of database entries
	1,825	Facial images stored in CIFASD Imaging Core data repository
Data repository for National Gene Vector Biorepository and Coordinating Center	96,059	Number of database records
Indiana CTSI HUB	3,612	Number of researchers with login (accounts) on Indiana CTSIHub
REDCap	491	New projects using REDCap initiated by IUSM researchers in FY 11/12.
	907	Total projects using REDCap since ABITC assumed responsibility for REDCap in 2010
Alfresco Share	34,793	Documents stored in Alfresco Share as of 30 June 2012
	1,125	Number of researchers who used Alfresco Share during FY 11/12 to support grant proposal writing
CTSI Grants Management System	522	Grant applications processed in FY 2011/2012
	29	Grant awards managed during FY 2011/2012
	1,648	Grant applications managed since inception in 2009

Table 7. Usage metrics for data resources managed and supported by ABITC and Research Technologies.

4.4. Visualization resources

The Research Technologies Advanced Visualization Lab (AVL) made significant contributions to IUSM projects in 2012. A few examples follow:

- **Support of Collaborative Initiative on Fetal Alcohol Spectrum Disorders (CIFASD) Imaging Core.** AVL continued its ongoing and integral involvement in the CIFASD Imaging Core. AVL staff worked closely with 3DMD, the hardware vendor of the facial structure laser scanners used by the Core, to diagnose and resolve several major hardware failures of the 3DMDface system. AVL assisted with the operational and logistical issues of adding new remote sites. Lab staff also modified instrumental data processing programs, which enabled the collection of more than 1000 new subjects. Those added in 2012 nearly doubled the size of the database to approximately 2500 subjects.
- **Support of Department of Pharmacology and Toxicology.** The AVL advised on the purchase and setup of modern stereoscopic monitors critical to the daily work of researchers in the Department of Pharmacology and Toxicology. The AVL also provided visualization consulting and produced videos which were ultimately submitted to the IEEE/ACM Supercomputing 2012 conference.
- **Center for Neuroimaging.** AVL staff are helping Neuroimaging Center staff acquire and install an IQ-Station, an interactive and immersive stereoscopic visualization environment. The IQ-Station was designed by the AVL as part of the Lab's effort to more widely distribute visualization resources throughout the IU campuses and state of Indiana. This system is being paid for by the Center for Neuroimaging, and because the Center is using an IU-designed system they are getting state-of-the art visualization capabilities at a fraction of the cost they would pay for a commercially provided system.

- **Schools of Nursing.** The AVL has additional collaborations and relationships with the Schools of Nursing. These collaborations include an interactive ultra-high resolution image of the Nursing simulation rooms and a variety of workflows to deliver the image content over the Internet.
- **School of Dentistry.** The AVL also had a variety of collaborations with the School of Dentistry. Projects from Dentistry have led to the creation of the IQ-Force, an interactive simulation device capable of providing real-time force feedback. New or improved workflows include more efficient generation of 3D data from imaging devices such as CT and MRI scans and the ability to better parallelize image processing on IU's supercomputing resources. The AVL also assisted the department of Orthodontics with 3D scanning and analysis of dental casts before and after treatment.

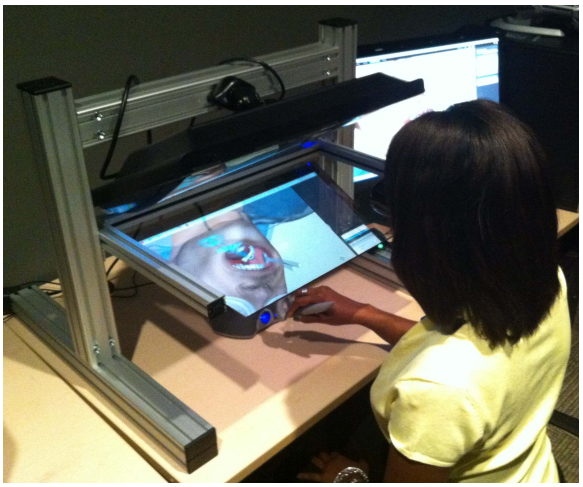

Figure 3. A researcher in the School of Dentistry uses the IQ-Force.

The Advanced Visualization Lab continues to support IUSM researchers who use its advanced visualization facilities, including the Virtual Reality Theater – a room-scale 3D visualization system.

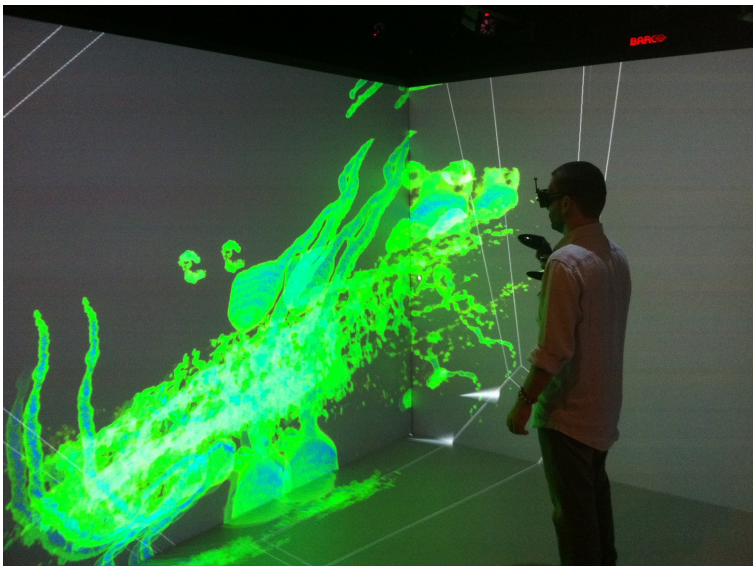

Figure 4. Researchers use volume rendering software (the Toirt Samhaigh tool) inside the Virtual Reality Theater to visualize the fibrous strands of neural connections in the brain of a fruit fly.

4.5. Support for grant proposal development

The Research Technologies Collaboration and Engagement Support Group supports the preparation of grant proposals led by IUSM researchers that make extensive use of advanced research information technology facilities, and those proposals that expand IU local resources. Five grants were awarded to IUSM researchers during the FY 11/12 year for a total of $3,793,034 based on current and prior year proposals developed with the aid of the Collaboration and Engagement support group. Metrics of grant proposals supported by ABITC and Research Technologies are summarized in Table 8. It is a coincidence that during the current reporting period five proposals were submitted and five awarded. Some of the proposals awarded were submnitted prior to the beginning of the current reporting period, and at least one of the proposals submitted during the current reporting period was declined.

Number of grants submitted	Amount requested	Number of grants awarded	Amount awarded
5	$8,291,598	5	$3,793,034

Table 8. Grants submitted in FY11/12 by IUSM researchers with the aid of ABITC and Research Technologies. (While the number of grants submitted and awarded are the same, this is a coincidence – the five submitted and five awarded are not the same five grants)

4.6. Education and outreach

Research Technologies has aided the educational and outreach mission of IU in a number of ways, most particularly in the creation of 3D educational movies. Such movies are particularly effective because 3D animations are attention-grabbing and compelling, especially to young people and the lay public. During the past year, Research Technologies used grant funds it received as part of an award from the National Science Foundation to create the video "Investigating Hidden Worlds." This visualization was created with the assistance of researchers and students from the Departments of Pharmacology & Toxicology and Computer & Information Science at IUPUI. Available in 2D and 3D versions, this movie explains a great deal of information about how proteins act and interact in the body, and how scientists study and understand these interactions. This video and a video about human 3D vision are available for download and viewing from http://3d.iu.edu/teragrid.

5. Consulting services delivered during FY 2012/2012 and grant activities supported

5.1. Short term and extended consultations

During FY 11/12, the Advanced Biomedical Information Technology core concluded a total of 30 short consultations – that is, answering questions, resolving straightforward problems, and providing relatively straightforward help that required less than about four hours of staff time to resolve. This is up from a total of 20 for FY 10/11.

The numerical majority of consulting contacts, requiring a large majority of staff effort, are extended consultations – that is, extensive interactions that take staff time ranging from in excess of four hours to person-years of effort. During FY 11/12, the Advanced Biomedical Information Technology core concluded a total of 64 extended consultations, with another 23 ongoing into FY 2012/2013. This is up significantly from a total of 27 extended consultations completed in FY 10/11.

Researcher	Department	Campus	Service	Status		Staff effort Invested		
				Completed	Ongoing	4 hours – 1 week FTE	1 week – 1 month FTE	> 1 month FTE
Goodman, Joshua	Biology	IUB	Informatics needs assessment for Flybase	✓		✓		

Researcher	Department	Campus	Service	Status		Staff effort Invested		
				Completed	Ongoing	4 hours – 1 week FTE	1 week – 1 month FTE	> 1 month FTE
Hetrick, Bill	Psychiatry	IUB	Software development	✓		✓		
Hobson, Charles	Business & Economics	IUN	Software development	✓				✓
Kini, Ranjan	Business & Economics	IUN	Software development	✓				✓
Delunas, Linda	Nursing	IUN	Software development	✓				✓
Mu, Wang	Biochemistry & Molecular Biology	IUPUI	Software development		✓			✓
Edenberg, Howard	Biochemistry/ Molecular Biology	IUPUI	Custom application development		✓	✓		
McClintock, Jeannette	Biochemistry/ Molecular Biology	IUPUI	Custom application development		✓	✓		
You, Teddy	Biochemistry/ Molecular Biology	IUPUI	Software migration, high performance systems and storage		✓			✓
Odell, Jere	Bioethics	IUPUI			✓		✓	
Blazer-Yost, Bonnie	Biology	IUPUI	Grant development	✓			✓	
Davis, Bob	Biostatistics	IUPUI	REDCap support		✓			✓
Matesa, Janetta	Biostatistics	IUPUI	Coordinate data management		✓		✓	
Puetz, Greg	Biostatistics	IUPUI	Data and application integration		✓			✓
Yiar, Constantin	Biostatistics	IUPUI	Data and application integration		✓			✓
Hui, Siu	Biostatistics/ Regenstrief	IUPUI	Access to high performance systems		✓		✓	
Li, Lang	Center for Computational Biology and Bioinformatics	IUPUI	Access to high performance systems and storage		✓		✓	
Liu, Yunlong	Center for Computational Biology and Bioinformatics	IUPUI	Access to high performance systems and storage		✓	✓		
Meroueh, Samy	Center for Computational Biology and Bioinformatics	IUPUI	Grant development and access to high performance systems	✓		✓		
Kovacs, Dick	Dean's Office - Medicine	IUPUI	Systems evaluation		✓	✓		
Kula, Katherine	Dentistry-Ortho and Orafacial	IUPUI	Data integration and application deployment	✓			✓	

Researcher	Department	Campus	Service	Status		Staff effort Invested		
				Completed	Ongoing	4 hours – 1 week FTE	1 week – 1 month FTE	> 1 month FTE
Considine, Robert	Endocrinology	IUPUI	Grant development	✓			✓	
Cote, Gregory	Gastroenterology	IUPUI	Software development		✓		✓	
Clare, Susan	General Surgery	IUPUI	Software evaluation and recommendation		✓	✓		
Hudson, Brenda	Indiana CTSI	IUPUI	Software development		✓			✓
Hunt, Joe	Indiana CTSI	IUPUI	Data collection & reporting		✓		✓	
Miller, Doug	Indiana CTSI	IUPUI	Software design		✓		✓	
Reeves, Lilith	Indiana CTSI	IUPUI	CTSI Hub support		✓			✓
Scahill, Sam	Indiana CTSI	IUPUI	Software design, data collection		✓			✓
Defazio, Joseph	Informatics	IUPUI	Software consulting	✓		✓		
Janga, Sarath	Informatics	IUPUI	Introduction to high performance systems	✓		✓		
Wilson, Marc	Information Service and Technology	IUPUI	Software migration, high performance systems and storage		✓			✓
Loehrer, Pat	IU Simon Cancer Center	IUPUI	Software development	✓				✓
Cornetta, Ken	Medical & Molecular Genetics	IUPUI	Software development		✓			✓
Cornetta, Ken	Medical and Molecular Genetics	IUPUI	Custom application development		✓			✓
Foroud, Tatiana	Medical and Molecular Genetics	IUPUI	Custom application development		✓		✓	
Moe, Sharon	Nephrology	IUPUI	Software evaluation and information	✓		✓		
Sokol, Deborah	Neurology	IUPUI	Access to infrastructure	✓		✓		
Badve, Sunil	Pathology	IUPUI	Grant development	✓		✓		
Sandusky, George	Pathology	IUPUI	Access to server support		✓			✓
Fuller, Deanna	Pathology & Laboratory Medicine	IUPUI	REDCap consultation and support	✓			✓	
Rigby, Mark	Pediatrics	IUPUI	Software deployment and project management		✓		✓	

Researcher	Department	Campus	Service	Status		Staff effort Invested		
				Completed	Ongoing	4 hours – 1 week FTE	1 week – 1 month FTE	> 1 month FTE
Denne, Scott	Pediatrics/ Neonatal Medicine	IUPUI	Software support		✓		✓	
Erickson, Craig	Psychiatry	IUPUI	REDCap configuration	✓				✓
Hulvershorn, Leslie	Psychiatry	IUPUI	Application support	✓			✓	
Hummer, Tom	Psychiatry	IUPUI	Application support	✓			✓	
Niculescu-Le, helen	Psychiatry	IUPUI	Data integration and application deployment		✓			✓
Niculescu, Alexander	Psychiatry	IUPUI	Data integration and application deployment		✓			✓
Stigler, Kimberley	Psychiatry	IUPUI	Application support	✓			✓	
Swiezy, Naomi	Psychiatry	IUPUI	Grant development	✓			✓	
Hutchins, Gary	Radiology and Imaging Sciences	IUPUI	Access to high performance systems and storage		✓	✓		
Biondich, Paul	Regenstrief	IUPUI	Access to infrastructure		✓	✓		
Downing, Michael	Regenstrief	IUPUI	Access to infrastructure	✓		✓		
Dexter, Paul	Regenstrief Institute	IUPUI	Software deployment		✓		✓	
Fryling, Kevin	VP Public Affairs & Government Relations	IUPUI	Software support		✓			✓
Hardwick, Emily	Indiana CTSI	IUPUI	Software design and development		✓			✓

Table 9. Summary of extended consultations – work taking > 4 hours of staff time – completed by ABITC during FY 11/12 or which were worked on actively during FY 11/12 and are still ongoing.

5.2. ABITC funded involvement in external grants

ABITC supports external grants to IUSM researchers in a number of ways. Many grant-funded projects that have relatively modest needs (up to 160 hours of staff time) are assisted, without any cost direct to the researcher, as an extended consultation. These activities are summarized in Table 9 above.

ABITC and Research Technologies often provide formal, committed match in support of grant proposals. In addition, for projects that involve extensive, dedicated research information technology service development and delivery, ABITC and Research Technologies often participate as a funded part of a project team. Section 5.2.1 describes current active grants with such involvement by ABITC and Research Technologies. Section 5.2.2 describes grant proposals in preparation as of the end of the reporting period.

5.2.1. Awarded grants

The following sections provide key information for grants current during the FY 11/12 reporting period – showing first grants led by IUSM faculty and supported by ABITC / Research Technologies, and then

grants led by staff of ABITC / Research Technologies that aid IUSM faculty and research. A total of six grants led by IUSM faculty were active during the current grant reporting period, with a total of $29,385,594 awarded to IU supported by $615,000 in direct match from ABITC / IUSM. Three grants led by ABITC / RT staff totaling $6,082,815 directly aid research by IUSM faculty.

The list below summarizes key information about current grant awards to IUSM faculty researchers that are supported by ABITC and Research Technologies, as well as grants to ABITC/Research Technologies that directly support the work of IUSM. "Formal match" in these listings refers to match that is a formal part of the grant budget; this always constitutes a minimum of ABITC/RT's contributions.

P.I.	Cornetta, Kenneth
Title	National Gene Vector Biorepository and Coordinating Center
Agency	NIH - NCRR
Grant Number	5P40RR024928
Dates	April 2012 – March 31,2017
Total Award to IU	$903,034
Subcontract amount to ABITC / Research Technologies	$153,938
Formal match provided by ABITC / Research Technologies as part of grant budget	$0
ABITC's role	The ABITC developed the website, data repository, and data management features for the operation of the gene vector biorepository. This includes all online NGVB workflows, including sample submission and requesting and sample data management.

P.I.	Foroud, Tatiana
Title	3D Facial Imaging in Fetal Alcohol Spectrum Disorder
Agency	NIH - NIAA
Grant Number	2U01AA014809
Dates	September 1, 2012 – May 31, 2017
Total Award to IU	$372,560
Subcontract amount to ABITC / Research Technologies	$162,725
Formal match provided by ABITC / Research Technologies as part of grant budget	$0
ABITC's role	The Advanced Visualization Lab has implemented a 3D camera solution allowing the rapid capture of facial surface morphology features that is being studied as a potential diagnostic tool for fetal alcohol spectrum disorders. AVL staff also operate and support the camera at various remote clinical sites, including the Ukraine.

P.I	Niculescu, Alexander
Title	Developing Blood Tests for Mood Disorders
Agency	NIMH
Grant Number	1DP2OD007363-01
Dates	September 30, 2010 – August 31, 2015
Total Award to IU	$2,310,000
Subcontract amount to ABITC / Research Technologies	$55,000
Formal match provided by ABITC / Research Technologies as part of grant budget	$0
ABITC's role	The Niculescu lab maintains data in six databases, which will be integrated to enable complex querying on multiple attributes. ABITC staff will also develop software that calculates the Convergent Functional Genomics score that correlates a particular gene with a mood disorder phenotype.

P.I.	Shekhar, Anantha
Title	Clinical and Translation Sciences Institute (CTSI)
Agency	NIH-NCRR
Grant Number	UL1RR025761-01
Dates	July 1, 2008 – June 30, 2013
Total Award to IU	$25,000,000
Subcontract amount to ABITC / Research Technologies	$489,000
Formal match provided by ABITC / Research Technologies as part of grant budget	$615,000
ABITC's role	The ABITC oversees the development and operation of the Indiana CTSI HUB and scientific workflow and data management tools, including REDCap, Alfresco Share, the grant management system, INResearch, and i2iconnect. As part of this, the ABITC participates in the CTSA Informatics and Communications Key Function Committees. Dr. Barnett was chair of the Communications Key Function Committee in 2011.

P.I	Shekhar, Anantha
Title	Administrative Supplement to support designated topic areas of CTSA activities - #3, Enabling data visualization through the Indiana CTSI HUB
Agency	NIH-NCRR
Grant Number	3UL1RR025761-04S2
Dates	Sept. 30,2011 – Aug. 30,2012
Total Award to IU	$500,000
Subcontract amount to ABITC / Research Technologies	$164,354
Formal match provided by ABITC / Research Technologies as part of grant budget	$0
ABITC's role	ABITC staff provided software development expertise to construct a DataViewer module that enables uploaded data to be easily visualized on the Indiana CTSI HUB. The software was used to visualize longitudinal data from Dr. Weaver's Camp Calcium project. The software is able to perform simple statistical calculations and graphs in a user-friendly fashion.

P.I	Shekhar, Anantha
Title	Advancing Community Engagement in Science
Agency	NIH-NCRR
Grant Number	3UL1RR025761-04S3
Dates	Sept. 30,2011 – Aug. 30,2012
Total Award to IU	$300,000
Subcontract amount to ABITC / Research Technologies	$92,208
Formal match provided by ABITC / Research Technologies as part of grant budget	$0
ABITC's role	The ABITC provided software development expertise to construct a collaborative website where members could share information about best practices for community engagement in health care research. ABITC staff were also involved in deploying and maintaining the system as the Indiana CTSI's goals evolve.

5.2.1.1. Grants led by ABITC and Research Technologies that support IUSM research

P.I.	Barnett, William
Title	Informatics Core for the Collaborative Initiative in Fetal Alcohol Spectrum Disorders
Agency	NIH - NIAA
Grant Number	2U24AA014818-09
Dates	August 10,2012 – May 31, 2017
Total Award to IU	$802,815
Subcontract amount to ABITC / Research Technologies	$802,815
Formal match provided by ABITC / Research Technologies as part of grant budget	$41,113
ABITC's role	The ABITC oversees the Informatics Core for this initiative, which collects data from four different clinical research programs at 15 sites internationally. The ABITC developed input and query tools, a data dictionary for data standardization, and tools for automated querying across studies and populations as well as web-based tools for data quality examination.

P.I	Barnett, William (local subcontract PI); Livny, Miron overall PI
Title	THE OPEN SCIENCE GRID The Next Five Years: Distributed High Throughput Computing for the Nation's Scientists, Researchers, Educators, and Students
Agency	NSF
Grant Number	1148698
Dates	09/01/2006 – 08/30/2012
Total Award to IU	$15,692,445
Subcontract amount to ABITC / Research Technologies	$3,820,000
Formal match provided by ABITC / Research Technologies as part of grant budget	$ 0
ABITC's role	ABITC and the Open Science Grid team have been working together to develop grid-based tools for processing computationally intensive applications such as parameter sweeps with Dr. Meroueh's SPLINTR application.

P.I	Stewart, Craig
Title	**ABI Development: National Center for Genome Analysis Support (NCGAS)**
Agency	**NSF**
Grant Number	**1062432**
Dates	**09/17/2011 – 09/17/2014**
Total Award to IU	**$1,460,000**
Subcontract amount to ABITC / Research Technologies	$ 0
Formal match provided by ABITC / Research Technologies as part of grant budget	$ 500,000
ABITC's role	The ABITC acts as a gateway for IUSM researchers to gain access to the bioinformatics support, hardened software, Galaxy web interfaces, and computational clusters to undertake genomics science. UITS fully funded Mason, the large memory system that is used for genome assembly and this system is available to IUSM.

5.2.1.2. Financial summary of current grant awards:

	# of awards	Total $	Subcontract to ABITC / RT	Formal match commitments from ABITC/RT
Grants led by IUSM faculty researchers and supported by ABITC and Research Technologies	6	$29,385,594	$955,200	$615,000
Grants led by ABITC and Research Technologies that support IUSM research	3	$6,082,815	N/A	N/A
Totals	9	$35,468,409	$955,200	$615,000

Table 10. Summary of grant incomes to IUSM, subcontracts to ABITC/RT, and match from ABITC/RT for grants supported or led by ABITC/RT which benefit IUSM.

5.2.2. Grants in preparation

NCGAS is partnering with the Indiana CTSI as part of its renewal this year to provide national leadership in genomics analysis. Established as a national resource for *de novo* sequence assembly of NSF funded projects on non-model organisms, the NCGAS is expanding its mission to support translational genomics research for the Indiana CTSI and nationally. As part of its partnership with the Indiana CTSI, the NCGAS will establish itself as a genome science core that can provide the analytical support for the next generation of genomics based research. It leverages high-speed research networks, lowering barriers for access and improved bioinformatics support, and partners nationally to improve and accelerate analysis.

The NCGAS is partnering with the Broad Institute to optimize the Trinity RNA-Seq analysis software, and with the Galaxy Project to develop web-based workflows. NCGAS will provide petaflops-scale supercomputing through Big Red II and large memory analysis capabilities through the Mason system, which is architected for genome assembly. It will leverage national cyberinfrastructures, originally developed to manage and analyze data from "big science" projects like astronomical observatories or the Large Hadron Collider, to provide the scale to handle genomics data. Specifically, Internet2 and the National Lambda Rail have established networks that can support large-scale data movement. NCGAS uses technologies such as Lustre-WAN, Globus Online, and software-defined networking to accelerate data transfers and support genomics data movement at scale. It has implemented an integrated national infrastructure model in partnership with national research infrastructures such as the Open Science Grid (which Indiana University operates), providing the computational capacity needed to analyze large genomics data sets.

As part of the process of preparing IU to meet the requirements of the CTSA renewal process, the ABITC will assist in achieving Federal Information Security Management Act (FISMA) compliance for all UITS research systems during 2013.

6. Campus, national, and international leadership by ABITC and Research Technologies staff in areas relevant to IUSM and health research in general

- Bill Barnett has been invited to participate in the Clinical Research Informatics Task Force led by Bill Tierney (Regenstrief) and Bill McConnell (IU Health). This task force is meant to formulate a strategic approach to share and integrate data across the three institutions.
- Bill Barnett continues to be active on the National Center for Advancing Translational Sciences CTSA National Informatics and Communication Key Function Committees, and has been focusing national attention on the CTSI HUB.

7. IU School of Medicine researchers' satisfaction with ABITC services and services from the Research Technologies division of UITS

The purpose of the annual UITS User Survey is to arrive at a clear, unbiased estimate and understanding of the university community's satisfaction (or lack thereof) with all services offered by University Information Technology Services. This survey has been done at part or all of IU since 1981, and its results are published openly on the web (http://www.indiana.edu/~uitssur/). Results of every survey done since 1981 and the text of every comment written on a survey (with obscenities and individual names removed) since 1982 are available for anyone with access to the World Wide Web.

To ensure that an objective survey is done with complete confidentiality, its execution is outsourced to the IU Center for Survey Research (http://csr.indiana.edu). The Center for Survey Research sends surveys to a randomly selected subgroup of the IU community in each of the following categories: faculty, staff, graduate students, and undergraduate students. The questions on the survey are primarily Likert opinion scales (1-5 rating scales with 5 always being the most favorable rating). For questions asking opinions of services, the results shown include the percentage of people who use the service (which we have taken to be the percentage of people who expressed an opinion about it), the average opinion score, and the percentage of people who were satisfied with the service (graded it as a 3 or better).

7.1. UITS user survey data for 2012 – IU School of Medicine responses and comparison with IU overall

The tables below show IU School of Medicine responses on the spring 2012 user survey for services offered by ABITC and the Research Technologies division generally.

Question 20: Alone, or in partnership with other campus units, UITS provides facilities and services in support of research. If you use such facilities and services, please indicate your overall satisfaction by selecting the appropriate response.

	IU School of Medicine			IU Overall		
	Average	Satisfaction	Usage	Average	Satisfaction	Usage
Central research and high performance computers (Big Red, Quarry, and RDC clusters) [F, Staff, G]	4.23 ± .11	100 ± .4%	6.50%	4.16 ± .09	92.6 ± 2.74%	15.2%
Center for Statistical and Mathematical Computing (Stat/Math Center; statmath@iu.edu, 278-4740) [All]	4.03 ± .10	100 ± .4%	8.20%	4.04 ± .08	94.5± 2.15%	19.6%
Scholarly Data Archive (formerly referred to as MDSS / HPSS) (MDSS/HPSS) [F, Staff, G]	3.76 ± .14	100 ± .4%	6.00%	4.05 ± .10	93.4± 2.56%	12.4%
Advanced Visualization Laboratory (AVL); www.avl.iu.edu [F, Staff, G]	4.02 ± .14	100 ± .4%	4.50%	4.15 ± .09	96.6 ± 1.97%	6.8%
Support for software applications using IU and national high performance computer resources (including TeraGrid, Open Science Grid, and XSEDE) [F, Staff, G]	4.38 ± .12	100 ± .4%	5.90%	4.13 ± .08	95.5 ± 1.71%	7.5%
Support for Life Sciences - Advanced Biomedical IT Core and National Center for Genome Analysis Support [Formerly Bioinformatics support and Center for Computational Cytomics] [F, Staff, G]	3.90 ± .21	87.9 ± 5.9%	5.80%	3.97 ± .10	90.7 ± 3.1%	5.8%

Table 11. IU School of Medicine respondents' satisfaction with individual UITS facilities and services, as compared with IU overall.

Question 21. Overall, how satisfied are you with the UITS research technology services available at IUPUI? [All]

Population	Average	Satisfaction	Usage
IUSM	4.40 ± .15	95.6 ± 3.8%	15.4%
IU Overall	4.18 ± .07	96.0 ± 1.85%	31.7%

Table 12. IU School of Medicine overall satisfaction with UITS research technology services, as compared to IU population as a whole.

7.2. UITS user survey data – comparison of data for IUSM over time

The following tables and graphs compare IUSM researcher satisfaction with and usage of research technology services from 2003 to 2012.

Central research and high performance computers (Big Red, Libra, Quarry and RDC clusters) [F, Staff, G]					
	Average	Satisfaction	Usage	Never heard of service	# of respondents
2003	4.40± .08	100± .3%	2.00%	25.8%	155
2004	3.95 ± .13	100 ± .3%	5.20%	19.0%	158
2005	4.05+/- .12	97.1+/- 2.5%	9.20%	15.9%	207
2006	3.86+/- .14	84+/- 4.9%	7.60%	21.6%	236
2007	3.72+/- .17	85.3+/- 5.4%	7.20%	13.0%	184
2008	4.12+/- .11	95.6+/- 3.0%	8.30%	29.5%	207
2009	3.76+/- .13	88.8+/- 5.3%	6.90%	24.8%	153
2010	N/A	N/A	N/A	N/A	N/A
2011	4.25 ± .12	92.6 ± 3.6%	12.30%	19.6%	219
2012	4.23 ± .11	100 ± .4%	6.50%	24.1%	133

Table 13. Satisfaction with and usage of central research and high performance computers from 2003 to 2012.

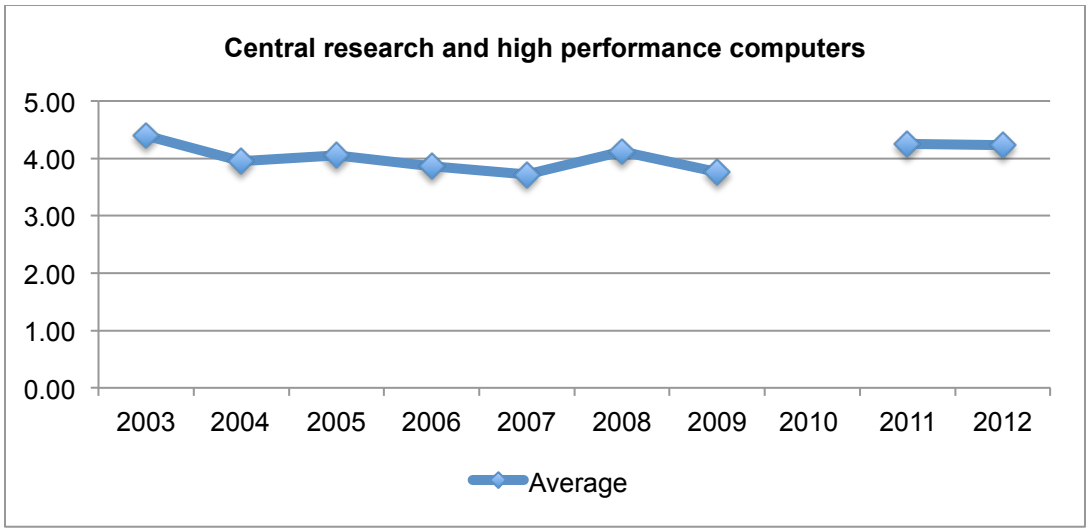

Figure 5. Average rating of central research and high performance computers from 2003 to 2012 in response to *Question 20: Alone, or in partnership with other campus units, UITS provides facilities and services in support of research. If you use such facilities and services, please indicate your overall satisfaction by selecting the appropriate response* as regards. (Responses are on a Likert scale of 1-5.)

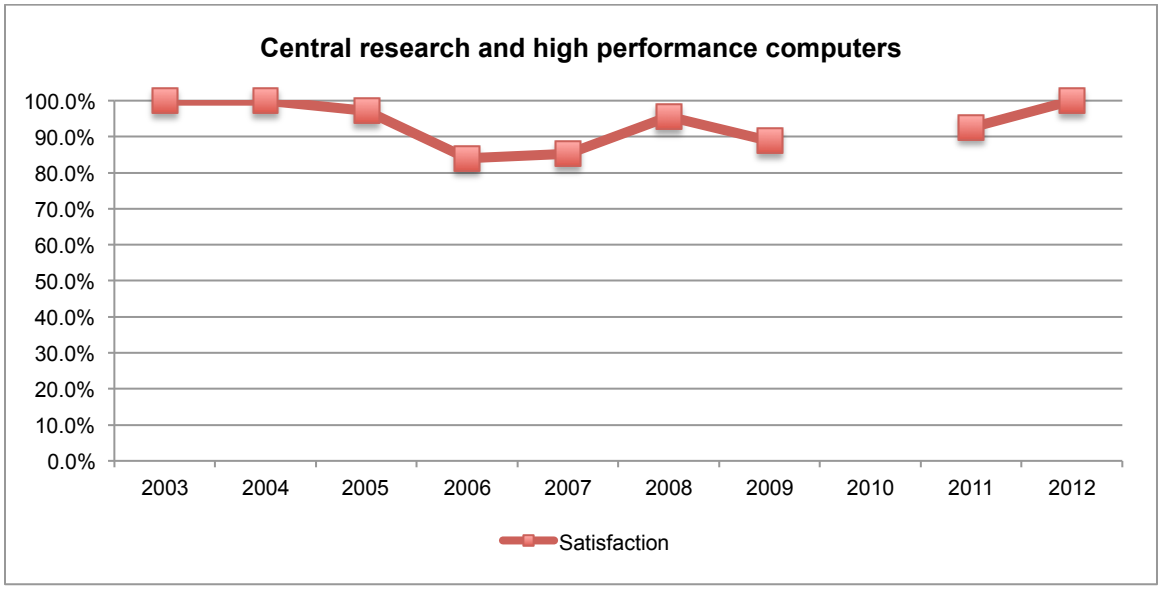

Figure 6. IUSM satisfaction with central research and high performance computers from 2003 to 2012.

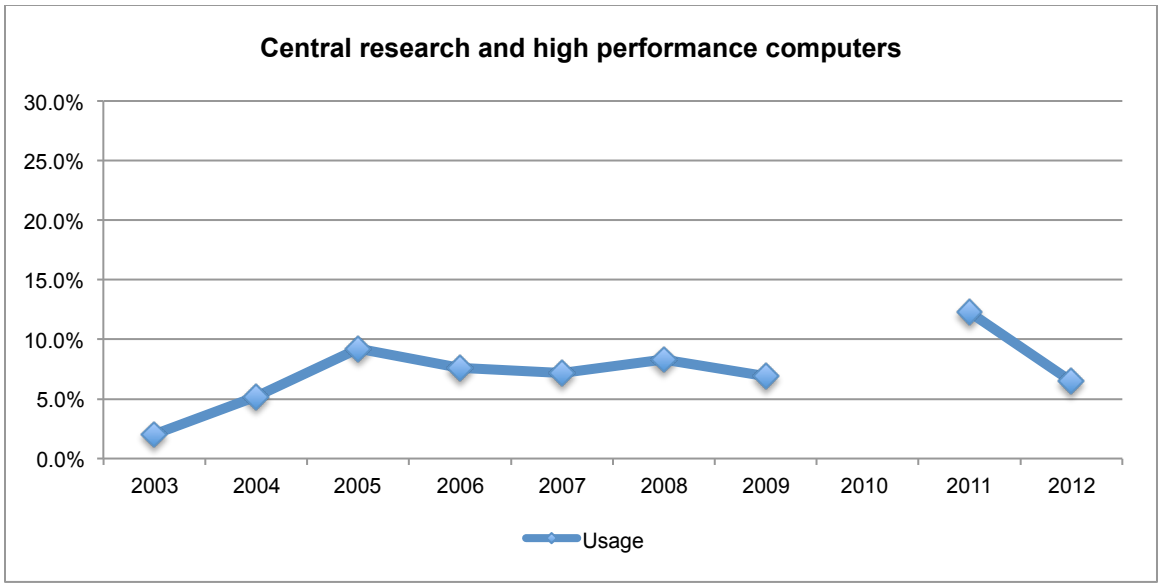

Figure 7. IUSM usage of central research and high performance computers from 2003 to 2012.

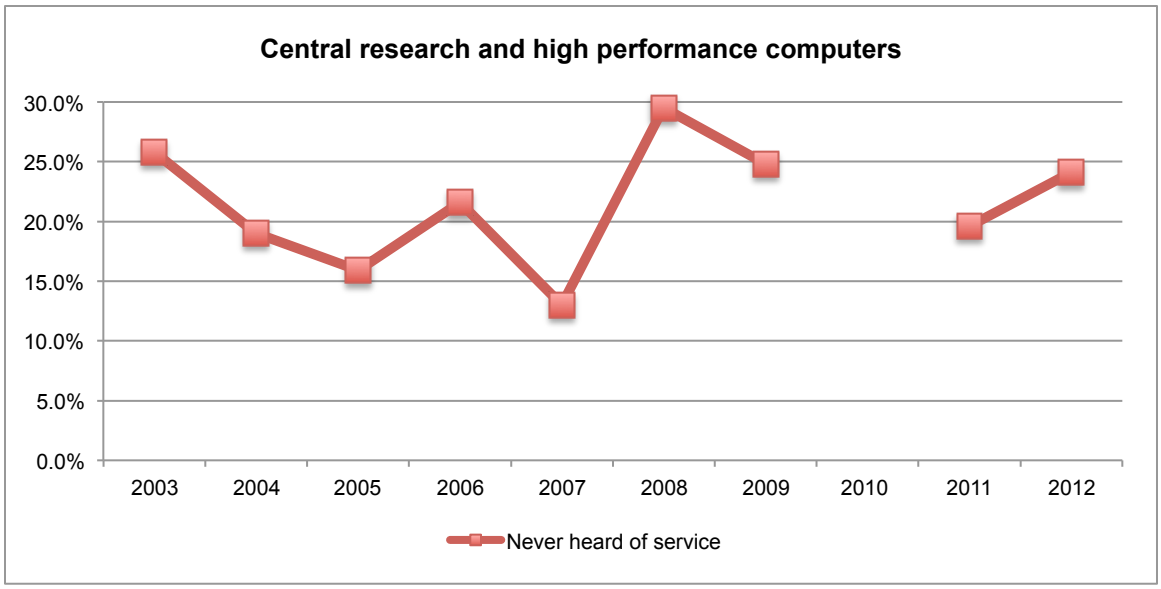

Figure 8. Percentage of responding IUSM researchers indicating they have never heard of IU's central research and high performance computers from 2003-2012.

Center for Statistical and Mathematical Computing (Stat/Math Center; statmath@iu.edu, 278-4740) [All]					
	Average	Satisfaction	Usage	Never heard of service	# of respondents
2003	3.92± .10	100± .3%	4.90%	23.2%	155
2004	3.49 ± .13	89.6 ± 5.1%	9.00%	20.9%	158
2005	3.94+/- .12	94.9+/- 3.2%	5.30%	15.5%	206
2006	4.11+/- .11	96+/- 2.8%	7.30%	23.9%	234
2007	3.73+/- .17	80.2+/- 6.0%	5.50%	13.6%	184
2008	4.20+/- .09	100+/- .2%	10.40%	29.1%	206
2009	3.38+/- .19	80.0+/- 6.7%	6.20%	23.8%	151
2010	N/A	N/A	N/A	N/A	N/A
2011	4.41 ± .09	100 ± .2%	7.40%	18.3%	219
2012	4.03 ± .10	100 ± .4%	8.20%	19.5%	133

Table 14. Satisfaction with and usage of the Center for Statistical and Mathematical Computing from 2003 to 2012.

Support for Life Sciences - Advanced Biomedical IT Core and National Center for Genome Analysis Support [Formerly Bioinformatics support and Center for Computational Cytomics] [F, Staff, G]					
	Average	Satisfaction	Usage	Never heard of service	# of respondents
2003	4.12± .12	100± .3%	3.20%	25.5%	157
2004	3.45 ± .16	89.2 ± 5.1%	4.00%	23.8%	160
2005	4.08+/- .11	100+/- .2%	6.10%	17.6%	205
2006	3.97+/- .15	82+/- 5.1%	7.00%	25.2%	234
2007	N/A	N/A	N/A	N/A	N/A
2008	N/A	N/A	N/A	N/A	N/A
2009	N/A	N/A	N/A	N/A	N/A
2010	N/A	N/A	N/A	N/A	N/A
2011	4.39 ± .12	96.7 ± 2.6%	12.10%	19.3%	218
2012	3.90 ± .21	87.9 ± 5.9%	5.80%	23.5%	132

Table 15. Satisfaction with and usage of support for life sciences between 2003 and 2012.

Support for software applications using IU and national high performance computer resources (including TeraGrid, Open Science Grid, and XSEDE) [F, Staff, G]					
	Average	Satisfaction	Usage	Never heard of service	# of respondents
2003	4.20± .12	100± .3%	4.1%	26.0%	154
2004	3.56 ± .17	77.3 ± 6.8%	4.10%	22.6%	159
2005	4.36+/- .11	95.4+/- 3.1%	5.80%	16.5%	206
2006	4.26+/- .09	100+/- .2%	5.60%	22.5%	231
2007	N/A	N/A	N/A	N/A	N/A
2008	N/A	N/A	N/A	N/A	N/A
2009	N/A	N/A	N/A	N/A	N/A
2010	N/A	N/A	N/A	N/A	N/A
2011	4.41 ± .09	100 ± .2%	11.20%	18.9%	217
2012	4.38 ± .12	100 ± .4%	5.90%	23.5%	132

Table 16. Satisfaction with and usage of software applications on local and national high performance computer resources between 2003 and 2012.

Advanced Visualization Laboratory (AVL); www.avl.iu.edu [F, Staff, G]					
	Average	Satisfaction	Usage	Never heard of service	# of respondents
2003	N/A	N/A	N/A	30.1%	73
2004	4.00 ± .20	80.0 ± 7.9%	3.90%	27.9%	111
2005	3.50+/- .10	100+/- .4%	1.00%	21.9%	114
2006	3.62+/- .20	75+/- 7.7%	6.50%	31.1%	135
2007	N/A	N/A	N/A	N/A	N/A
2008	N/A	N/A	N/A	N/A	N/A
2009	N/A	N/A	N/A	N/A	N/A
2010	N/A	N/A	N/A	N/A	N/A
2011	4.50 ± .08	100 ± .2%	6.40%	20.3%	217
2012	4.02 ± .14	100 ± .4%	4.50%	24.4%	131

Table 17. Satisfaction with and usage of advanced visualization facilities between 2003 and 2012.

Scholarly Data Archive (formerly referred to as MDSS / HPSS) (MDSS/HPSS) [F, Staff, G]					
	Average	Satisfaction	Usage	Never heard of service	# of respondents
2003	4.25± .15	87.5± 5.5%	3.3%	24.5%	155
2004	4.21 ± .16	85.3 ± 5.8%	6.30%	23.9%	159
2005	4.55+/- .08	100+/- .2%	5.30%	20.0%	205
2006	4.03+/- .14	89+/- 4.2%	8.30%	25.2%	234
2007	3.41+/- .18	79.2+/- 6.1%	7.50%	13.6%	184
2008	3.78+/- .14	89.3+/- 4.4%	10.30%	30.9%	207
2009	3.79+/- .21	77.1+/- 7.0%	6.80%	24.2%	153
2010	N/A	N/A	N/A	N/A	N/A
2011	4.43 ± .09	100 ± .2%	10.90%	18.8%	218
2012	3.76 ± .14	100 ± .4%	6.00%	22.1%	131

Table 18. Satisfaction with and usage of massive data storage between 2003 and 2012.

Overall, how satisfied are you with the UITS research computing services available at IUPUI?					
	Average	Satisfaction	Usage	Never heard of service	# of respondents
2003	3.90± .12	97.5± 2.6%	14.80%	12.5%	176
2004	3.89 ± .12	96.8 ± 2.9%	26.00%	7.8%	167
2005	4.25+/- .09	99.2+/- 1.5%	30.30%	8.5%	212
2006	4.16+/- .10	95+/- 2.8%	30.70%	6.9%	245
2007	4.13+/- .12	96.5+/- 2.8%	30.70%	4.1%	195
2008	4.17+/- .12	94.5+/- 3.3%	28.40%	9.3%	215
2009	4.00+/- .14	93.5+/- 4.2%	25.60%	7.8%	154
2010	N/A	N/A	N/A	N/A	N/A
2011	4.23 ± .11	95.7 ± 2.8%	27.30%	7.6%	223
2012	4.40 ± .15	95.6 ± 3.8%	15.40%	16.7%	138

Table 19. Overall satisfaction with and usage of research computing services at IUPUI between 2003 and 2012.

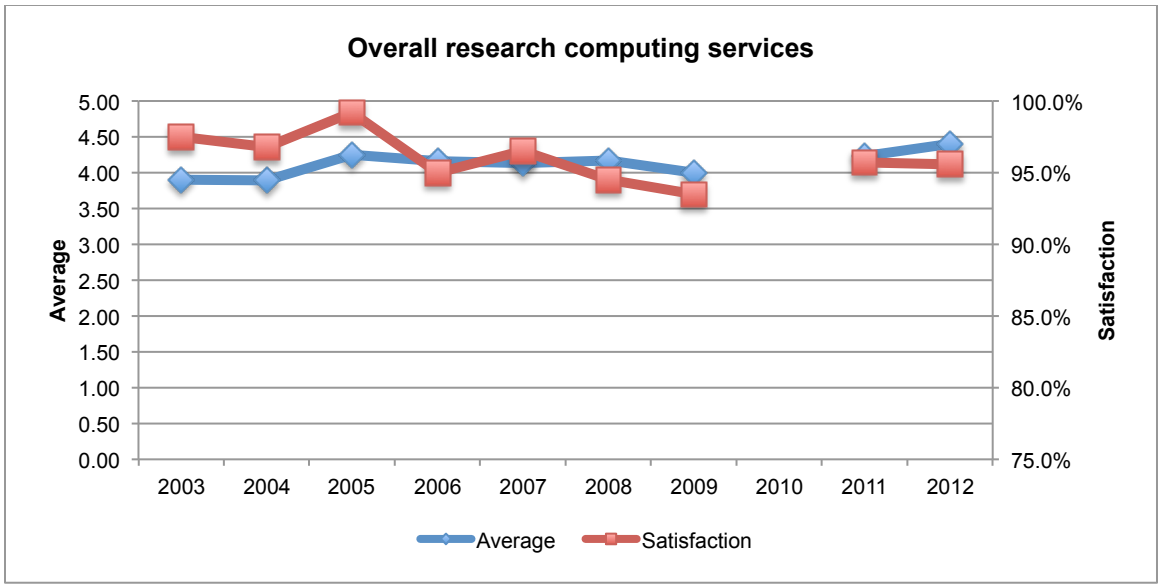

Figure 9. IUSM satisfaction with and average rating of overall research computing services at IUPUI from 2003 to 2012 in response to *Question 20: Alone, or in partnership with other campus units, UITS provides facilities and services in support of research. If you use such facilities and services, please indicate your overall satisfaction by selecting the appropriate response* as regards (Responses are on a Likert scale of 1-5.)

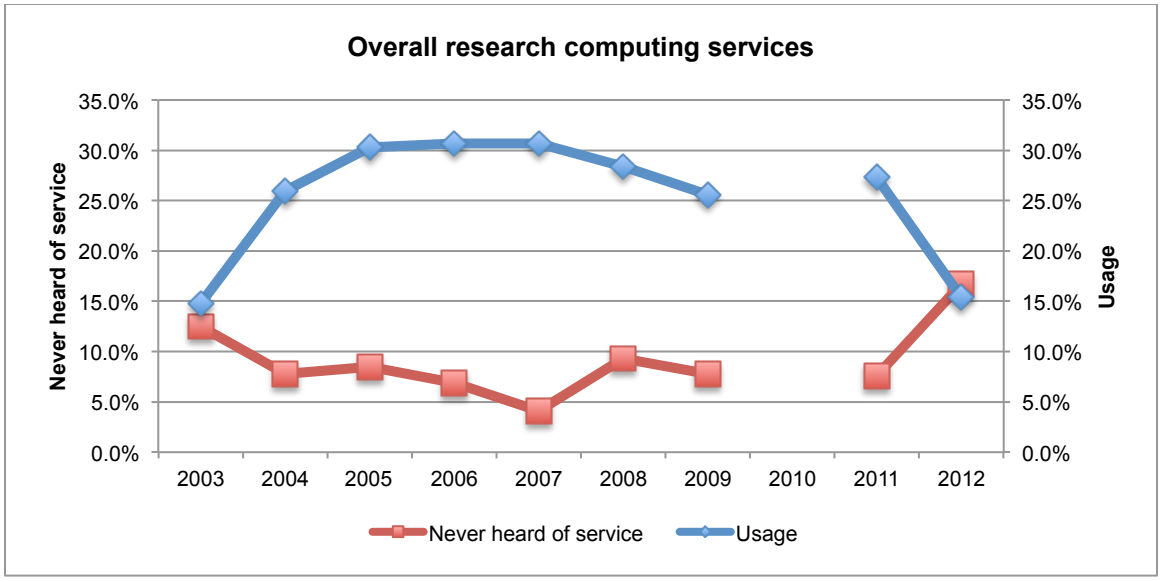

Figure 10. Percentage of responding IUSM researchers who use research computing services as compared to those who have never heard of the services, from 2003 to 2012.

8. Systems/Equipment – current Indiana University facilities, equipment, and other resources used to provide core services

8.1. Physical facilities

IU's cyberinfrastructure leverages the university's unusual arrangement of two major research campuses separated by 50 miles and connected by university-owned optical networks. This creates tremendous resilience in case of natural or man-made disaster, as well as an outstanding testbed for development of grid and distributed computing innovations. Table 20 summarizes IU's data center facilities.

	Machine room total ft^2	Avail. ft^2	Power total	Net power avail.	Cooling capacity total (tons)	Cooling capacity avail. (tons)
ICTC	8,300	1,400	600 kW	70 kW	290	150
IUB Data Center	30,000	15,000	1.46 MW	317 kW	2200	550

Table 20. Summary of physical facilities at Indiana University.

8.1.1. IU Bloomington Data Center

The IU Bloomington Data Center (http://it.iu.edu/datacenter/) provides a highly secure and green environment for IU's largest computational and storage systems. The facility is secured with card-key access, biometric authentication, and 7 x 24 x 365 video surveillance. Three circuits feed the new Data Center, travelling redundant physical paths from two different substations. Any two circuits can fully power the building.

8.1.2. Informatics & Communications Technology Complex

The Informatics and Communications Technology Complex (ICTC) houses IU's Data Center in Indianapolis. The ICTC is secured with card-key access and 7 x 24 x 365 video surveillance. The electrical design for the ICTC includes UPS service and generator backup for critical components of systems such as head nodes, data cache, and network switches. Compute nodes are provided with conditioned power Liebert Data Waves.

8.1.3. Sustainability of physical facilities

IU Bloomington's Data Center is significantly more efficient than prior facilities. The walls are made of 9,000 cubic yards of poured concrete that offers several sustainability features including: longevity, thermal mass to decrease heating and cooling needs, recycled content, minimal waste, and regional production. The single-story facility is surrounded by an earthen berm, offering added insulation and protection from weather events.

8.2. Overall structure and support of IU's advanced research cyberinfrastructure

The overall structure of Indiana University's cyberinfrastructure, including network connections, is shown in Figure 11. PTI staff provide support for all users of IU's research cyberinfrastructure – local, national, and international – as part of their ongoing operational responsibilities, including support for high performance computing systems, data storage systems, and visualization systems. This is sometimes supported with external grants and contracts, when a contract or grant determines terms of or access to such services. Otherwise, IU general funds budget support users local to and outside IU who use IU cyberinfrastructure.

Online support is provided on a 7 x 24 basis with IU's award winning Knowledge Base (kb.iu.edu). Support for security needs and emergency situations is provided by telephone on a 7 x 24 basis via staff at the IU GlobalNOC. In depth support is available via email, telephone, and in person meetings.

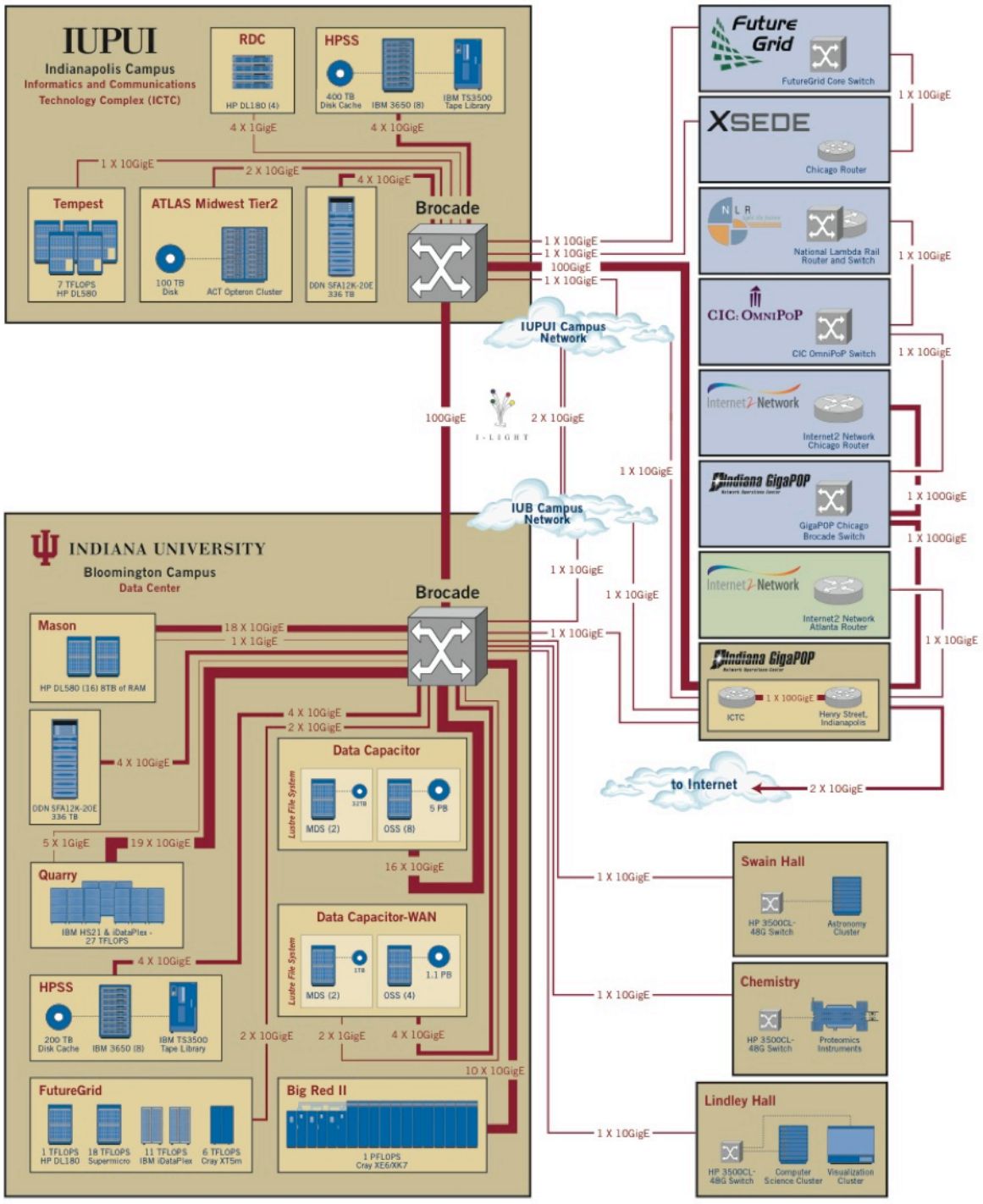

Figure 11. Schematic diagram of IU cyberinfrastructure showing network connections between IU and other national networks and network connections and cyberinfrastructure within IU.

8.3. High performance computing (HPC) systems

Table 21 summarizes IU's production high-performance computing systems. Details of each system follow.

Name	Architecture	TFLOPS	Total RAM (TB)	Local disk (TB)
Big Red II	Cray XE6/XK6 (AMD x86-64 and NVIDIA K20) – to be in operation April 2013	1000.37	47	180
Big Red	IBM PowerPC 970MP (JS21 blades)	40.96	8	73
Quarry	IBM e1350 Intel Xeon (HS21 blades)	26.11	4.9	42
Mason	HP DL580 G7 Intel Xeon servers	3.81	8	16
Research Database Ccomplex	HP DL160 database servers, Dell 2950 Web server	N/A **	0.3	72
Totals		**1071.25**	**68.2**	**383**

Table 21. Summary of computational resources at Indiana University. ** Not used for calculations.

- *Big Red II.* A new system from Cray Inc. has been announced and will be installed at IU prior to May 1, 2013. The Cray XE6/XK6 consists of 1020 nodes total: 344 XE6 nodes, each with two 2.5 GHz AMD Abu Dhabi processors and 64 GB of memory; and 676 XK6 nodes, each with one 2.3 GHz AMD Interlagos processor and one NVIDIA K20 accelerator with 32 GB of system memory and 5 GB of GPU memory. The nodes are interconnected in a 3D Torus using Cray's Gemini interconnect that provides 20 GB/s of bandwidth per node. This system will have more bandwidth to high performance file systems such as the Data Capacitor than ever before, as they will connect via a low-latency InfiniBand network that will provide an aggregate throughput to storage of 48 GB/s.
- *Big Red.* Big Red is an IBM e1350 distributed shared memory cluster with 4096 processor cores, 6 TB total memory capacity, and a peak theoretical processing capability of 40.96 TFLOPS. The compute nodes consist of 1024 IBM JS21 Blade servers, each with two dual-core PowerPC 970MP processors, 8GB of memory, a 73GB local SATA disk for scratch space, and a PCI-X Myrinet 2000 adapter for high-bandwidth, low-latency MPI applications. Four JS21 Blades are used as login and development nodes, and 16 p505 storage nodes are similarly configured. In addition to local scratch disk, the Big Red compute nodes are connected to the Data Capacitor (see Storage systems, section 8.4) via four shared 10Gbps Ethernet links. Big Red will be retired in the summer of 2013.
- *Quarry.* Quarry is an IBM e1350 distributed shared memory cluster with 2960 processor cores, 4.9 TB total memory capacity, and a peak theoretical capability of 26.11 TFLOPS. The compute nodes consist of 140 HS21 Blade servers and 230 dx360 iDataPlex nodes, each with two quad-core Intel Xeon processors and 8-16 GB of memory. The cluster includes 42 TB of local spinning disk and is attached to the Data Capacitor for high performance storage.
- *Mason.* Mason is an HP distributed shared memory cluster with 512 processor cores, 8 TB total memory capacity, and a peak theoretical capability of 3 TFLOPS. The compute nodes consist of 16 DL580 G7 servers, each with four eight-core Intel Xeon L7555 processors, 512 GB of memory, and a PCIe 10Gb Ethernet adapter for high-bandwidth data transfer. The cluster includes 16 TB of local spinning disk.
- *The IU portion of the US ATLAS Midwest Tier 2 Center (*http://mwt2.usatlasfacility.org*/).* The IU portion of the MWT2 facility is a heterogeneous cluster of 20 Dell 1950 servers, 56 Dell R410 servers, and 80 white-box servers, connected by a 1.0 Gbps network. This heterogeneous cluster has a total of 1312 processor cores, 4.0 TB total memory capacity, and a peak theoretical capability of 13.6 TFLOPS. The Dell and HP compute nodes include a mix of 4-core Quad Core Xeon E5440 Processors and 6-core Intel Xeon CPU X5660 processors, with between 2 and 4 GB

of memory per core. The white-box servers include a mix of Dual and Quad-Core AMD Opteron processors.

- *Research Database Complex.* The Research Database Complex (RDC) is dedicated to research-related Oracle databases and data-intensive applications that require an Oracle database. The RDC also provides an environment for database-driven web applications with a research focus. The RDC consists of 4 HP DL160 servers, each with dual Intel E5620 processors, two 72 GB SAS disks, and 72 GB of memory. The web environment is a Dell 2950 with a Quad-core Intel Xeon processor and 8 GB of memory. The RDC has 72 TB of SAN-attached storage for database hosting.

8.4. Data storage systems

In addition to the locally attached storage listed above, IU has three major disk-based file systems and one archival storage system that serve local and remote users. These systems are summarized in Table 22 and detailed below.

Name	Architecture	Disk (PB)	Tape (PB)
Research File System / Home Directories	GridScalar	0.25	NA
Data Capacitor II / DC-WAN	Lustre – to be in operation by April	6.14	NA
Scholarly Data Archive	HPSS	0.60	15
Totals		**6.99**	**15**

Table 22. Summary of data storage resources available at Indiana University.

- *The Research File System.* The IU Research File System is used to provide home directory space for IU's HPC systems. RFS current has a capacity of 60 TB and provides universal access and group collaboration via file sharing. In 4Q2012 the system will be upgraded to a new DataDirect Networks (DDN) solution that will provide on two IU campuses 336 TB of storage that will be asynchronously mirrored for disaster recovery and availability. Users can access files from their desktops, via the web, and via SFTP. Users have a highly flexible system for granting access to files, and the underlying OpenAFS technology used for the system can enable users at multiple institutions to share files. The new environment will use GPFS as the underlying file system with the same interfaces researchers use today. Researchers can request dedicated project space for each project requiring dedicated storage and collaboration. Project space quotas start at 50 GB and can be increased upon request.

- *The IU Data Capacitor.* The current Data Capacitor consists of Dell R610 servers running the Lustre file system. Four servers are used for object storage, and two are used for Lustre metadata. Each of the object storage servers and metadata servers has a 10-gigabit Ethernet card. An additional 24 Dell 1950s are available as data transport servers to support clients that do not mount the file system natively. The Data Capacitor uses a DDN SFA10000 storage controller to provide 1.1 TB of production disk and 350 TB of disk space used for testing and special projects such as middleware development accessed locally from the IU network. In 4Q2012 the Data Capacitor will be upgraded to a 5 PB Lustre file system with hardware from DDN that uses eight object storage servers, two metadata servers, and eight Lustre routers all connected via full data rate (FDR) InfiniBand to two DDN SFA12000 storage controllers. The new Data Capacitor hardware is expected to provide 48-56 GB/s of bandwidth to IU research systems.

- *The Data Capacitor wide area network (DC-WAN)* file system is a high speed/high bandwidth Lustre storage system for research computing that serves all IU campuses and other sites throughout the country. DC-WAN consists of Dell 2950 servers running the Lustre file system. DC-WAN has four servers used for object storage equipped with 10-gigabit Ethernet cards and two used for Lustre metadata that use Gigabit Ethernet. DC-WAN uses an S2A9550 storage appliance to provide 339 TB of usable disk. The maximum local I/O in to and out of the DC-

WAN file systems is 40 Gbps. DC-WAN is currently serving several XSEDE users that require DC-WAN's capabilities. IU provides wide area file system connections for several other research collaborators and facilities, including XSEDE. After the transition to the new Data Capacitor is complete in 2Q 2013, the current 1.1 PB file system will be refocused to be used as a larger DC-WAN.

- *IU's Scholarly Data Archive (SDA)*. SDA uses High Performance Storage System (HPSS) software to make available to IU researchers a total storage capacity exceeding 15 PB. Data are written to a fast, front-end disk cache and migrated over time to IBM TS3500 tape libraries on the Indianapolis and Bloomington campuses. Data written to IU's HPSS system are copied simultaneously to both locations, providing highly reliable disaster protection. Users can access data over the network from central research systems or from personal workstations, using SFTP, pftp_client, HSI/Htar, CIFS, and HTTP. The default quota is 5 TB of mirrored data, with additional space provided upon request. SDA stores and provides access to data for the IUScholarWorks Repository (http://scholarworks.iu.edu), a document and data archiving system created using DSpace software.

8.4.1. Backup and replication within IU Storage Systems

The backup and/or data replication procedures for IU storage systems are as follows:

- *The Research File System.* RFS is backed up nightly to the SDA and saves versions for at least the previous seven days, seven weeks, and two months. While users must request a restore of one of these versions, the previous day's version of each of the user's files is immediately accessible in the one-day backup directory in each user's account.
- *The IU Data Capacitor and DC-WAN.* Data stored on the Data Capacitor and DC-WAN system are not backed up automatically. The Data Capacitor was primarily designed for the short-term storage of data. However, data from the Data Capacitor can easily be transferred to the SDA from any of IU's compute resources and thus replica copies may easily be maintained.
- *IU's Scholarly Data Archive (SDA)*. By default, data stored within the IU Scholarly Data Archive are stored in duplicate copies – one in the tape silo located at IU Bloomington, one in the tape silo located at IUPUI in Indianapolis. The HPSS metadata specifying which tapes contain any given file is backed up continuously, with multiple copies existing both in Indianapolis and Bloomington.

As noted in section 8.7, the system security and documentation of system security is in compliance with NIST 800 Security Standards.

8.4.2. Facilities for handling sensitive data

IU has put in place appropriate administrative, technical, and physical controls to protect data in accordance with the HIPAA security rule. Electronic protected health information (ePHI) may be stored on all of the HPC and storage facilities operated by RT and ABITC.

8.4.3. Disaster recovery planning

IU has a written disaster recovery plan for every service and system it provides. (See a full list of services at: https://webdb.iu.edu/uitsfs/scripts/abc/reports/web_files/0910/RCQS/Basic/RCQS_09-10_UA_BASIC.pdf) IU has a contract in place for use of an off-site disaster recovery facility in case of a disaster affecting one or more of IU's campuses. In the event that a disaster were to strike one core campus (IUPUI or IUB), the disaster recovery plans call for restoring service at the core campus that remains operational; however, we do have plans for service recovery in the event of a disaster striking both campuses simultaneously.

8.5. Networking

The primary connection between IU and national research networks is a 100 Gbps network link from Internet2 to the Indiana GigaPOP in Indianapolis. The Indiana GigaPOP is a collaborative facility located in Indianapolis and operated by the IU GlobalNOC on behalf of the collaborating partners: Ball State University, Indiana University, Purdue University, and University of Notre Dame. IU was the first site to connect to Internet2 at 100 Gbps as part of the Monon100 project. In January 2013 IU's 100 Gbps connection will be extended from Indianapolis to the main campus in Bloomington. IU also has a dedicated 10 Gbps connections to the XSEDE network. The Indiana GigaPOP has a 10 Gbps dedicated connection to the CIC OmniPOP that may be upgraded to 100 Gbps 2013. For redundancy, the GigaPOP also maintains four 10 Gbps redundant and physically isolated connections to commodity Internet. The IU Research Network has as its backbone the 100 Gbps link from the GigaPOP to the IUPUI campus in the Informatics and Communications Technology Complex building and from there to Bloomington and the IUB Data Center (both physical facilities described in section 8.1).

8.6. Advanced visualization facilities

The IU Advanced Visualization Laboratory (AVL) serves as a university-wide resource for visualization, virtual reality, advanced graphics, and visual telecollaboration for researchers, educators, students, and artists in all departments on all campuses. AVL has eight full-time staff and can host graduate students for extended projects.

Major AVL visualization resources include large-format, reconfigurable virtual reality and stereoscopic theaters and ultra-high resolution tiled display walls. The Lab also supports a variety of smaller stereoscopic and interactive displays as well as stereoscopic and ultra-high resolution cameras, 3D scanners, and haptic feedback devices.

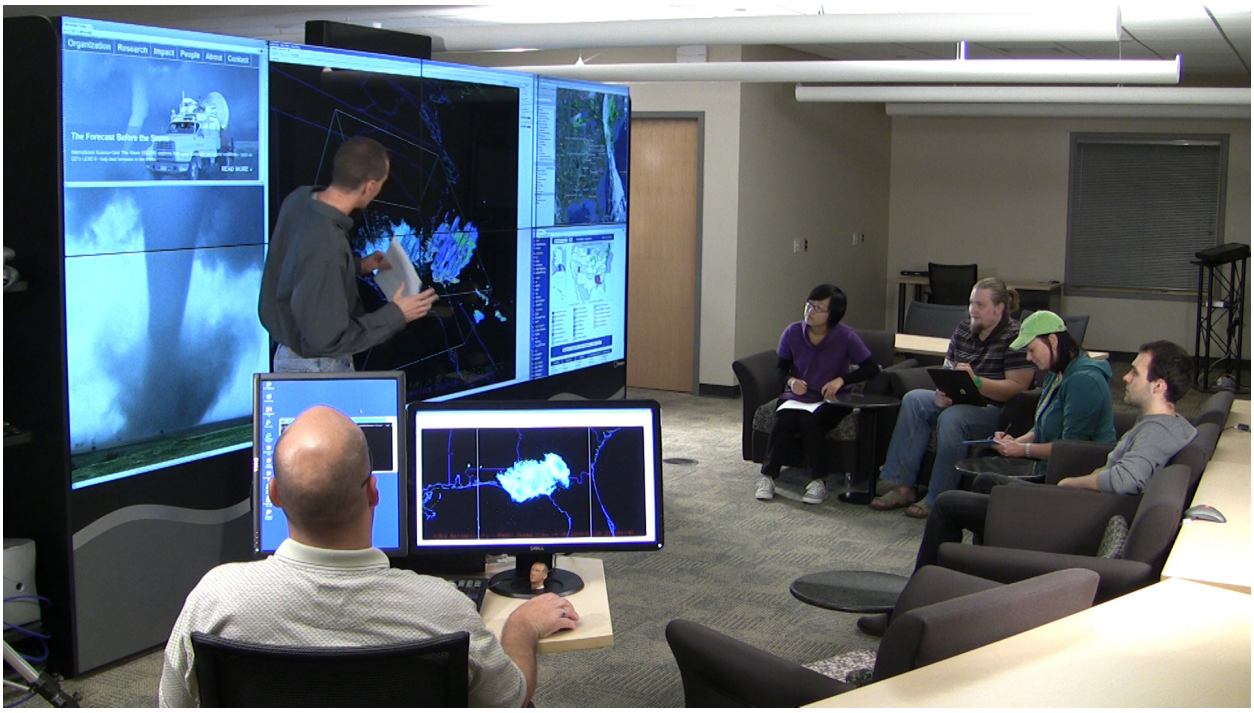

Figure 12. Built using eight high-resolution projection cubes totaling 15.3 million pixels, the Display Wall is capable of receiving input from multiple sources simultaneously, making it ideal for teleconferencing, group collaborations involving multiple video inputs, and/or multiple highly advanced visualization applications. It is driven by a single computer.

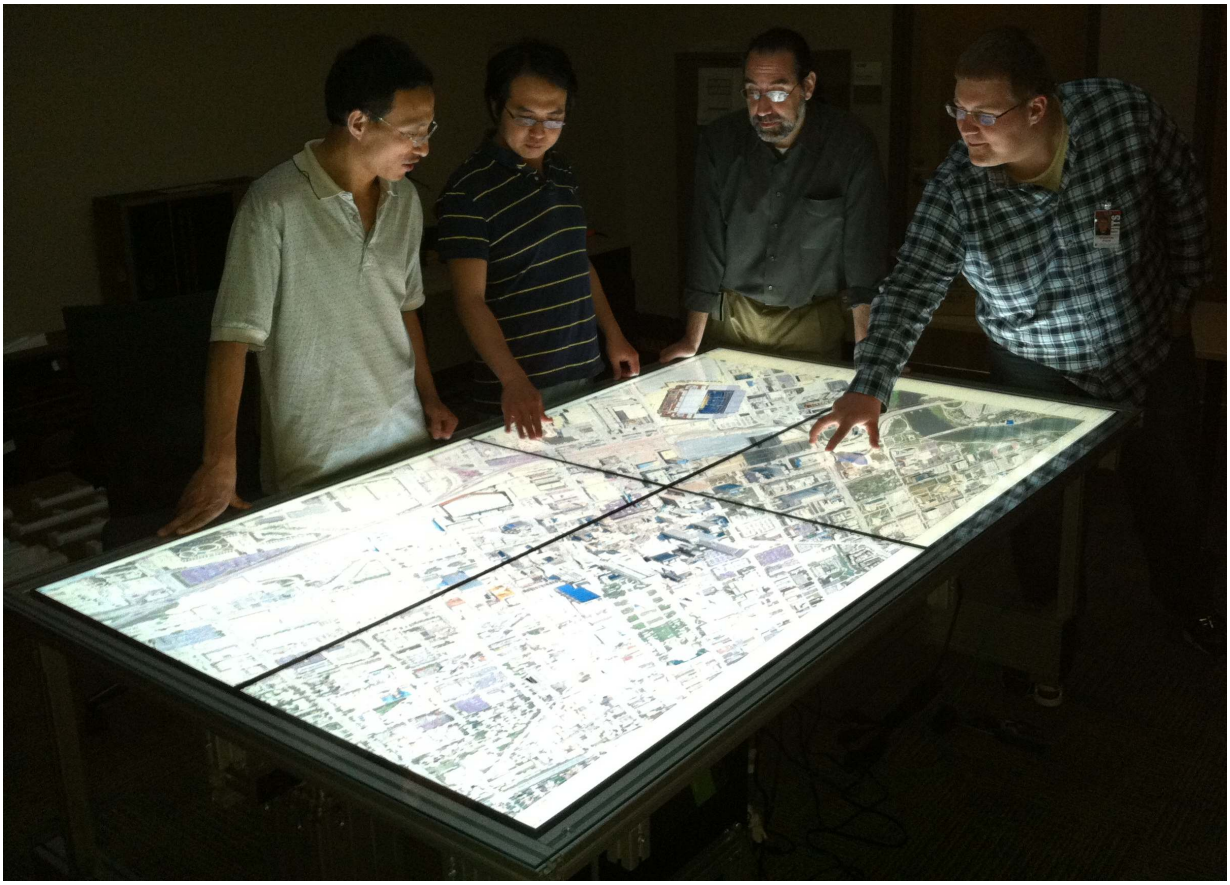

Figure 13. The IQ-Tilt features four 46" monitor tiled together in a 2x2 configuration. This nearly 100" display is treated as one logical Windows desktop, driven by a single computer, and multi-touch enabled. Its name comes from the fact that this display pivots on an axis and can be reconfigured in less than ten minutes into either a horizontal table position or a vertical wall position.

Figure 14. The IUPUI Virtual Reality Theater is a bright, high-resolution, immersive virtual reality technology suitable for individual and group use. The Theater is reconfigurable and driven by workstation computers running either Windows or Linux.

8.7. Federal systems security policy and federal funding agency policy compliance

IU high performance computing and storage systems described here are managed and administered in ways that meet National Institute of Standards and Technology (NIST) 800-53 security standards. OVPIT and UITS comply with the systems management, accessibility, and personal resource guidelines in the NIH Grants Policy Statement.

8.8. Human resources

Staff of the Advanced Biomedical IT Core dedicated to research, programming, and consulting for the IU School of Medicine include the following:

- The ABITC Director (1 FTE, of which at least 30% is devoted to IUSM support)
- ABITC Manager (1 FTE)
- Principal Analyst / Programmer (5 FTE)
- Senior Analyst/Programmer (1 FTE)
- Analyst / Programmer (2 FTE)

This represents a total of 9.3 FTEs devoted specifically to support of IUSM researchers by ABITC. This is a change of 1 FTE increase as compared to the end of FY 10/11. Of these staff, a total of 3.3 are funded by base funds (IU general funds), and 5 are funded on grant awards from external funding agencies.

Other staff of the Research Technologies division of UITS that offer services to the IU community as a whole, including IUSM researchers, include:

- The Research Storage group (6 FTE)
- The High Performance Systems group (12 FTE)
- The Scientific Applications and Performance Tuning group (9 FTE)
- The Campus Bridging and Research Infrastructure group (7 FTE)
- The Advanced Visualization Lab group (8 FTE)
- The Research Analytics group (7 FTE)
- The National Center for Genome Analysis Support group (4.5 FTE)
- The High Throughput Computing group (6 FTE)
- The Collaboration and Engagement Services group (3 FTE)

This represents a total of 69.05 FTEs who offer to the university community as a whole services that are used very heavily by IUSM researchers. Of these staff, a total of 55.17 are funded by base funds (IU general funds), and 13.88 are funded on grant awards from external funding agencies.

Group	Base funded FTE	External Grant-funded FTE	FTE Total
ABITC	3.3	6.0	9.3
NCGAS	0	4.5	4.5
Research Technologies exclusive of ABITC and NCGAS	55.17	13.88	69.05
Total	**58.47**	**24.38**	**82.85**

Table 23. Number of base-funded and grant-funded FTEs in ABITC, NCGAS, and the remainder of RT.

9. Current price schedule for available core services

Most services are provided at no direct cost to IUSM, funded by general university funds and Responsibility Center funding allocations transferred to the Office of the Vice President for Information Technology.

There is an option for paying for dedicated staff time when IUSM researcher needs extend beyond the baseline services offered by UITS and ABITC. Such services can be planned for by funding a position or a fraction thereof as part of a grant proposal. Help can also be paid for on an ad hoc basis when needed. Projects requiring more than 160 hours of work will be charged at the rate of $55.00 per staff hour, or a fractional portion of core staff can be included within the project's grant budget (in which case the cost is the prorated actual cost of the salaries and benefits of the staff dedicated to the project). These rates have been approved by the Core's advisory committee.

10. ABITC Advisory Committee members

- Keith Dunker, Director, Center for Computational Biology and Bioinformatics
- Vince Sheehan, CIO, IUSM
- Howard Edenberg, Director, Center of Medical Genomics
- Gary Hutchins, Director, Center of Excellence in Imaging
- Barry Katz, Director, Department of Biostatistics
- Kay Connelly, Professor, School of Informatics

11. Publications and presentations during reporting period by ABITC staff and RT staff engaged in supporting IUSM research

11.1. Book chapters

Knepper, R., S. Michael, W. Johnson, R. Henschel, and M. Link. The Lustre File Systems and 100 Gigabit Wide Area Networking. An Example Case from SC11, IEEE International Conference on Networking, Architecture and Storage, Jun 2012.

11.2. Conference papers

Catlin, A. C., and W. Barnett, "HUBzero Frameworks for Institutional and Project Scale Information Management"2011 CTSA Informatics Key Function Committee Face-to-Face Meeting, Bethesda, MD, Oct 2011.

Barnett, W. K., "2011 Guide to Research Networking" Clinical and Translational Sciences Award (CTSA) Informatics Key Function Committee (KFC) meeting, Sep 2011.

Barnett, W. K., "i2iConnect: Bridging Inventors and Industry" Indiana CTSI Industry Partnership Meeting, Bloomington, IN., Sep 2011.

Grobe, M., W. Barnett, and A. Shankar, "A HUBzero/Joolma! VIVO Application" VIVO Annual 2nd Annual Conference, Washington, DC. Aug 2011.

Grobe, M., "Enriching VIVO Profile Information from Existing Research Profile Systems" VIVO Annual 2nd Annual Conference, Washington, DC., Aug 2011.

11.3. Conference Proceedings

Weber, G. M., W. Barnett, M. Conlon, D. Eichmann, W. Kibbe, H. Falk-Krzesinski, M. Halaas, L. Johnson, E. Meeks, D. Mitchell, et al., "Direct2Experts: a pilot national network to demonstrate interoperability among research-networking platforms" JAMIA, Nov 2011.

Barnett, W. K., CTSA Research Networking Affinity Group, Jul 2011.

Demeler, B., R. Singh, M. Pierce, E. H. Brookes, S. Marru, and B. Dubbs, "UltraScan gateway enhancements: in collaboration with TeraGrid advanced user support"2011 TeraGrid Conference: Extreme Digital Discovery (TG '11), Salt Lake City Utah, ACM, New York, NY, USA, Jul 2011.

Marru, S., H. Chae, P. Tangchaisin, S. Kim, M. Pierce, and K. Nephew, "Transitioning BioVLab cloud workbench to a science gateway"2011 TeraGrid Conference Extreme Digital Discovery (TG '11), Jul 2011.

11.4. Journal Articles

Michael, S., L. Zhen, R. Henschel, S. Simms, E. Barton, and M. Link, "A study of lustre networking over a 100 gigabit wide area network with 50 milliseconds of latency." Proceedings of the fifth international workshop on Data-Intensive Distributed Computing Date, pp. 43-52, Jun 2012.

11.5. Posters

Kohara, E. K., H. Zhang, R. Arthur, G. Eckert, and M. Ando, Non-Destructive Analysis of Artificial Caries Lesions in Human Enamel, Indiana University School of Dentistry Research Day, Apr 2012.

11.6. Presentations

Barnett, W. K., High Performance Data Management and Computational Architectures for Genomics Research at National and International Scales, Bio-IT World Expo, Singapore, Jun 2012.

Barnett, W., The NCGAS Model for Genomics Support, The Daphnia Genomics Jamboree, Bloomington, IN, May 22, 2012.

LeDuc, R., RNA-seq Analysis, The Daphnia Genomics Jamboree, Bloomington, IN, May 22, 2012.

Barnett, W. K., A Nation-Wide Area Networked File System for Very Large Scientific Data, Bio-IT World, Boston, MA, Apr 2012.

LeDuc, R., "Data Management? I'm a Biologist!" Research Computing Day, University of Florida, Gainsville, Apr 2012.

Barnett, W. K., Collaborative Infrastructure for Health-Care Research: The Indiana CTSI HUB, AAAS Annual Meeting, Vancouver, CA., Feb 2012.

Barnett, W. K., Panel on Collaborative Science, University of Utah, Feb 2012.

Jacobs, M., and C. A. Stewart, "Penguin Computing / IU Partnership HPC "cluster as a service" and Cloud Services." Coalition for Academic Scientific Computation, Arlington, VA, Feb 2012.

Stewart, C. A., Cyberinfrastructure Begins at Home, Rutgers University, New Brunswick, NJ, Feb 2012.

Doak, T. G., L. - S. Wu, C. A. Stewart, R. Henschel, and W. K. Barnett, National Center for Genome Analysis Support, Pacific Symposium on Biocomputing, Big Island, HI, Jan 2012.

Doak, T. G., L. - S. Wu, C. A. Stewart, R. Henschel, and W. K. Barnett, National Center for Genome Analysis Support, Plant and Animal Genomes, San Diego, CA., Jan 2012.

McLennan, M., and W. Barnett, "The HUBzero Platform for Scientific Collaboration." CIC Techforum, Champaign, IL, CIC Techforum, University of Illinois at Champaign., Oct 2011.

Shankar, G., "NNTC Bioinformatics – Current Status and Future Directions" National NeuroAIDS Tissue Consortium Meeting, Washington, DC, Sep 2011.

12. References cited

[1] Arenson, A.D., L.N. Bakhireva, C.D. Chambers, C.A. Deximo, T. Foroud, J.L. Jacobson, S.W. Jacobson, K.L. Jones, S.N. Mattson, P.A. May, E.S. Moore, K. Ogle, E.P. Riley, L.K. Robinson, J. Rogers, A.P. Streissguth, M.C. Tavares, J. Urbanski, Y. Yezerets, R. Surya, C.A. Stewart and W.K. Barnett. "Implementation of a shared data repository and common data dictionary for fetal

alcohol spectrum disorders research". *Alcohol*, 44(7-8), 643-647. 2010. PMCID: 2888879. Available from: http://dx.doi.org/10.1016/j.alcohol.2009.08.007 or http://hdl.handle.net/2022/7194 [cited 6 Dec 2011]

[2] Arenson, A., L. Bakhireva, T. Chambers, C. Deximo, T. Foroud, J. Jacobson, S. Jacobson, K. Jones, S. Mattson, P. May, E. Moore, K. Ogle, E. Riley, L. Robinson, J. Rogers, A. Streissguth, M. Tavares, J. Urbanski, H. Yezerets and C.A. Stewart. Implementation of a Distributed Architecture for Managing Collection and Dissemination of Data for Fetal Alcohol Spectrum Disorders Research. In: *Distributed, High-Performance and Grid Computing in Computational Biology*. W. Dubitzky, A. Schuster, P. Sloot, M. Schroeder and M. Romberg, eds. Springer Berlin / Heidelberg, 2007. Available from: http://dx.doi.org/10.1007/978-3-540-69968-2_4 or http://hdl.handle.net/2022/1025 [cited 6 Dec 2011]

[3] Stewart, C.A., M. Link, D.S. McCaulay, G. Rodgers, G. Turner, D. Hancock, P. Wang, F. Saied, M. Pierce, R. Aiken, M. Mueller, M. Jurenz, M. Lieber, J. Tillotson and B. Plale. "Implementation, performance, and science results from a 30.7 TFLOPS IBM BladeCenter cluster". *Concurrency and Computation: Practice and Experience*, 22(2), 157-174. 2010. Available from: http://dx.doi.org/10.1002/cpe.1539 [cited 6 Jan 2010]

[4] Stewart, C.A., D. Hart, R. Sheppard, H. Li, R. Cruise, M. Moskvin and L. Papiez *Parallel computing in biomedical research and the search for peta-scale biomedical applications*. Elsevier, Oxford, City, 2004.

[5] Stewart, C.A., D. Hart, A. Shankar, E. Wernert, R. Repasky, M. Papakhian, A.D. Arenson and G. Bernbom. Advanced information technology support for life sciences research. *In: Proceedings of 31st annual ACM SIGUCCS fall conference.* (San Antonio, TX, USA, 2003). ACM. Available from: http://portal.acm.org/citation.cfm?id=947472 [cited 6 Dec 2011]