Services and support for IU School of Medicine and Clinical Affairs Schools by the UITS/PTI Advanced Biomedical Information Technology Core and Research Technologies Division in FY 2013 – Extended Version

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PERVASIVE TECHNOLOGY INSTITUTE
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RESEARCH TECHNOLOGIES
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University Information Technology Services
Pervasive Technology Institute

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1. Executive summary

In the 1990s the IU School of Medicine (IUSM) set a goal to be one of the 10 best US public schools of medicine (measured by annual receipts and expenditures of NIH grant funds), and is considering and expanding goals for excellence in clinical care and research nationally and internationally. University Information Technology Services (UITS), especially its Research Technologies Division (RT) and the Advanced Biomedical Information Technology Core (ABITC, of the Pervasive Technologies Institute), support basic, clinical, and translational research conducted by the School of Medicine and the Clinical Affairs (CA) schools.

This report discusses ABITC/RT services to the IUSM and other CA schools including the Schools of Nursing, Dentistry, Health and Rehabilitation Sciences, and Optometry; the Fairbanks School of Public Health at IUPUI; the School of Public Health at IU Bloomington; and the School of Social Work. Because of size and history the IUSM receives the most resources.

These services contribute to innovations, publications, medical therapies, and new data resources created and maintained for the medical and clinical research communities. Examples include

- Discovery and validation of Blood Biomarkers for Suicidality
- Support for Collaborative Initiative for Fetal Alcohol Spectrum Disorder and 3D imaging
- Support for massive computational searches for drug candidates through the SPLInter prediction tool (created by Dr. Samy Meroueh of IUSM)
- Support for the Alzheimer's Disease Neuroimaging Initiative (ADNI) with data at IU exceeding 100 TeraBytes (TB)

These charts show new and continuing grants to IUSM/CA users of RT/ABITC resources.

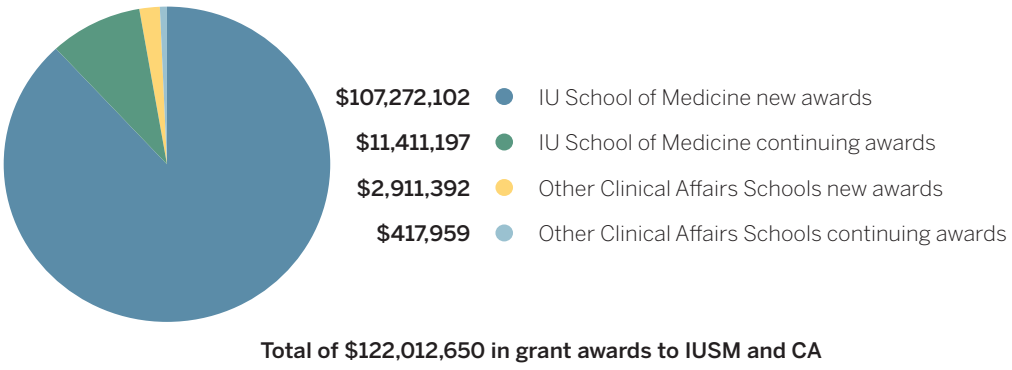

Figure 1. Total active grants for IUSM/CA research users of ABITC/RT services (awarded in and before 2013)

Aggregate new and continuing awards to IUSM/CA total $820,839,285 in external funding, including $122,012,650 in grants to IUSM/CA research users of ABITC and RT services. Total Facilities & Administration monies constitute $29,652,665 of this. ABITC and RT received $6,082,815 in grants led by these groups and which provide services relevant to IUSM/CA schools, including three IUSM grant awards continuing through this reporting period. Abundant cyberinfrastructure (CI) and IT staff expertise augment IUSM and CA grant competitiveness. ABITC/RT help IUSM/CA researchers by supporting, writing and editing grant proposals and providing match. Along with CTSI renewal, RT helped prepare two grant proposals, leading to

$894,726 in new awards to IUSM researchers, not counting the $30M Indiana CTSI award IUSM will receive, announced after the end of this reporting period. ABITC/RT provided matching effort and other support for seven IUSM-led grants awarded before this reporting period that remained active during the period. ABITC/RT provide IU CA schools with a variety of services valued in the millions of dollars yearly, measured by actual costs to IU and by costs for comparable services at commercial market rates. Some are described below.

Managing HIPAA-aligned services. ABITC leads HIPAA alignment of IT storage and supercomputing services, which adds great value for researches. It eliminates having to de-identify electronic protected health information (ePHI) data before analyzing it. Researchers can store and analyze data that are inherently impossible to de-identify, such as facial scans of children suffering from in-utero alcohol exposure. IU's was the first US unclassified supercomputer center to offer this. ABITC is responsible for all HIPAA-aligned UITS services.

Hosting HIPAA-aligned and secure online services and databases. Many ABITC/RT services are related to managing and analyzing data – much of it ePHI. These include the following.

- The Indiana CTSI HUB is Indiana's central portal for translational research and the core online organizing facility for the Indiana Clinical and Translational Sciences Institute (CTSI). ABITC services include federated identity support for trusted access (in keeping with NIH guidance), clinical trials listings, volunteer trials recruitment (INResearch), a grants management system for administering Indiana CTSI grant applications and awards, and i2iConnect – a national technology transfer service for licensing inventions.
- REDCap (Research Electronic Data Capture) enables researchers to quickly design and start small surveys and/or clinical studies in a HIPAA-aligned environment.
- Alfresco Share allows researchers to collaborate with external colleagues on preparing reports, articles, or grant proposals and share ePHI. (This is impossible with IU's other collaboration services like Box, and commercial offerings like Google online tools.)
- Data repositories support specific NIH grants to IUSM researchers, including the data repository for the Collaborative Initiative on Fetal Alcohol Spectrum Disorder and the National Gene Vector Biorepository and Coordinating Center.

During FY 2013 IUSM and Indiana CTSI asked ABITC to support new services and systems. ABITC developed new security plans and processes to make them HIPAA aligned. ABITC operates these services, added in this reporting period, as production facilities for Indiana CTSI:

- Indiana Biobank system. Indiana CTSI created this as the definitive database for specimens in its system. ABITC coordinated finalizing the contract for Remedy Informatics™ software for the database and oversees the system implementation. It will be in production in December 2013, hosted on UITS systems.
- The Indiana CTSI Registry system. ABITC creates and manages research registries that will use the Remedy Informatics platform to manage clinical study data and incorporate electronic medical records data to enhance research. This system is in production and hosted on UITS systems and managed by ABITC staff.
- The Comprehensive Bone Marrow Transplant (Comprehensive BMT) system, managed by ABITC and hosted on UITS systems, uses Remedy to manage the IUSM bone marrow transplant program.
- The Indiana CTSI OnCore Clinical Trials Management System manages clinical trials, including recruiting, reporting, billing, and order sets. It is hosted on UITS systems.
- Mirror copy of Indiana Network for Patient Care (INPC) database. At the request of the Regenstrief Institute, ABITC hosts a mirror copy of the INPC electronic health records database on the Research Database Complex servers. Data can easily be analyzed with

the Quarry supercomputer as part of the Observational Medical Outcomes Partnership (OMOP) program. UITS is partnering with Regenstrief in a proposal to the Patient Centered Outcomes Research Institute (PCORI) to establish a clinical data research network (CDRN) that will further utilize health records in research.

ABITC support for these services, and their use by IU clinical researchers, has expanded during the current reporting period. Use metrics appear in Figure 2 and **Error! Reference source not found.**.

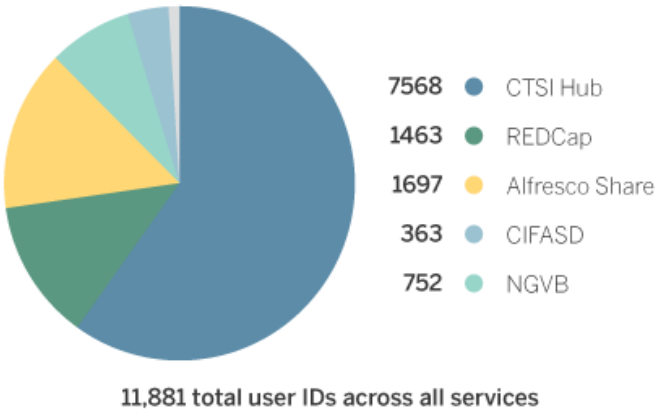

Figure 2. Number of users (user IDs per service) on various ABITC/RT services and data sources that support IUSM/CA schools. The number of user IDs per service is a good measure of the workload associated with maintaining that service. The number of distinct users is less than the sum of the login IDs per service, as many researchers have IDs on more than one service.

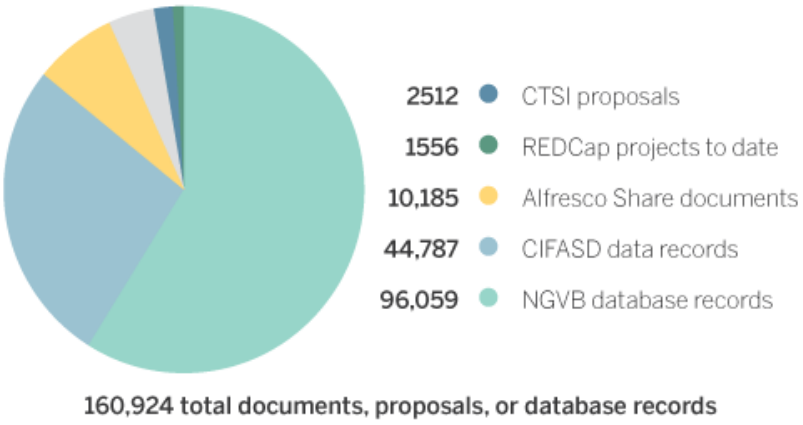

Figure 3. Number of records (database records, documents, or projects) stored in services and data sources operated by ABITC and RT in support of IUSM and CA schools

Delivery and support of advanced cyberinfrastructure for medical and clinical research. RT/ABITC provide and support some of the nation's most advanced CI (computation, storage, and visualization) systems. IU's best, largest, and fastest supercomputers and storage systems are all HIPAA aligned so researchers can store and analyze data sets that include ePHI without de-identifying data. Some data –complete DNA sequences and facial images – are impossible to de-

identify, so any systems that store or analyze such data must be HIPAA aligned. IU was the first US non-classified institution in (beginning in 2008) to operate HIPAA-aligned advanced CI.

The next most-used ABITC/RT resource (after online collaboration tools such as Indiana CTSI and databases of biomedical and clinical data) is disk storage for other than databases. During FY 2013 IU purchased and installed the Data Capacitor II (DC) which provides high-capacity, high-performance I/O for short-term analysis and storage of data sets of all sorts with a total capacity of 5 PetaBytes (PB – quadrillions of Bytes). It is the disk storage companion to Big Red II and key in IU's strategy for Big Data. It would take a stack of DVDs more than three quarters of a mile high – more than a million DVDs – to hold 5 PB. The DC can move data to and from IU's supercomputers at 20 GigaBytes (thousands of MegaBytes) per second.

IUSM researchers store millions of records and documents in ABITC/RT resources. They were prodigious users of storage, with 174 TB of data on disk, 11.6% of IU's total on disk, and 1.9 PB on magnetic tape, 10% of IU's total on tape. CA researchers outside IUSM stored 0.03 TB on disk, 0.002% of IU's total on disk, and 70 TB on magnetic tape, 0.6% of IU's total on tape..

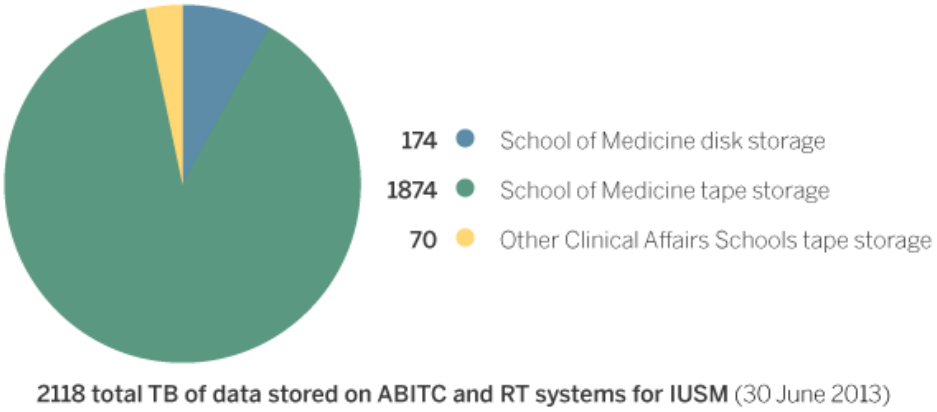

Figure 4. Storage of data on disk and tape by researchers at the IUSM and CA schools.

The Scientific Data Archive (SDA) tape-based archival storage service offers secure, replicated data storage over long periods of time. Data are copied in duplicate to an Indianapolis tape library and again to one in Bloomington, a service unique among US university computing centers. Data remain available for the foreseeable future. Publications can remain in escrow to be made public later on, benefiting innovations that might later have practical applications.

In FY 2013 IU purchased and installed the Big Red II supercomputer, a one-PetaFLOPS Cray supercomputer capable of one quadrillion mathematical operations per second, or what a person doing one calculation per second with a hand calculator would do in more than 31 million years. It is ranked as the 2nd-fastest university-owned and operated supercomputer, and the biggest and fastest HIPAA-aligned supercomputer at any US institution of higher education. It can rapidly move and analyze massive amounts of data. To determine its configuration we interviewed clinical and biomedical researchers to ensure it could meet their Big Data challenges. A Big Red II video, with comments by IUSM's Dr. Andrew Saykin, is online at http://go.iu.edu/8NN

Supercomputer use at IU is "co-led" by faculty researchers and ABITC/ RT staff who work with them. Sometimes RT staff working on federally-funded CI projects create a solution and go hunting for a problem it solves. This approach has had dramatic payoffs, like optimizing the Trinity RNA sequencing program to run 75% faster than the previous version.

IUSM researchers used 14.9% of the supercomputer CPU (processor) hours used by IU researchers, or 5,826,435 CPU hours. With CA researchers, IU supercomputer use totaled 5,837,444 CPU hours, or 14.9% of all IU supercomputer resources. Six of Big Red's top 25 users, two of Mason's top 25, and one of Quarry's top 25 were IUSM researchers. IUSM's Samy Meroueh used over 3 million hours on the Open Science Grid. Because it is federally supported, he used it at no cost. . IUSM/CA use of RT-managed supercomputers is very high, with 130 IUSM accounts. CA researchers bring the total to 201. Survey data show 10.2% of IUSM faculty directly or indirectly use an IU supercomputer or other system, which is high compared with other universities and medical schools.

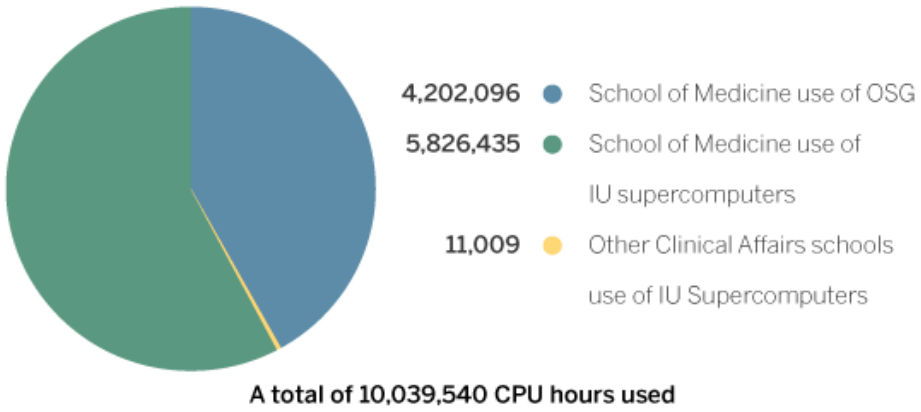

Figure 3. CPU hour usage by IUSM and CA researchers

IU supercomputers perform things smaller computers or cloud facilities cannot. The cost of CPU time IUSM researchers used on UITS and OSG systems, purchased from Amazon's On-Demand Instances, would have been $1,204,745. RT storage used by IUSM would have cost $346,752; that used by all CA schools would have cost $8,400. Understanding and visualizing data, including 3D objects, is a research challenge. IUSM researchers use 3D scanning cameras to develop diagnostic tools for fetal alcohol spectrum disorder. They develop workflows that facilitate the analysis and visualization for IUSM and IU School of Dentistry (IUSD) data. IUSM work was showcased during a presentation at the IEEE (Institute of Electrical and Electronics Engineers) Cluster Visualization Showcase. UITS technical staff assisted with user studies conducted by IUSD to assess the value of virtual interfaces for training students.

ABITC provides IUSM researchers with extensive consulting and programming. Extended consultations, requiring from 4 hours to many person-months or years of staff time – are the main support we provide IUSM and CA researchers. It is is critical to effective use of IU's advanced cyberinfrastructure to accelerate IU's biomedical, health, and clinical research. In the process ABITC and RT consultants and programmers come to deeply understand the research which makes them more effective and efficient. During FY 2013, the ABITC increased its support for IUSM research and handled 28 extended consultations. Another 56 were ongoing June 30, 2013. Many are part of grant-supported activities or involve OVPIT and UITS funding as part of matching effort for IUSM and CA grants. Many are part of baseline funded by OVPIT/UITS general funds. These efforts help complete research projects quickly and effectively, create results and software projects that support new grant proposals, and build grant competitiveness.

The UITS User Satisfaction Survey (www.indiana.edu/~uitssur/) shows the IU community's use of and satisfaction with UITS services. Satisfaction is measured on a 1-5 Likert scale, where 1 is "not at all satisfied" and 5 is "highly satisfied." The ABITC average satisfaction score was 3.97,

up from 3.90 in 2012. Just over 94% (87 % in 2012) ranked them 3 or higher – the "satisfaction %." Over 11% of IUSM researcher respondents used ABITC services directly; more use them indirectly via the Indiana CTSI portal. IUSM researcher ratings appear in Appendix 1.

Yet challenges remain. One is cultural. IUSM has a culture of internal recharge for core services rather than providing ongoing funding. This works well for services that can be contracted for in advance, and that grant proposal review panels will likely review favorably. These include programming services that ABITC and RT deliver for IUSM and CA researchers.

But work related to use of supercomputers, visualization systems, haptic systems, and other cutting-edge cyberinfrastructure tends to be potentially high-reward, but very high risk. It is very difficult to operate a core service on a business model that from the researcher's viewpoint offers the value proposition "buy this service, and with a significant probability this service will not do you any good, but with some probability it will revolutionize your research." High-risk, high-reward services that align with institutional priorities as they do with advanced CI at IU may be better funded as a strategic institutional investment. The NIH has funded the renewal of the Indiana CTSI project. ABITC has less than 1 FTE of staff effort uncommitted to pre-defined and ongoing grant work. That is not enough to maintain our investment in the CI-enabled discovery and grant funding at the level CA researchers enjoy today. The equipment replacement funding for IU's supercomputers, storage, and visualization systems will not allow for the rate of growth that has put IU to be where it is today.

Funding is a challenge. IU's CI investment is key in sustaining researcher grant competitiveness and advancing the research that leads to new tools and therapies for improving health. This report shows that ABITC and RT advanced CI resources are widely and heavily used by IUSM and CA researchers, much of their research depends on them. IU's investment supports their innovation, discovery, and development of new diagnostic tools and therapies.

2. Introduction

Indiana University set in the 1990s a goal to be among the absolute leaders in higher education in development and application of advanced information technology. More recently President McRobbie set a goal for IU to be one of the "great universities of the 21st century." The IU School of Medicine set a goal to be one of the 10 best public schools of medicine in the US (as measured by annual receipts and expenditures of NIH grant funds), and is considering and expanding goals for excellence in clinical care and research nationally and internationally. University Information Technology Services (UITS) supports these goals via support for School of Medicine research (basic, clinical, and translational), notably via its Research Technologies (RT) division and the Advanced Biomedical Information Technology Core (ABITC).

ABITC is a certified core of the IU School of Medicine (IUSM) and the Indiana Clinical and Translational Sciences Institute (CTSI), and a management unit in RT and the Pervasive Technology Institute (PTI). It supports biomedical and health-related researchers across IU, especially those doing basic biomedical, translational, and clinical research who use electronic protected health information (ePHI). Its goal is to provide IUSM/CA researchers with IT solutions, partner in innovative approaches to research through programming and consulting, and help researchers maximize the capability and breadth of IU's advanced cyberinfrastructure (CI).

ABITC provides consulting and programming services and is a front door to RT services, including data storage, supercomputing, visualization and analytical support, and collaboration and engagement support. It includes 9.3 FTEs; 3.8 are base funded. Of those, 2.5 FTE provide matching effort to support IUSM grant awards, more than is dedicated to any other IU academic unit. More than 93 RT FTEs provide services directly or indirectly that aid IUSM/CA research and research education.

IUSM supplies IT services and support via Information Services and Technology Management (ISTM); the Bioinformatics Core, Center for Computational Biology and Bioinformatics; the Biostatistics Core, Division of Biostatistics, and department or research groups. Their expertise is in particular algorithms and software. ABITC can provide these and other advanced IT services at scale. ABITC/RT provide IUSM amounts of HIPAA-aligned storage without comparison at any US medical school. ABITC can also implement and deliver advanced computational services via Big Red II, the largest university-owned, university-funded supercomputer in the US. ABITC delivers visualization capabilities that match the most sophisticated capabilities at any US medical school or sensitive government agency.

The history of UITS service to IUSM/CA schools includes early support for medical researchers on IU supercomputers = a full-time bioinformatician, as of 1998. During fall 1999 IUSM led the preparation of a historic grant proposal to the Lilly Endowment for $105M for the Indiana Genomics Initiative (INGEN). 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, the direct predecessor to ABITC, provided deep expertise and extensive consulting to a few IUSM researchers and became the first certified as an IUSM core, but outside the IUSM organizational umbrella. There were early, big successes (Stewart et al, 2003; Stewart et al, 2004) but they affected a small number of researchers, rather than creating a cyberinfrastructure[1] that

[1] Cyberinfrastructure consists of computing systems, data storage systems, advanced instruments and data repositories, visualization environments, and people, all linked together by software and high performance networks to improve research productivity and enable breakthroughs not otherwise possible (Stewart, 2007).

IUSM researchers used in their everyday research. The limiting factor was the systems were not HIPAA aligned, so IUSM researchers had to de-identify their data before using them.

The impetus for change was UITS involvement in the Collaborative Initiative for Fetal Alcohol Spectrum Disorder (CIFASD). Craig Stewart the PI on the NIH U24 grant to provide the informatics core for this international collaboration funded by the National Institute on Alcohol Abuse and Alcoholism (NIAAA) and included IUSM researchers. Supporting this research, especially that of Dr. Tatiana Foroud, required storing facial images of children affected by fetal alcohol spectrum disorder (FASD), data inherently impossible to de-identify. Dr. William K. Barnett, then RT life sciences senior manager, led the process of HIPAA alignment for all major RT systems, completed in 2008. This made a fundamental change in value and ease of use.

RT is led by Associate Dean and Pervasive Technology Institute Executive Director Craig Stewart, with the following divisions and senior divisional leadership:

- Dr. William K. Barnett, Director of Science Community Tools. His responsibilities include ABITC, the National Center for Genome Analysis Support, and the High Throughput Computing group.
- Mr. Matthew R. Link, Director of Systems. His responsibilities include RT supercomputers, storage systems, database operations, campus bridging, and high performance and parallel applications support.
- Dr. Eric Wernert, Director of Visualization and Analytics. His responsibilities include virtual reality, visualization, and haptics systems, applications, and support, science gateways, and research analytics.
- Ms. Therese Miller, Senior Manager of the Collaboration and Engagement Support Group. Her responsibilities include support for grant proposal preparation and educational and outreach activities for Research Technologies and the Pervasive Technology Institute.

Appendix 2 shows the RT organizational chart as of June 30, 2013 (including ABITC). This is the 2nd annual report on ABITC/RT services provided to IUSM/CA researchers. For the 2012 Annual Report of the Advanced Biomedical Information Technology Core, see Barnett et al, 2012. More general reports on the use of IU cyberinfrastructure in support of research and education are also available (Link, 2012; Link et al, 2013).

The relationship between ABITC, RT, UITS, the Indiana University Pervasive Technology Institute (PTI), and the Office of the Vice President for Information Technology (OVPIT) bears brief explanation. PTI's mission is to improve the quality of life in the State of Indiana and beyond through novel research, innovation, and service delivery in the broad domain of information technology and informatics. PTI is a collaboration of the School of Informatics and Computing, Maurer School of Law, College of Arts and Sciences, UITS, and OVPIT. PTI reports administratively to OVPIT. PTI includes two types of centers: research centers and cyberinfrastructure and service centers. The research centers are traditional computer science- and informatics-oriented faculty research labs. Their role is fundamentally to do science – not engineering. The PTI Cyberinfrastructure and Service Centers include the Research Technology (RT) Division. These centers take Research Center innovations, make them more robust, and implement them as new services and applications that enhance research innovation, faster discovery, and greater competitiveness for grant funds. Many incorporate innovations by PTI researchers, implemented in "production quality" applications delivered and supported by ABITC and RT. These resources are available to all researchers including those at IUSM and CA.

The following section presents some important and socially significant scientific advances relevant to IUSM and CA schools.

Discovery and Validation of Blood Biomarkers for Suicidality

Project Lead: Dr. Alexander Niculescu, Indiana University School of Medicine
ABITC/RT Lead: Ganesh Shankar, ABITC Core, Consulting and Development

Clinicians today do not have a reliable test to detect inclination or propensity toward suicide. They rely on indirect tests such as patient-reported symptoms and feelings to decide whether someone requires immediate help and care. A quantitative test would be clinically useful for predicting and tracking suicidal tendencies and could allow clinicians to treat patients earlier. Dr. Niculescu, at the Dept. of Psychiatry, IU School of Medicine, has discovered that SAT1 mRNA levels may serve as a biomarker for suicidality when used in conjunction with other tests.

Individuals contemplate and are victims of suicide every day. This loss affects families and friends and leads to lifelong emotional trauma. Members of the military services are at high risk for depression and suicide. Current tests for suicide rely on self-reports and are subjective and prone to error. Developing an objective diagnostic tool would be highly useful in predicting and tracking the inclination toward suicide and would help in prevention. Developing a biomarker panel from the current research will be a crucial step in creating an objective measure of suicidality.

Dr. Niculescu has been researching mood disorders over the past two decades, and suicide more recently. He is focusing on developing molecular biomarkers for mood disorders as objective measures of mental state and ideation. The Advanced Biomedical IT Core provided software development expertise to finish developing the Convergent Functional Genomics scoring algorithm. This algorithm was instrumental in identifying the SAT1 biomarker for suicide. Dr. Niculescu published the results in *Molecular Psychiatry* and the paper was the most viewed and downloaded from the Nature.com website for September 2013, indicating the paper has been well received and has made an impact.

Figure 6. Dr. Niculescu's research has identified a biomarker for suicidality that can be identified in blood samples.

SPLInter Molecular Interaction Prediction Tool on the Open Science Grid

Project Lead: Rob Quick, Open Science Grid, Indiana University
ABITC/RT Lead: Rob Quick, High-throughput Computing

Small molecule therapeutics, such as the anti-cancer drug Gleevec, work by binding to a specific protein in the body and modulating its function. Cancer researchers work to pinpoint proteins in cancer cells, and find compounds that target those proteins, all in hopes of shutting them down. With the help of the Open Science Grid (OSG) nearly 4 million hours and thousands of compound docking simulations have been delivered to the SPLInter project at the IU School of Medicine. The SPLInter (Structural Protein-Ligand Interactome) project is an online database that predicts interactions of small organic molecules with proteins through structure-based molecular docking and scoring.

The more compounds that are docked and scored, the greater the diversity of the interactome, or the set of molecular interactions in a given cell. This increases the chances of making promising discoveries and speeds the research process from simulation, to ordering, to wet lab testing in a more efficient manner.

The SPLInter project is headed by Samy Meroueh. The OSG effort is headed by Rob Quick. The interactome can be accessed at biodrugscreen.org.

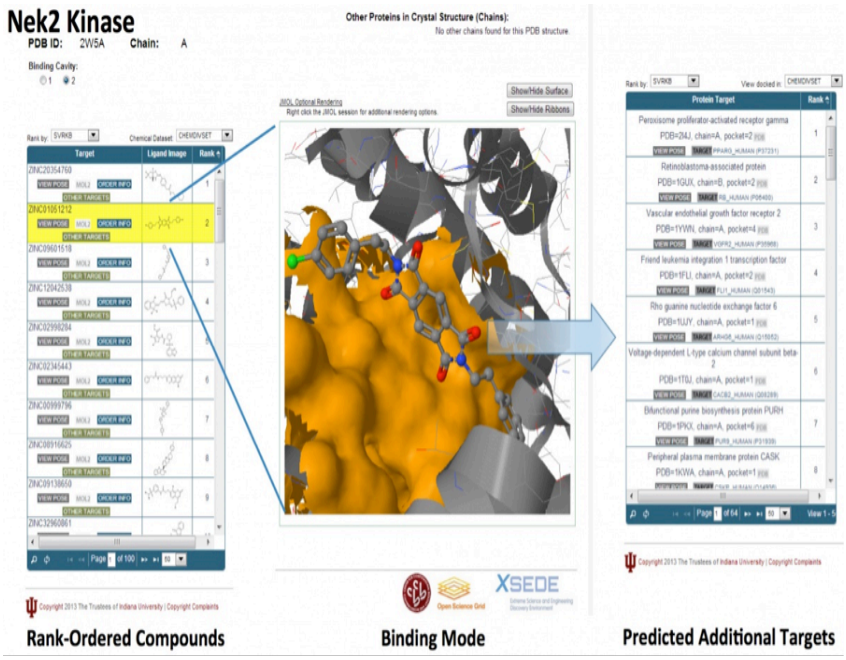

Figure 7. Different perspectives of protein epidermal growth factor receptor (EC 2.7.10.1) (Proto-oncogene c-ErB-1) (Receptor tyrosine-protein kinase erbB-1). The table lists rank-ordered compounds docked to the target, and provides links to external websites for purchasing information. Image courtesy www.biodrugscreen.com.

Support for Collaborative Initiative for Fetal Alcohol Spectrum Disorder and 3D Imaging (October 2013)

Project lead: Jeff Rogers, Advanced Visualization Lab, Research Technologies, Indiana University
ABITC/RT Lead: Jeff Rogers, Advanced Visualization Lab, RT

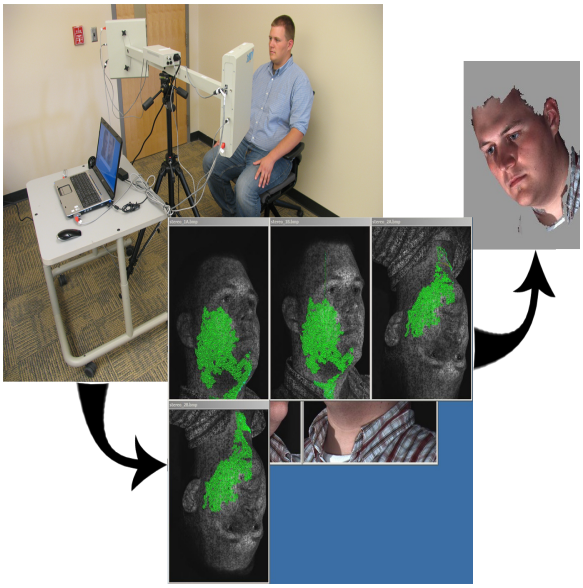

Figure 8. The 3dMD camera system set up to capture a subject, data acquisition processing, and the final 3D dataset ready for research analysis.

The Collaborative Initiative on Fetal Alcohol Spectrum Disorders (CIFASD) 3D Imaging Core has acquired three new 3dMD facial capture systems with funding from the National Institute on Alcohol Abuse and Alcoholism, doubling the number of capture sites the facial imaging project can support.

With more than 3,400 subjects and six facial capture sites, the 3D facial database continues to grow. IU's Advanced Visualization Lab (AVL) processes the data into several formats for analysis by researchers around the globe, including University College London's Professor Peter Hammond. The results of analyzing longitudinal data will have significant impact on the understanding of FASD.

Tatiana Foroud, P. Michael Conneally Professor of Medical and Molecular Genetics, Chancellor's Professor, and Director of Hereditary Genomics Division, is the Principal Investigator of the 3D Facial Imaging project in the CIFASD. With AVL support Dr. Foroud incorporated more 3D facial data collection sites into the project, including international sites in the Ukraine and South Africa. For nearly a decade, the AVL has provided support locally and to remote capture sites across the globe, including hardware support and troubleshooting, along with custom data processing and analysis software. Support involving the additional capture systems will increase the amount of cross-cultural, cross-racial subject data gathered around the world.

Cook Medical Data On a Sphere

Project Lead: David Reagan, Advanced Visualization Lab, Research Technologies, Indiana University
ABITC/RT Lead: David Reagan, Advanced Visualization Lab, RT

Figure 9. A map showing shipments of Cook Inc. products worldwide, displayed on the Science on a Sphere visualization system in the Cyberinfrastructure Building.

The Advanced Visualization Lab worked with Cook Medical to visualize shipping data using the Cyberinfrastructure Building's Science On a Sphere installation.

The Science On a Sphere display allowed AVL staff to display Cook's global shipping data in their natural state – on a globe. These visualizations were highlighted during a recent meeting of the Bloomington Chamber of Commerce. The AVL established a workflow for creating global maps that will scale to support greater volumes of data from Cook, as well as similar datasets from other sources.

Based in Bloomington, Indiana, Cook Medical is a global company specializing in the development of healthcare devices. AVL staff created two types of visualizations of Cook shipping data for use on the Science On a Sphere display, a global display system that uses computers and video projectors to display planetary data onto a six-foot-diameter sphere. The first visualization is a network graph where, for each order, an arc is drawn from the source of the order to the shipping destination. These arcs are colored according to the type of product ordered. The second visualization (Figure 8, above) shows a choropleth map, where each country is shaded according to the number of products received.

Alzheimer's Disease Neuroimaging Initiative Data at IU Passes 100-Terabyte Level

ABITC/RT project lead: Kurt Seiffert

The National Center for Genome Analysis Support (NCGAS, part of PTI) has achieved a significant early accomplishment in support of IUSM researchers through Dr. Andrew Saykin, a national leader in the Alzheimer's Disease Neuroimaging Initiative (ADNI). ADNI will store the full human genomes of 808 individuals, and use this 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 the resources provided by NCGAS and RT, IU is one of three national data repositories for ADNI, storing over 100 Terabytes of ADNI genomic data. IU's high performance and robust storage system will thus enhance the national infrastructure of ADNI and position IUSM researchers for better access to these critical research data. Local storage on IU supercomputer systems also will enhance the ability of Dr. Saykin and other IU researchers to analyze these data. As a national genomics repository, IU is strategically positioned for future collaborations in genomics research. Figure 11 compares the analysis capabilities of Big Red II to those of the Mason supercomputer cluster, IU's former top system for assembling gene sequences.

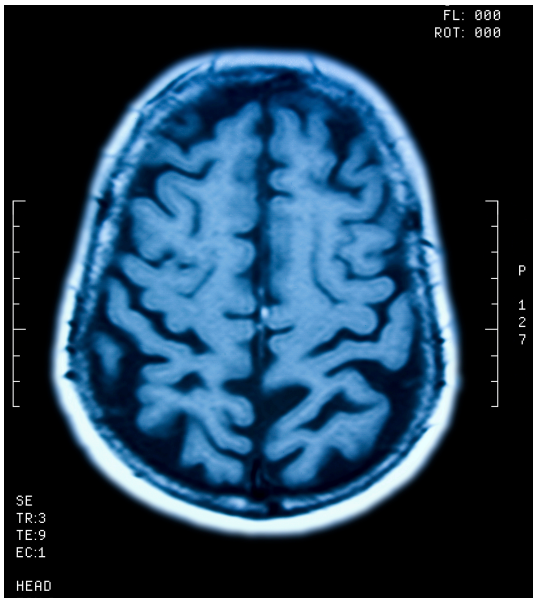

Figure 10. A brain image created by IU radiology experts. IU researchers and others involved in the ADNI project are trying to understand the causes of Alzheimer's disease by linking brain image data and behavioral test data to genome sequences of individual patients.

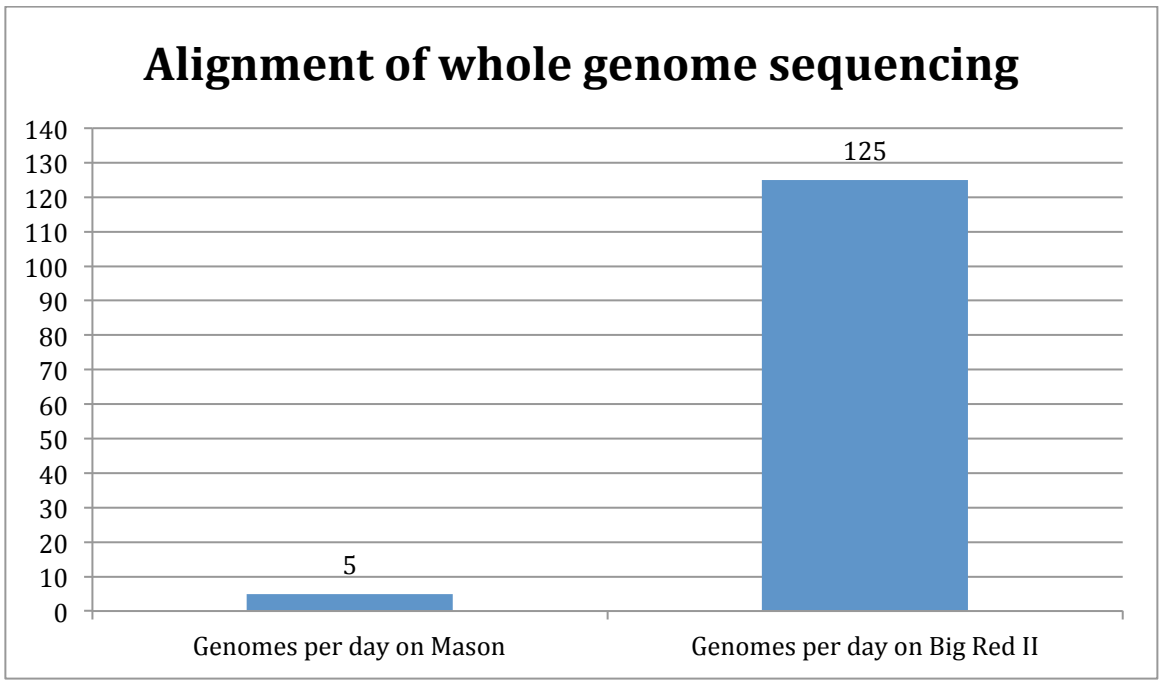

Figure 11. Chart comparing the analysis capabilities of IU's Big Red II to the IU Mason supercomputer cluster, IU's former top system for assembling gene sequences. With Mason it was possible to assemble 5 human genomes a day. With Big Red IU researchers can assemble the personal genomes of 25 x more patients per day.

BLAST, Galaxy workflows, and Open Science Grid

ABITC/RT project lead: Rob Quick

BLAST (Basic Local Alignment Search Tool) is the most frequently used alignment tool in genomics research for comparing sequence information across species to identify like or similar genes. Researchers use it to infer functional and evolutionary relationships between sequences, so it is important in identifying gene function. It is very computationally intensive, but one BLAST run can be neatly divided into many subtasks that are executed in parallel. This makes BLAST an ideal candidate for high-throughput computing architectures. The RT High Throughput Computing (HTC) group and NCGAS teams created a transparent job manager that executes BLAST through the NCGAS Galaxy interface and automatically parses jobs out to the Open Science Grid (OSG), a national resource of over 200 research clusters. An initial test improved execution time from six days to four hours. Researchers can now perform these alignment analyses without needing to manage the details of what computer systems are involved, lowering the barriers to using this tool, while accelerating the delivery of results.

3. Support for grant-funded activities by IUSM and other CA schools

Grant funding can be key to innovation. During FY 2013 new and continuing awards to IUSM researchers supported by and using ABITC/RT services totaled $118,683,299, including $28,817,481 in Facilities and Administration funds realized over the course of these grants. New and continuing awards to other CA researchers supported by and using ABITC/RT services totaled $3,329,351, of which $835,184 represented Facilities & Administration funds. Three led by ABITC/RT staff totaling $6,082,815 directly aid IUSM faculty research. In sum, ABITC/RT activities supported or led awards of $124,681,645 in aid of the IUSM mission.

RT assisted with several new IUSM researcher grant proposals. Along with the Indiana CTSI renewal, RT helped prepare two grant proposals that led to $894,726 in new IUSM awards. ABITC/RT provided matching effort and other support for seven ongoing IUSM faculty grants

awarded before the reporting period, and that remained active during it. $30,000,000 was the Indiana Clinical and Translational Studies Institute renewal in which ABITC/ RT were key. This grant received the highly unusual score of 11, when 10 is the highest possible for an NIH grant.

ABITC/RT often provide formal, committed match in support of grant proposals. They are often funded parts of project teams in projects that involve dedicated research IT service development and delivery. Section 3.1 describes active grants with this kind of involvement.

3.1. Grant awards led by IUSM faculty active during reporting period

Key information for grants current during the FY 2013 reporting period appears in Appendix 3: Part A shows IUSM faculty-led grants supported by ABITC/ RT, and Part B, ABITC/RT-led grants that aid IUSM faculty and research. A financial summary appears in Table 1 below. ABITC/RT provided formal match support for seven IUSM faculty-led grants active during the current grant reporting period, with a value to IU of $29,085,594. These are supported by $1,544,500 in match from ABITC/IUSM. Three ABITC/RT staff-led grants totaling $6,082,815 directly aid IUSM faculty research.

"Formal match" refers to match that is a formal part of the grant budget. ABITC/RT contribute additional services and facilities in support of federally funded grant awards, including facilities (virtual machines), facilities and resources supporting staff work (when subcontracts to UITS include only salary and benefits, not facilities and administration costs); and staff time not paid for by grant awards and subcontracts. These contributions are also shown.

3.2. Financial summary of current active grant awards

	# of awards	Total $	Subcontract to ABITC / RT	Formal match commitments from ABITC/RT	Value of additional UITS services and budgetary contributions
Grants led by IUSM faculty researchers and supported by ABITC and Research Technologies	6	$59,385,594	$2,046,725	$1,544,500	$1,019,776
Grants led by ABITC and Research Technologies that support IUSM research	3	$17,955,260	$4,622,815	$541,113	$2,162,003
Totals	9	$77,340,854	$6,669,540	$2,085,613	$3,181,779

Table 1. Summary of grant incomes to IUSM, subcontracts to ABITC/RT, and match from ABITC/RT for grants supported or led by ABITC/RT

3.3. Grants of note in review as of end of reporting period

In FY 2013 the Broad Institute submitted a proposal to the National Cancer Institute, with RT and the NCGAS as partners. It proposed the following

The Broad Institute will improve the bioinformatics capabilities of Trinity.

- RT will optimize the Trinity software to run on supercomputers.
- NCGAS will provide Trinity as a free service to the cancer researchers who want to undertake RNA sequence analyses.

Under this proposal RT and NCGAS would provide petaFLOPS-scale supercomputing through Big Red II and large-memory analysis capabilities through Mason, architected for genome assembly. The project would also leverage national networks and cyberinfrastructure services.

We would implement and integrate a national Trinity services model in partnership with national research infrastructures such as the Open Science Grid (operated by IU), providing the computational capacity to analyze large genomics data sets. Trinity represents the state of the art in RNA sequencing tools, so is particularly important for biomedical researchers. After the end of the reporting period but before this report was completed, we learned the proposal was funded. This will bring IU $1.26M for Trinity-related services which will support the national community, including IU researchers.

Staff who support national communities often benefit their home institutions through the relationships they've built with local researchers, and can augment formal services with informal technical aid and insight over lunch or in casual discussions.

In FY 13, the ABITC participated in a proposal led by William Tierney, Regenstrief Institute, collaborating with the Indiana CTSI, to the NIH Patient Centered Outcomes Research Institute (PCORI) solicitation to help create a Clinical Disease Research Network (CDRN). Regenstrief would coordinate creating the CDRN and collecting and managing data from multiple local hospitals. ABITC would create and manage disease registries for osteoporosis, neurofibromatosi, and obesity. ABITC would improve the INResearch software to increase patient recruitment. RT would provide computational capacity and software for computational aspects of the CDRN; UITS would provide software applications hosting and data storage for the proposed network.

In FY 2013, ABITC participated in an IU response, led by Bernice Pescosolido, Department of Sociology, in collaboration with the IUSM, the Regenstrief Institute, the School of Informatics and Computing, and Research Technologies, to the NIH Big Data to Knowledge (BD2K) Centers of Excellence request for applications. It takes an innovative Network Science approach to Big Data research by establishing Big Data research architectures and demonstrations in a variety of health research contexts. RT would provide the center's storage and computational resources and establish two new computational architectures – a MapReduce/Hadoop architecture for distributed data storage and analysis, and a Big Data Appliance for pattern analysis of Semantic Web Resource Description Framework (RDF) triple stores.

4. Description of services provided by ABITC/RT

Below are some ABITC/RT services that support ongoing and national research initiatives and consortia led by IUSM/CA researchers..

4.1. Database, document, and collaboration systems

Appendix 4 provides a summary of ABITC/RT services to IUSM/CA schools. ABITC's most important activity in usage, impact, and visibility is the Indiana CTSI HUB – the electronic front door for all Indiana CTSI web-based collaboration and support. (For details of all ABITC/RT-managed database services, see Appendix 5.) ABITC staff put it in place along with new software that allows for secure, InCommon-based user authentication (https://incommon.org), an NIH best practice. Figure 12 shows the Indiana CTSI HUB home page.

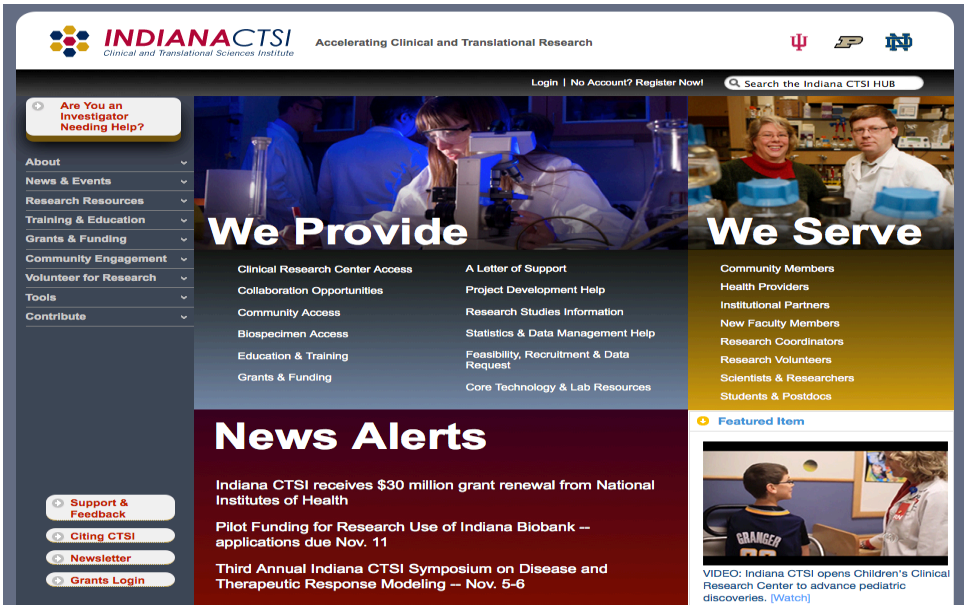

Figure 12. Screen image of the IndianaCTSI HUB, showing some of the main services, the login link (upper right corner), and some video display capabilities.

Database services that are new or newly managed by ABITC are the result of IUSM's request.

ABITC also improved many services, including the CTSI Grants Management System, which enables grant administrators, reviewers, and applicants to collaborate during the application and award process. New reporting capabilities help CTSI administrators create multiple reports within and across multiple grants. the Indiana University Research and Technology Corporation (IURTC) has disclosed this software which will be contributed back to the Clinical and Translational Science Awards (CTSA) community as an open-source release. Six CTSAs have already expressed interest in this software. It has facilitated 113 grant competitions, with over 2,000 proposal submissions and over 500 awards, totaling over $18 million in translational research funding. In this 5-year period 2,512 users have used the system.

ABITC and RT operate eight different database, collaboration, and document systems that hold an aggregate of 160,924 database records, documents, or trials. Some 903 distinct IUSM users and 60 IU users from all CA schools access one or more of these systems.

4.2. Supercomputers, clusters, and database servers

IU was the first US university (and now only one of two in the US) to provide HIPAA alignment so researchers can store and analyze electronic ePHI on supercomputers and massive data storage systems. ABITC and RT lead a working group to establish and document best practices in HIPAA alignment for US research universities. The ability to store and analyze ePHI is useful in research and disaster response. Moving data from clinical and translational research systems to IU's supercomputers without de-identifying them enables analyses that would otherwise be impossible. HIPAA alignment meant IU supercomputers could help with daily predictions of progress of the H1N1 pandemic (Tizzoni et al, 2012).

The Big Red II supercomputer and Data Capacitor II disk storage system were the period's most significant acquisition. Big Red II is a one-PetaFLOPS Cray supercomputer (a PetaFLOPS is a quadrillion mathematical operations per second.). It can do in one second what a person doing one mathematical operation per second with a hand calculator could do in more than 31 million years. It can rapidly move and analyze massive amounts of data. The first university-owned,

university-funded PetaFLOPS supercomputer in the US, Big Red is ranked as the 2nd-fastest supercomputer owned and operated for a single US university. Partly from input from CA researchers, it was configured to meet Big Data challenges in biomedical research.

The Data Capacitor II (DC II), with the Lustre® open source parallel file system, is a major upgrade to IU's storage infrastructure. It accelerates the current data read/write speed 2.5 times, up to 50GBs, and provides a new geographically replicated and fault-tolerant file system for home directories. If a file is accidentally deleted, it can be recovered for a period of a few hours to 30 days. These systems are the result of extensive analysis of IU community needs, including IUSM faculty (see Link et al, 2013) and will greatly aid IUSM bioinformaticians, radiologists, brain scientists, and neurologists, and the IUSM Biobank initiative.

Dean Brater and Dr. Andrew Saykin comment:

- *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 is available today. The new [supercomputer] is an exciting development that will undoubtedly enable new discoveries by many investigators at IU and beyond."

For a video about Big Red II shown at its dedication see http://go.iu.edu/95B. For press releases and other information see http://rt.uits.iu.edu/bigred2/press.php.

Figure 13. Big Red II – IU's newest, and fastest-ever supercomputer. To the best of our knowledge, Big Red II is the fastest non-classified, HIPAA-aligned supercomputer in the US.

Appendix 6 lists RT/ABITC computational resources clusters with IUSM/CA use metrics. For more information on these systems see http://rt.uits.iu.edu/ci/systems/index.php.

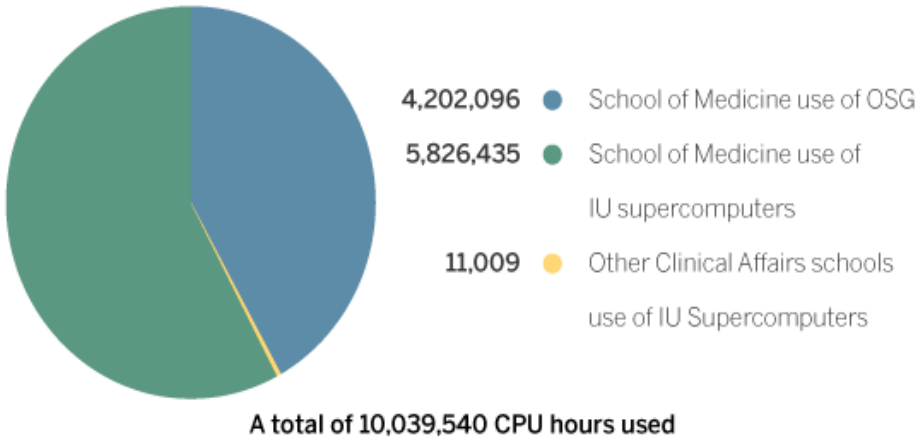

Figure 14. CPU hour usage by IUSM and CA researchers

For backup and disaster planning for supercomputer and data storage facilities, see Appendix 3.

As of the end of the reporting period 11 IUSM researchers had accounts on Big Red II, using it in "early production" mode. Among the top users is Dr. Andrew Saykin, who has been working with RT staff on Big Data challenges related to his research into Alzheimer's disease. The system was still not in full production mode, so data for Big Red II are not included in **Error! Reference source not found.**.

For most of the reporting period, the original Big Red was the main workhorse. Table, below, shows IUSM researchers among the top 25 users of Big Red during FY 2013.

	Top users of Big Red (as ranked by CPU utilization)		
	Campus / School	**Department**	**Processor core hours used**
1	External to IU (grant funded)		5,071,218
2	**IUPUI-IUSM**	**Bioinformatics**	**2,635,452**
3	IUB-non IUSM	Office of VP for Info Tech	2,558,058
4	IUPUI-non IUSM	Engineering & Technology	1,758,264
5	IUPUI-non IUSM	Chemistry	1,547,734
6	**IUPUI-IUSM**	**Biochemistry/Molecular Biology**	**1,486,853**
7	IUB-	Chemistry	1,228,719
8	IUPUI-	Chemistry	1,109,351
9	IUPUI-	Chemistry	1,016,786
10	IUPUI-	Chemistry	995,434
11	**IUPUI-IUSM**	**Pharmacology & Toxicology**	**995,389**
12	IUB-	Chemistry	564,675
13	**IUPUI-IUSM**	**Biochemistry/Molecular Biology**	**531,398**
14	IUB-	Chemistry	426,691
15	IUB-	Public Health	422,349
16	IUB-	Physics	359,943
17	**IUPUI-IUSM**	**Biochemistry/Molecular Biology**	**344,983**
18	IUB-	Informatics	332,403

	Top users of Big Red (as ranked by CPU utilization)		
	Campus / School	**Department**	**Processor core hours used**
19	IUB-	Informatics	264,345
20	IUB-	Informatics	258,530
21	External to IU (grant funded)		244,327
22	**IUPUI-IUSM**	**Pharmacology & Toxicology**	**205,369**
23	External to IU (grant funded)		204,340
24	IUB-	Physics	201,047
25	IUB-	Chemistry	172,101

Table 2. Top 25 users of CPU hours on Big Red for FY 2013. IUSM researchers appear in bold.

4.3. Storage systems

RT manages and supports three major disk-based file systems and one archival storage system that serve local and remote users. Their main characteristics appear in Appendix 7 with information on use by IUSM/CA researchers. The raw capacity of the Data Capacitor II is 5 PB, some of which is consumed in the process of formatting the disk media. The formatted capacity of the RT storage systems available to IUSM/CA researchers is 5.41 PB, or what the equivalent of more than one million DVDs could hold. The DC can move data to and from IU's supercomputers at 20 GigaBytes (thousands of MegaBytes) per second.

The IU Scholarly Data Archive (SDA) is a distributed, tape-based storage archive system that stores data in duplicate – one copy in Indianapolis and another in Bloomington. If one copy is destroyed, in anything other than a regional emergency, the second copy remains safe. IU uses the very secure High Performance Storage System (HPSS) software, designed along the requirements of US nuclear weapons labs, to manage data storage. SDA includes a storage capacity exceeding 15 PB. 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 allowance is 50 TB of mirrored data, with additional space upon request.

The IUScholarWorks Repository (http://scholarworks.iu.edu) is IU's definitive electronic document repository. Operated by a partnership of the IU Libraries and UITS, IUScholarWorks is a comprehensive storage, curating, and discovery system. Researchers can store and disseminate published articles, preprints of articles, data sets, presentations, and any other academic document. Its value to IUSM/ CA researchers is the ability to publish data sets and analysis scripts, increase access, and ease the replication of analyses. Objects are stored with metadata that enable others to find your work. IUScholarWorks information is stored on the Scholarly Data Archive, so is stored in duplicate and kept secure. IUScholarWorks holds tens of thousands of digital objects that will be accessible and available for decades to come.

IUSM researchers store millions of records and documents in ABITC/RT services. They were prodigious users of storage services, with some 174 TB of data on disk, 11.6% of the total on disk at IU, and 1.9 PB of data on magnetic tape, 10% of the total on tape at IU. CA researchers stored 0.03 TB of data on disk, 0.002% of the total on disk at IU, and 70 TB of data on magnetic tape, 0.6% of the total on tape at IU. The figure below shows the storage of data on disk by IUSM, and IUSM/CA researchers combined.

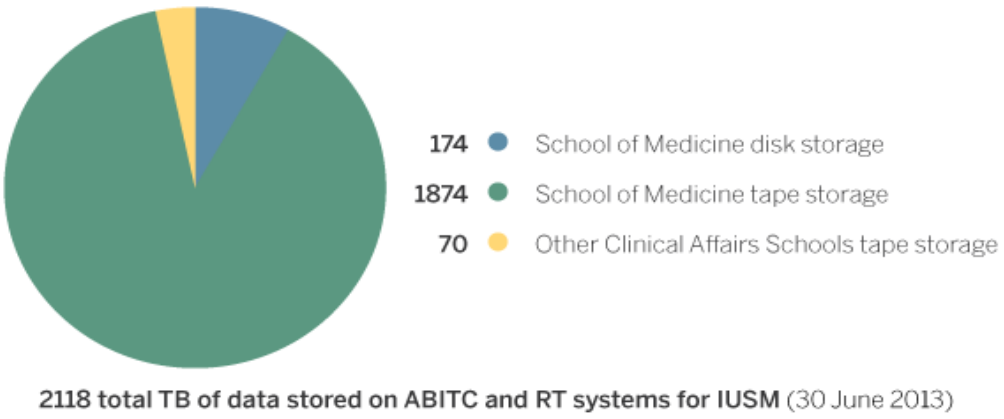

Figure 15. Storage of data on disk and tape by researchers at the IUSM and CA schools.

Table , below, shows the campus, school, and departmental affiliations of the top 25 IU Scholarly Data Archive users. Four are IUSM researchers.

	Top users of Scientific Data Archive as ranked by amount of data stored		
	Campus/School	**Dept.**	**TB in use**
1	IUB-	Library & Information Sciences	1826
2	**IUPUI-IUSM**	**Biostatistics**	**949**
3	IUB-	Genomics and Bioinformatics	926
4	IUB-	Astronomy	666
5	IUB-	Arts & Sciences	662
6	IUB-	Vice President for IT	601
7	IUB-	Psychological & Brain Sciences	425
8	IUB-	Chemistry	421
9	IUB-	Vice President for IT	389
10	IUB-	Chemistry	379
11	IUB-	Vice President for IT	331
12	IUB-	Computer Science	239
13	**IUPUI-IUSM**	**Radiology & Imaging Sciences**	**234**
14	IUB-	Astronomy	216
15	IUB-	Vice President for IT	194
16	IUB-	Chemistry	177
17	External	Jacobs School of Music	171
18	IUB-	Vice President for IT	164
19	IUB-	Libraries	126
20	**IUPUI-IUSM**	**Center for Bioinformatics**	**119**
21	IUB-	Chemistry	117
22	IUB-	Chemistry	116
23	**IUPUI-IUSM**	**Medical & Molecular Genetics**	**112**
24	IUB-	Grant funded	93
25	IUB-	Astronomy	85

Table 3. Top users of IU storage systems for FY 2013, showing usage by IUSM (in bold) .

Many ABITC/ RT services are related to managing and analyzing data, often ePHI. The following resources involve storage of records and documents in the proportions shown in Figure 17, which follows the text.

- The Indiana CTSI HUB is the state of Indiana's central portal for translational research and the core online organizing facility for the Indiana CTSI.
- REDCap (Research Electronic Data Capture) enables researchers to quickly design and start small surveys and/or clinical studies in a HIPAA-aligned environment.
- Alfresco Share allows researchers to collaborate with external colleagues on preparing reports, articles for publication, or grant proposals and share ePHI.
- Data repositories support specific NIH grants to IUSM researchers, including the data repository for the Collaborative Initiative on Fetal Alcohol Spectrum Disorder and the National Gene Vector Biorepository and Coordinating Center.

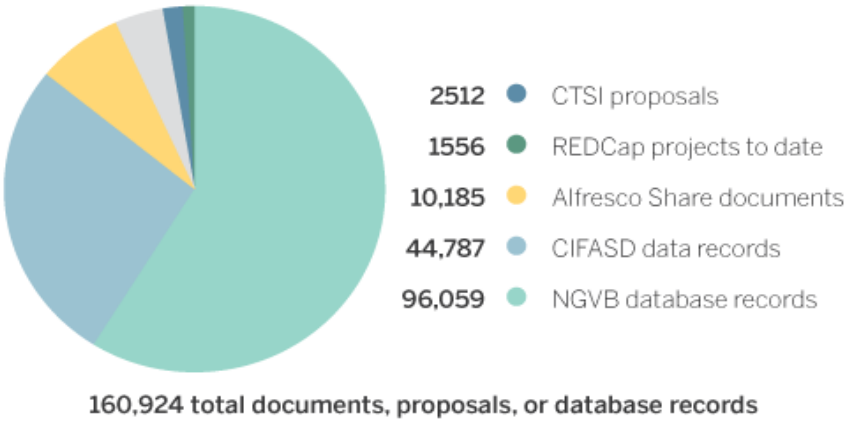

Figure 4. Number of records (database records, documents, or projects) stored in services and data sources operated by ABITC/RT in support of IUSM/CA schools

4.4. Visualization

The RT Advanced Visualization Lab (AVL) assisted researchers and educators from CA schools in FY 2013. Select projects below rely on a combination of staff expertise and advanced visualization infrastructure.

- **Support of Collaborative Initiative on Fetal Alcohol Spectrum Disorders (CIFASD) Imaging Core.** AVL staff assisted with the acquisition of three new scanning systems, doubling the number of capture sites, and led the technical effort to set up, test, and document them. AVL staff traveled to Ukraine to set up and train a new capture site. Remote sites continue to rely on AVL staff support. Staff processed data from 1,615 new subjects from six global capture sites in 2012-2013 and sent the data to researchers around the world.
- **Presenting work from our collaboration with Department of Pharmacology and Toxicology.** Staff presented a scientific video titled "Molecular Simulations of Dynamic Properties of Wild Type and Mutated 14-3-3 sigma Proteins" at the IEEE Cluster 2013 Visualization Showcase, highlighting last year's collaboration between AVL staff and researchers from the department. Existing visualizations from molecular simulations were enhanced with stereoscopic rendering techniques.
- **Applying analytics and visualization to biomedical research.** AVL staff are working with researchers from the Department of Radiology and Imaging Sciences to investigate and develop data-intensive computing methods/tools, focusing on EBMM (Empirical Bayes Mining Method) and ML (Machine Learning) approaches. The goal is to advance knowledge about drug action at scales. This effort is leading to an external grant proposal to develop, apply, and disseminate flexible and scalable data mining approaches to harness Big Data to

advance biomedical research. This work benefits from access to a range of RT visualization systems, including IQ-Stations, IQ-Walls, and large-format visualization theaters.

- **Exploiting HPC Resources for the 3D-Time Series Analysis of Caries Lesion Activity.** AVL staff collaborated with School of Dentistry researchers to create visualizations and quantitative assessment of caries lesion activity based on collections of SkyScan µ-CT (microfocus computed tomography) images taken during the dynamic caries process. Analyzing caries progression (or reversal) is data-driven and computationally demanding and involves image segmentation, model construction, and interactive analysis and visualization. XSEDE's supercomputing, storage, and visualization resources aid the discovery process.
- **Enhancing education at the School of Dentistry.** The Lab continued its support for IUSD haptic training scenarios. Staff provided on-site maintenance and operational support for the IUSD IQ-Force technology and helped with user studies conducted by IUSD faculty.

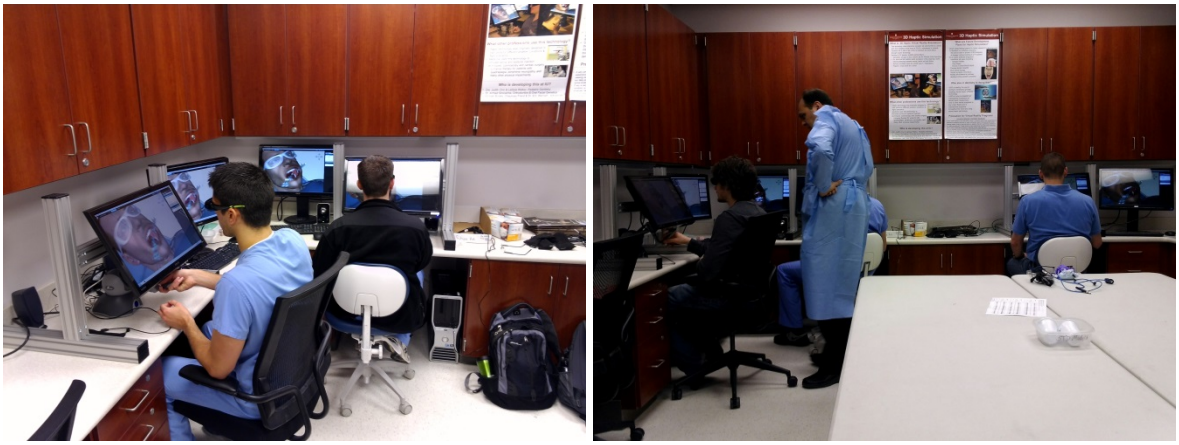

Figure 18. IU School of Dentistry students experience the IQ-Force simulator environment during a user study.

5. Consulting and support services

5.1. Who supports IU School of Medicine and Clinical Affairs researchers?

- **Advanced Biomedical Information Technology Core** (ABITC, https://pti.iu.edu/rtl/aitc) Led by Dr. William Barnett and managed by Ganesh Shankar, ABITC is funded by IU general funds, subcontracts from and administrative supplements to the Indiana CTSI grant award, and 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 and translational research, and support for NIH-funded researchers. Formerly known as the INGEN Advanced IT Core, in 2011 it was renamed to clarify support for biomedical research.
- **National Center for Genome Analysis Support** (NCGAS – http://ncgas.org) Led by Dr. Craig Stewart as PI, directed by Dr. William Barnett, and managed by Dr. Richard LeDuc, NCGAS is largely funded by an NSF grant to provide genome analysis services to the US research community, particularly NSF-funded researchers. With IU general funds, NCGAS also supports IU healthcare researchers. Its focus is genome and RNA assembly. In this reporting period Dr. Barnett and NCGAS applied for NIH funding to expand support for NIH-funded researchers.
- **Collaboration and Engagement Support group**
  This supports grant proposal development and writing by IUSM and CA researchers.
- For the RT organization chart see Appendix 2 Appendix 8 shows other RT management groups that directly and indirectly support IUSM/CA schools.

5.2. 7 x 24 emergency support

Support for security issues and emergency situations is provided by telephone, 24x7, via the IU Support Center at 812-855-6789. Backup, disaster recovery, and IU CI policy statements appear in Appendix 9.

5.3. Shorter-term consultations

ABITC and RT provide a great deal of online information at http://rt.uits.iu.edu/sct/abitc/ and http://rt.uits.iu.edu/ci/index.php/, and self-serve answers via the IU Knowledge Base (kb.iu.edu), Researchers can also send email to:

- RT Life Sciences: rtls@iu.edu
- ABITC, RT, and IU cyberinfrastructure: researchtechnologies@iu.edu
- Indiana CTSI support: hubsupport@indianactsi.org

Customer support is divided into short- and long-term consultations. Help requests receive automated replies almost immediately, and follow-up by email or phone within 24 hours. Short-term consultations comprise issues resolved in less than 4 hours of staff effort. During FY 2013 ABITC completed 1,572 short-term consultations, most related to REDCap use.

5.4. Extended consultations

Most ABITC/CA consulting is extended, taking from 4 hours to several person-years of staff time. This reflects two dynamics:

- Effective help requires deep comprehension of the research.
- Most consulting is related to grant subcontracts or matching effort supporting IUSM grants.

During FY 2013 ABITC concluded 28 extended consultations; 56 are ongoing, showing ABITC's organic involvement in supporting CA researchers. In FY 2012, 64 were completed and 27 in FY 2011. Appendices 10A and 10B detail extended consultations IUSM/CA by ABITC (10A) and by other RT groups (10B). .

5.5. Support for use of federally-funded cyberinfrastructure services

The NSF provides the national open research community, including NIH-funded researchers, federally funded CI resources at no cost. The challenge is that one has to apply to use them (as in XSEDE – the eXtreme Science and Engineering Discovery Environment) or adapt one's computer applications to a specific grid architecture (as in the Open Science Grid). ABITC/RT have helped researchers in the IU Schools of Medicine and Dentistry use millions of dollars worth of resources on XSEDE and its predecessors.

FY 2013's focus has been Open Science Grid support (http://www.opensciencegrid.org/). OSG provides services for high-throughput computing – a grid of computers completes many small jobs, instead of running very large jobs with hundreds to thousands of processors. Through OSG researchers can consume resources at a seemingly unlimited rate. Adapting applications to work on the OSG is labor intensive. The High Throughput Computing Group (Science Community Tools directorate of RT) invested more than a month of staff time to support the SPLInter project led by Dr. Samy Meroueh, adapting the web portal so molecular docking computations could be done on the OSG. The portal is among the science gateways maintained on XSEDE web sites, so SPLInter will be more visible and usable by US scientists. This project has delivered millions of CPU hours to SPLInter users. The group also created a portal to support running BLAST (Basic Local Alignment Search Tool) jobs on OSG. Three people collaborated for three months to create a workflow through the NCGAS Galaxy genomics portal that automatically parses jobs out to the

OSG. Galaxy is one of the most user-friendly and widely used portals for biomedical and biological researchers. IU researchers have used thousands of hours of CPU time through the Galaxy BLAST gateway.

A diagram of IU cyberinfrastructure showing network connections within IU and between IU and other national networks appears in Appendix 10.

5.6. Support for grant proposal development

The RT Collaboration and Engagement Support Group helps IUSM/CA researchers prepare grant proposals that involve advanced IT research resources. In FY 2013 RT and ABITC supported two IUSM proposals that led to $1,275,594 in awards. Appendix 12 shows grant support activities by researcher.

6. Education, outreach, participation in the national research community, and intellectual contributions by ABITC/RT staff

6.1. Education and outreach

RT has advanced IU's educational and outreach missions with 3D educational movies. 3D captures the attention of lay viewers, especially the young. In FY 2013 ABITC, RT, and the Pervasive Technology Institute created a YouTube channel with 2D and 3D visualizations, many related to health and medicine, detailed in the table below.

Title	2D or 3D	URL
Predicting Epidemic Pathways	2D	http://www.youtube.com/watch?v=ONEOc-MTm1Q
Investigating Hidden Worlds	Both	http://3d.iu.edu/biology
Big Data in Drug Discovery	2D	http://www.youtube.com/watch?v=Brsye_2nNPw
David Wild on Drug Discovery	2D	http://www.youtube.com/watch?v=Brsye_2nNPw
Cancer epigenomics study using the next generation sequencing data	2D	http://www.youtube.com/watch?v=-GRAGmLJIYE

Table 4. 2D and 3D visualizations created by RT in collaboration with Clinical Affairs schools as education and outreach tools.

6.2. Campus, national, and international leadership by ABITC/RT staff in areas relevant to IUSM/CA schools

- Dr. William K. Barnett is active at the national level in biomedical research and CI:
  - He was appointed in 2013 co-director of Translational Informatics for the Indiana CTSI.
  - He participates in the IUSM/IU Health Clinical Research Informatics Task Force led by Bill Tierney (Regenstrief) and Bill McConnell (IU Health). This task force is formulating a strategic approach to sharing and integrating data across the three institutions.
  - Active on the National Center for Advancing Translational Sciences CTSA National Informatics and Communication Key Function Committees, he focuses national attention on the CTSI HUB.
  - He was elected to the Association of American Medical Colleges (AAMC) Group on Information Resources (GIR) Steering Committee in 2012.
  - He is faculty of the AAMC GIR annual Leadership Institute.
- Dr. Craig A. Stewart held a part-time NSF appointment as an Expert in the BIO Directorate Division of Biological Infrastructure. This involved research and formulating federal strategies for biological research that overlap with many NIH concerns and areas of focus.

- Robert Quick was appointed OSG Production Manager and is key intermediary between OSG researchers and management.

Publications and presentations during FY 2013 by ABITC and RT staff appear in Appendix 12.

7. IUSM satisfaction with ABITC and RT services

The UITS Annual User Satisfaction Survey is a formal, anonymous survey administered by the IU Center for Survey Research (http://csr.indiana.edu) that measures satisfaction with UITS services. The Center sends surveys to randomly selected IU faculty, staff, graduate students, and undergraduates. Most questions are Likert opinion scales (1-5 rating scales with 5 most favorable). We analyze these data to find average opinion score, percentage satisfied with the service (grade 3 or better), and percentage who use the service (i.e.: the percentage who expressed an opinion). To evaluate research services we focus on faculty, staff, and graduate student input. The results surveys since 1981 (survey inception) are online at http://www.indiana.edu/~uitssur/

Tables 12 and 13 show IUSM responses on the spring 2013 survey, with IUSM views and usage of ABITC/RT resources compared with IU overall.

	IU School of Medicine			IU Overall		
	Average	Satisfaction	Usage	Average	Satisfaction	Usage
Central research and high performance computers (Big Red, Quarry, and RDC clusters)	4.03 ± .07	97 ± 1.3%	10.2%	4.16 ± .09	92.6 ± 2.74%	15.2%
Center for Statistical and Mathematical Computing (Stat/Math Center; statmath@iu.edu, 278-4740)	3.93 ± .08	92. ± 2.2%	9.5%	4.04 ± .08	94.5± 2.15%	19.6%
Scholarly Data Archive (formerly referred to as MDSS / HPSS) (MDSS/HPSS)	4.06 ± .07	97.2 ± 1.4%	9.9%	4.05 ± .10	93.4± 2.56%	12.4%
Advanced Visualization Laboratory (AVL); www.avl.iu.edu	4.04 ± .08	92.6 ± 2.1%	5.7%	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)	4.12 ± .07	98.1 ± 1.2%	7.2%	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]	3.97 ± .21	94.2 ± 1.9%	11.4%	3.97 ± .10	90.7 ± 3.1%	5.8%

Table 5. IUSM satisfaction with UITS resources, compared with IU overall. In all cases the data show a weighted average of the responses of faculty, staff, and graduate student responses.

Population	Average	Satisfaction	Usage
IUSM	4.24 ± .05	98.0 ± 0.9%	51.2%
IU Overall	4.18 ± .07	96.0 ± 1.85%	31.7%

Table 6. IUSM overall satisfaction with RT services as compared to IU as a whole.

The average satisfaction score for ABITC was 3.97, up from 3.90 in 2012. Just over 94% (up from 87 % last year) rated it 3 or higher (satisfaction %). Just over 11% of IUSM researcher respondents used ABITC services directly; more use them indirectly via the Indiana CTSI portal.

Other services ranked by IUSM researchers (faculty, staff, and graduate students), including IU's supercomputers, the Scholarly Data Archive, and AVL, averaged at least 4.03 with satisfaction of at least 92%. 10.2% reported they used RT supercomputers and 9.9% used the Scholarly Data Archive. Overall satisfaction with RT services was 4.24% with a 98% satisfaction rate. Use of ABITC/RT resources was up, 51.2%. Use by more than half of IUSM researchers is significant, especially given the high average satisfaction levels.

8. Budgets, fees for core services, and future challenges

IU's investing in advanced computing as a strategic asset is unusual. IU President McRobbie credits the late IU President Myles Brand as among the first US university presidents to understand the strategic importance – particularly advanced IT – to 21st-century universities. This means most RT services are funded by general university funds from the Office of the Vice President for Information Technology, with no direct cost to IUSM.

Options for securing dedicated staff time when needs go beyond baseline UITS/ABITC services include building a position (or part) in a grant proposal, or purchasing time as needed.

- Projects requiring more than 160 hours of work are charged $79.00 per staff hour.
- A % of an FTE can be included in a project budget as the prorated amount of salary and benefits of the staff on the project. The Core's advisory committee approved these rates.

Yet challenges remain. One is cultural: The IUSM practice of internal recharge for core services (vs. ongoing funding). This works for services that can be contracted for in advance, done reliably, and which grant reviewers will viewed favorably. ABITC/RT with IUSM/CA often delivers new applications and software that are secure, reliable, and perform well. This work is high value and low risk. Work related to use of supercomputers, visualization systems, haptic systems, and other cutting-edge CI may be high reward, but high risk. "Buy this service, and with a significant probability it will not do you good, but with some probability it will revolutionize your research" is not a good business model. Such services are better funded as strategic institutional investments, especially when they align with institutional priorities. The NIH has funded the renewal of the Indiana CTSI project. ABITC has less than 1 FTE not committed to work on an ongoing grant award. That is not enough for the work behind the level of discovery and grant success IUSM/CA researchers enjoy today.

IU, ABITC, RT, UITS, and IUSM face a challenge as the regulatory landscape changes. Granting agencies are requiring Federal Information Systems Management Act (FISMA) compliance to finalize grant awards. One ABITC staff is an expert in cybersecurity responsible for HIPAA and FISMA compliance. As of 1/1/2013 funding is available for only 50% of his salary and benefits.

RT lacks the staffing required to meet requests to change our system management and maintenance plans as IU's supercomputers grow more essential in the everyday work of IUSM researchers. Equipment replacement funding for IU's supercomputers, storage systems, and visualization systems is inadequate to continue the growth in capability that has put IU where it is today. Funding remains a challenge.

These facts and figures show IU's CI investment increases IUSM/CA competitiveness for the grant funding that supports their work, and is key to advancing research and creating new tools and therapies for improving health.

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- *National Science Foundation under grants 01116050 MRI: Creation of the AVIDD Data Facility: A Distributed Facility for Managing, Analyzing and Visualizing Instrument-Driven Data (Michael A. McRobbie, PI); 0521433 MRI: Acquisition of a High-Speed, High Capacity Storage System to Support Scientific Computing: The Data Capacitor (Craig A. Stewart, PI); 0521433 ABI Development: National Center for Genome Analysis Support (Craig A. Stewart, PI)*
- *National Institutes of Health NIAAA awards U24 AA014818-01 (Craig A. Stewart, PI) and U24 AA014818-04 (William K. Barnett, PI) Informatics Core for the Collaborative Initiative on Fetal Alcohol Spectrum Disorder*
- *Subcontracts through the following NIH grant awards: 5P40RR024928 (Kenneth Cornetta, PI), 2U01AA014809 (Tatiana Foroud, PI), 1DP2OD007363-01 (Alexander Niculescu, PI), UL1RR025761-01 (Anantha Shekhar, PI), 3UL1RR025761-04S2 (Anantha Shekhar, PI), and 3UL1RR025761-04S3 (Anantha Shekhar, PI)*
- *Funding from the general funds of Indiana University*

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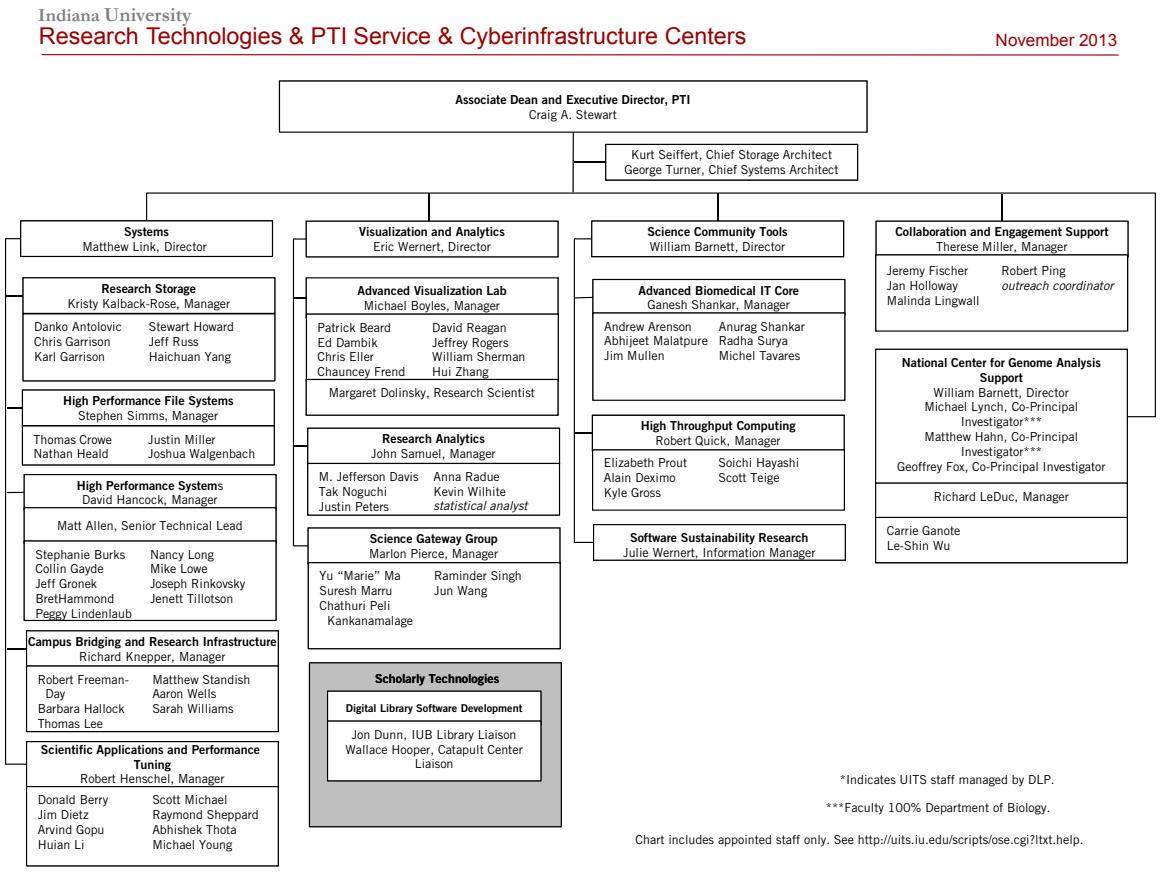
APPENDICES

Appendix 1. Summary of 2013 UITS annual User Satisfaction Survey showing IUSM researcher ratings of key services offered by ABITC and RT.

IU School of Medicine Satisfaction Scores			
	Average	**Satisfaction**	**Usage**
Central research and high performance computers (Big Red, Quarry, and RDC clusters)	4.03 ± .07	97 ± 1.3%	10.2%
Center for Statistical and Mathematical Computing (Stat/Math Center; statmath@iu.edu, 278-4740)	3.93 ± .08	92.2 ± 2.2%	9.5%
Scholarly Data Archive (formerly referred to as MDSS/ HPSS) (MDSS/HPSS)	4.06 ± .07	97.2 ± 1.4%	9.9%
Advanced Visualization Laboratory (AVL); www.avl.iu.edu	4.04 ± .08	92.6 ± 2.1%	5.7%
Support for software applications using IU and national high performance computer resources (including TeraGrid, Open Science Grid, and XSEDE)	4.12 ± .07	98.1 ± 1.2%	7.2%
Support for Life Sciences - Advanced Biomedical IT Core and National Center for Genome Analysis Support [Formerly Bioinformatics support and Center for Computational Cytomics]	3.97 ± .21	94.2 ± 1.9%	11.4%

Appendix 2. Research Technologies organization chart



Appendix 3A. Total active grants led by IUSM/CA researchers who use ABITC/RT services

P.I.	Shekhar, Anantha
Title	Indiana Clinical and Translational Sciences Institute
Agency	NIH – NCATS
Grant Number	1UL1TR001108
Dates	September 2013 – April, 2018
Total Award to IU	$30,000,000 * - awarded after end of reporting period
Subcontract amount to ABITC / Research Technologies	$929,500
Formal match provided by ABITC / Research Technologies as part of grant budget	$929,500
Value of UITS services and budgetary contributions provided in support of this grant beyond grant budget and formal match agreements	$529,753 total to date; $52,975 2012/2013
ABITC / RT role	Dr. Barnett, Director of ABITC, is Co-PI and Co-director of

	the Translational Informatics Program. The ABITC supports the Indiana CTSI HUB and core informatics resources such as The Indiana Biobank, the Indiana CTSI Registry system, REDCap, Alfresco Share, and the Grant Management System.

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
Value of UITS services and budgetary contributions provided in support of this grant beyond grant budget and formal match agreements	$87,865 total to date; $3,000 2012/2013
ABITC / RT 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
Value of UITS services and budgetary contributions provided in support of this grant beyond grant budget and formal match agreements	$17,476 FY 2012/2013 (= to date)
ABITC / RT role	The Advanced Visualization Lab has implemented a 3D camera solution allowing the rapid capture of facial surface morphology features, which 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 /	$0

Research Technologies as part of grant budget	
Value of UITS services and budgetary contributions provided in support of this grant beyond grant budget and formal match agreements	$36,177 total to date; $7,235 FY 2012/2013
ABITC / RT role	The Niculescu lab maintains data in six databases on mood disorders, 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
Value of UITS services and budgetary contributions provided in support of this grant beyond grant budget and formal match agreements	$308,071 total to date; $61,614 in FY 2012/2013
ABITC / RT 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
Value of UITS services and budgetary contributions provided in support of this grant beyond grant budget and formal match agreements	$94,086 total to date; $1000 FY 2013-2013
ABITC / RT 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.

Appendix 3B. Active grants led by ABITC/RT that support IUSM research

P.I.	Barnett, William
Title	Informatics Core for the Collaborative Initiative in Fetal Alcohol Spectrum Disorders
Agency	NIH - NIAAA
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
Value of UITS services and budgetary contributions provided in support of this grant beyond grant budget and formal match agreements	$11955 total to date; $2391 FY/2013
ABITC / RT 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	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
Value of UITS services and budgetary contributions provided in support of this grant beyond grant budget and formal match agreements	$20,000 total to date; $10,000 this FY
ABITC / RT 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.

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
Value of UITS services and budgetary contributions provided in support of this grant beyond grant budget and formal match agreements	$2,130,048 total to date; $426,009 this FY (approximate)
ABITC / RT 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.

Appendix 4. Summary of ABITC/RT services to IUSM/CA schools

Service	Description	Chargeback, baseline, or grant funded?	HIPAA aligned ?
Data and document management (including ePHI)			
Alfresco Share	Document Creation, Management, Sharing	Baseline	Y
Collaborative Initiative on Fetal Alcohol Spectrum Disorder data repository	Database of clinical research records	Grant funded (no charge to users)	Y
CTSI Grants Management System	Document Creation, Management, Sharing	Baseline	
Remedy Registry System	Research Registries	Chargeback	Y
REDCap	Web-based Data Management	Baseline	Y
Database hosting generally in Oracle and MySQL	Creation, consulting, and management of relational databases	Baseline and/or chargeback if custom programming is needed	As needed
Web gateways			
Indiana CTSI HUB	Web Portal for Indiana CTSI	Grant funded	Y
Indiana University Cyberinfrastructure Gateway	Web Portal to IU cyberinfrastructure		
Supercomputers, high performance computing systems, and access to national cyberinfrastructure facilities			
Big Red II	Supercomputer	Baseline	Y
Quarry	Supercomputer	Baseline	Y
Mason	Large memory supercomputer cluster	Baseline	Y
Condominium Cluster Service	Server hosting	Chargeback	
Research Database	Oracle/MySQL	Baseline	Y

Cluster	Databases		
VM and web hosting services			
Science gateway hosting service - XSEDE	Hosting for science gateways and interactive web interfaces delivering scientific services	Grant funded	
Data storage			
Research File System	Online File Storage	Baseline	Y
Data Capacitor II	High Speed File System	Baseline	Y
Scholarly Digital Archive	Permanent Data Archive on tape, replicated in two physical locations	Baseline up to 50 TB	Y
Visualization, Augmented Reality, and Virtual Reality systems			
IQ-Wall, IQ-tilt, IQ-Table, and IQ-Station monoscopic (2D) and 3D visualization facilities	Visualization Facilities	Use of facilities at UITS is a baseline service; IQ-Wall, IQ-Tilt, IQ-Table, and IQ-Station can be built and installed in departments and labs at the cost to UITS (which starts under $10,000)	
Virtual Reality Theater	Room-scale 3D Visualization Facility	Use of this facility (and consulting on how to use it) is a baseline service. Creation of 3D visualizations may be baseline or chargeback	
IQ-Force – Haptic feedback augmented reality system	Desktop or desk-size haptic feedback system	Use of facilities at UITS is a baseline service; IQ-Force can be built and installed in departments and labs at the cost to UITS (which starts under $10,000)	
Consulting and programming services			
Software consulting, applications development, software optimization, and science gateway development	Creation, development, and optimization of applications	Baseline or chargeback. Chargeback work – generally creation of software under direction of a faculty PI, may be done on an hourly basis, or as a grant. When on a grant, and MOU is required and F&A monies are expected to flow to UITS if UITS houses the staff and provides office equipment	
Consulting on genome analysis and bioinformatics through National Center for Genome Analysis Support	Genome analysis services	Grant funded	
Grant preparation support	Grant preparation support	Baseline for support of grant proposals that use IU's advanced cyberinfrastructure	

Appendix. 5 ABITC/RT-managed database services with usage metrics

Service or Database (An * indicates that a service is accessible via Indiana CTSI HUB	Description of Service	Services delivered		
		Number of Users	Number of Records	Description of Records
Service				

Indiana CTSI HUB https://www.indianactsi.org/	Central portal for translational research for the state of Indiana. Core online organizing facility for Indiana CTSI. ABITC staff have developed key service components including federated identity support for trusted access (in keeping with NIH guidance), clinical trials listings, volunteer trials recruitment (INResearch), and i2iConnect – a national technology transfer service for licensing inventions.	5,074		Total number of distinct users for this service
CTSI Grants Management System https://www.indianactsi.org/grants/index.php/index/index	A grants management system for administering Indiana CTSI grant applications and awards		2,512	Proposals Submitted
			110	Grant Competitions Managed
			523	Grant Awards made through this system over 5 years
		2512		Users over 5 years
REDCap* http://project-redcap.org	Enables researchers to quickly design and start small surveys and/or clinical studies in a HIPAA-aligned environment.	1,463		
			681	New projects using REDCap initiated by IUSM researchers in FY 2013.
			1,556	Total projects using REDCap since ABITC assumed responsibility for REDCap in 2010
Alfresco Share http://wiki.alfresco.com/wiki/Alfresco_Share	Online collaboration tool for researchers collaborating with external colleagues on preparing reports, articles for publication, or grant proposals. Allows sharing ePHI	1,697		
			10,185	Documents stored in Alfresco Share as of 30 June 2013
Data repository for Collaborative Initiative on Fetal Alcohol Spectrum Disorder http://cifasd.org	Supports Fetal Alcohol Spectrum Disorder – the only international repository of consistently coded and collected data on the impact of in-utero exposure to alcohol in humans. Includes data inherently impossible to de-identify, including 3D scans of children affected by CIFASD	20	3,002	Number of distinct subjects (people)
			44,787	Total number of database entries
			1,865	Facial images stored in CIFASD Imaging Core data repository
Data repository for	Central resource for researchers	752	96,059	Number of database

National Gene Vector Biorepository and Coordinating Center https://ngvbcc.org/Home.action	conducting gene therapy studies. Provides archiving services, insertional site analysis, pharmacology and toxicology resources, and a reagent repository.			records
Indiana Biobank system www.indianabiobank.org/	Intended to become the definitive database for specimens available anywhere in the Indiana CTSI system. ABITC led finalization of the contract for Remedy Informatics™ software for this database.			not yet in production
Indiana CTSI OnCore Clinical Trials Management System	This system manages clinical trials, including recruiting, reporting, billing, and order sets.	363	644	Number of clinical trials (number of records not tracked as of now)
Total number of user logins to data services.		11881		
Total number of records of any and all sorts, including documents and trials in OnCore			160924	

Appendix 6. Computational resources at IU with IUSM/CA use metrics

Name	Architecture and distinctive features	TFLOPS	Total CPU hours used by IUSM researchers in FY 2013	% of total CPU use by IUSM researchers in FY 2013	Total CPU hours used by CA researchers in FY 2013	% of total CPU use by CA researchers in FY 2013
Big Red II	1 PetaFLOPS Cray supercomputer with advanced proprietary interconnect for handling big data	1000.37	Not in 'production/ as of end of reporting period	N/A	N/A	N/A
Big Red	IU's six-year-old supercomputer workhorse – especially good for molecular dynamics and protein folding	40.96	5,236,779	19.0%	0	0%
Quarry	IBM Intel-based cluster used for a variety of computing tasks	26.11	521,900	5.3%	11009	0.1%
Mason	HP large-memory nodes (512 GB each) for de-novo genome assembly	3.81	67,756	4.0%	0	0%
Research Database Complex	Variety of HP database servers	0.31	NA*	NA*	NA*	NA*
Totals		**1071.56**	**5,826,435**	**9.4%**	**11009**	**0.03%**

***Usage of database servers is calculated in terms of records and transactions; CPU usage is not a relevant metric for these systems.**

Appendix 7. IU data storage systems with IUSM/CA use metrics

Name	Architecture and distinctive features	Disk (PB) usable (formatted)	% disk space used by IUSM researchers as of 6/30/2013	% disk space used by other CA research-ers as of 6/30/2013	Tape (PB)	% tape space used by IUSM researchers as of 6/30/2013	% tape space used by other CA researchers total 6/30/2013
Research File System	Robust and replicated disk server for home directories and reliable storage and fast access of files – storage for individuals and projects	0.06	1%	0.02%	NA	NA	NA
Data Capacitor / DC-WAN	High capacity, high performance I/O for short term analysis and storage of data sets of all sorts	4.75	12.1%	<0.1%	NA	NA	NA
Scholarly Data Archive	Secure, tape based storage with data replicated at IUB and IUPUI	0.60	NA	NA	15	10.4%	0.6%
Totals		**5.41**	**11.6%**	**<0.1%**	**15**	**10.4%**	**0.6%**

Note: All are HIPAA aligned, allowing ePHI storage. Further information on all of these systems is available at http://rt.uits.iu.edu/ci/storage/

Appendix 8 – Advisory committee, staffing, and staff funding details – ABITC and Research Technologies

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

ABITC staff

Staff of the Advanced Biomedical IT Core dedicated to research, programming, and consulting for the IU School of Medicine include the following as of 7/1/2013:

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

Of these staff, 3 are paid for by base funding. Of those base funded staff, all but 0.5 FTE are committed as formal matching effort on grant awards to IUSM

Research Technologies staff

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

- Research Storage group (12 FTE)
- High Performance Systems group (12 FTE)
- Scientific Applications and Performance Tuning group (9 FTE)
- Campus Bridging and Research Infrastructure group (7 FTE)
- Advanced Visualization Lab (11 FTE)
- Research Analytics group (7 FTE)
- National Center for Genome Analysis Support (3.5 FTE)
- High Throughput Computing group (6 FTE)
- The Collaboration and Engagement Services group (5 FTE)

This represents a total of 76.8 FTEs who offer to the university community services that are heavily used by IUSM researchers.

Appendix 9: Backup, disaster recovery, and policy alignment for IU cyberinfrastructure 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 Scholarly Data Archive (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 in the SDA are stored in duplicate copies – one in the tape silo at IU Bloomington, and one in the tape silo at IUPUI in Indianapolis. The HPSS metadata specifying which tapes contain any given file is continually backed up, with multiple copies in Indianapolis and Bloomington.

IU has a written disaster recovery plan for every service and system it provides. (See a full list of services at: http://go.iu.edu/8PY. IU has a contract to use an off-site disaster recovery facility in the event a disaster affects one or more of IU's campuses. Were a disaster to strike a core campus (IUPUI or IUB), service would be restored on whichever core campus remained operational. Plans exist for service recovery if both campuses struck simultaneously.

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.

Appendix 10A. Summary of extended consultations – work taking > 4 hours of staff time – completed by ABITC during FY 2013.

Dept.	School	Campus	Service provided	Service status		Staff effort provided (FTE equivalent)		
				Done	On-going	4hrs-1wk	1 – 4 wks	>4 wks
Health Sciences	IUSM	IUB	Ingenuity software license	✓				
Optometry	School of Optometry	IUB	Software evaluation and proposal	✓		✓		
Biochemistry/Molecular Biology	IUSM	IUPUI	Custom application development	✓		✓		
Biochemistry	IUSM	IUPUI	Migrated Proteomics Informatics System	✓				✓
Endocrin-ology	IUSM	IUPUI	Software development	✓		✓		
Gastero-enterology	IUSM	IUPUI	Software development	✓			✓	
General Surgery	IUSM	IUPUI	Evaluate Registry software for Breast Cancer research	✓		✓		
Indiana CTSI	IUSM	IUPUI	CTSA Cross-Institutional Search Pilot	✓		✓		
Indiana CTSI	IUSM	IUPUI	CTSA KFC presentation	✓		✓		
Indiana CTSI	IUSM	IUPUI	Software development for Clinical Trials Search	✓				✓
Indiana CTSI	IUSM	IUPUI	Software design, proposal development –CORUS Match	✓		✓		

Indiana CTSI	IUSM	IUPUI	Upgrade Alfresco to Enterprise Version	✓			✓	
Indiana CTSI	IUSM	IUPUI	Registry Software evaluation	✓				✓
Indiana CTSI	IUSM	IUPUI	Clinical Trials Software evaluation	✓			✓	
Indiana CTSI	IUSM	IUPUI	Ticketing system for Clinical Trials Management Software	✓		✓		
Indiana CTSI	IUSM	IUPUI	IU Health Informatics Summit	✓		✓		
Indiana CTSI	IUSM	IUPUI	CTSI External Grant Review	✓		✓		
Indiana CTSI	IUSM	IUPUI	Software development deployment and support - CORUS	✓				✓
Indiana CTSI	IUSM	IUPUI	Custom URL	✓				
IU Simon Cancer Center	IUSM	IUPUI	Software deployment	✓			✓	
Komen Tissue Bank,	IUSM	IUPUI	Software deployment	✓			✓	
Medical and Molecular Genetics	IUSM	IUPUI	Evaluate Registry software for Alzheimer's Research	✓		✓		
Medicine, Dean's Office	IUSM	IUPUI	Consultation Differentiate between Registry and EMR system capabilities	✓				
Psychiatry	IUSM	IUPUI	Software deployment	✓			✓	
Radiology	IUSM	IUPUI	Data storage services	✓				
Radiology	IUSM	IUPUI	Database evaluation and services	✓				

Regenstrief	RI	IUPUI	Software deployment	✓		✓		
Regenstrief	RI	IUPUI	Grant development	✓				
Research Technologies	RT/PTI	IUB	Data Access Committee on CIFASD grant		✓	✓		
Research Technologies	RT/PTI	IUB	CIFASD – continuing IRB review		✓	✓		
Nursing	IUSM	IUN	Software development deployment and support		✓	✓	✓	
Data Management Board	IUH	IUPUI	HIPAA Collaboration		✓		✓	
Neurological Surgery	IUH	IUPUI	Software deployment		✓			✓
Neurological Surgery	IUH	IUPUI	Software deployment		✓			✓
Biostatistics	IUSM IUPH	IUPUI	REDCap support		✓			✓
Biostatistics	IUSM IUPH	IUPUI	Data and application integration		✓	✓		
Center for Computational Biology and Bioinformatics	IUSM	IUPUI	Software deployment, access to high performance systems and storage		✓	✓		
Center for Computational Biology and Bioinformatics	IUSM	IUPUI	Software deployment, access to high performance systems		✓	✓		
Educational Affairs, Dean's Office	IUSM	IUPUI	Grant support, access to collaboration systems		✓	✓		
Indiana CTSI	IUSM	IUPUI	CTSI Aligned Communications meetings		✓			✓
Indiana CTSI	IUSM	IUPUI	Software development for Volunteer		✓			✓

			Registry					
Indiana CTSI	IUSM	IUPUI	Grants Management System deployment and support		✓			✓
Indiana CTSI	IUSM	IUPUI	IRB Review Committee		✓		✓	
Indiana CTSI	IUSM	IUPUI	CTSI HUB deployment and support		✓			✓
Indiana CTSI	IUSM	IUPUI	Alfresco deployment and support		✓			✓
Indiana CTSI	IUSM	IUPUI	REDCap deployment and support		✓			✓
Indiana CTSI	IUSM	IUPUI	Data collection & reporting		✓	✓		
Indiana CTSI	IUSM	IUPUI	CTSI Hub support		✓		✓	
Indiana CTSI	IUSM	IUPUI	Software design, data collection		✓			✓
Indiana CTSI	IUSM	IUPUI	CTSA Strategic Goals Committee		✓			✓
Indiana CTSI	IUSM	IUPUI	CTSA Key Function Committee		✓			✓
Indiana CTSI	IUSM	IUPUI	CTSA Sharecenter Committee		✓			✓
Indiana CTSI	IUSM	IUPUI	CTSA Key Function Committee		✓			✓
Indiana CTSI	IUSM	IUPUI	VIVO Foundation Sponsors Committee		✓			✓
Indiana CTSI	IUSM	IUPUI	HUBzero Foundation participation		✓			✓
Indiana CTSI	IUSM	IUPUI	Oversee CTSI HUB deployment		✓			✓
Indiana CTSI	IUSM	IUPUI	CTSA Communications Key		✓			✓

			Function Committee					
Indiana CTSI	IUSM	IUPUI	CTSA Research Networking Affinity Group		✓			✓
Indiana CTSI	IUSM	IUPUI	Manage Biobank System Implementa-tion		✓			✓
Indiana CTSI	IUSM	IUPUI	CTSI Grant Renewal		✓		✓	
Indiana CTSI	IUSM	IUPUI	Translational Informatics Program Co-Director		✓			✓
Indiana CTSI	IUSM	IUPUI	Manage Registry System Implementa-tion		✓			✓
Indiana CTSI	IUSM	IUPUI	Clinical Research Informatics Strategic Committee		✓		✓	
Indiana CTSI	IUSM	IUPUI	Clinical Research Informatics Tactical Committee		✓		✓	
Indiana CTSI	IUSM	IUPUI	HIPAA Security Committee participation		✓			✓
Medical & Molecular Genetics	IUSM	IUPUI	Software development and support		✓			✓
Medical and Molecular Genetics	IUSM	IUPUI	Custom application development		✓		✓	
Medicine, Dean's Office	IUSM	IUPUI	Systems evaluation		✓	✓		
Neurology	IUSM	IUPUI	Registry Software for Cerebrovas-cular outcomes		✓	✓		
Pathology	IUSM	IUPUI	Access to server		✓	✓		

			support					
Pediatrics	IUSM	IUPUI	Bone Marrow Transplant Software deployment and project management		✓			✓
Pediatrics	IUSM	IUPUI	Bone Marrow Transplant Software deployment and project management		✓			✓
Pediatrics	IUSM	IUPUI	Pediatric Intensive Care Unit Software deployment and project management		✓	✓		
Pediatrics	IUSM	IUPUI	Access to software services, evaluation		✓			✓
Psychiatry	IUSM	IUPUI	Data integration and application deployment		✓			✓
Psychiatry	IUSM	IUPUI	Convergent Functional Genomics Calculator development		✓			✓
Psychiatry	IUSM	IUPUI	Data integration and application deployment		✓			✓
Psychiatry	IUSM	IUPUI	Mood Survey Android App development		✓			✓
Radiology and Imaging Sciences	IUSM	IUPUI	Access to high performance systems and storage		✓	✓		
Urology	IUSM	IUPUI	Registry Software deployment for Urology research		✓	✓		

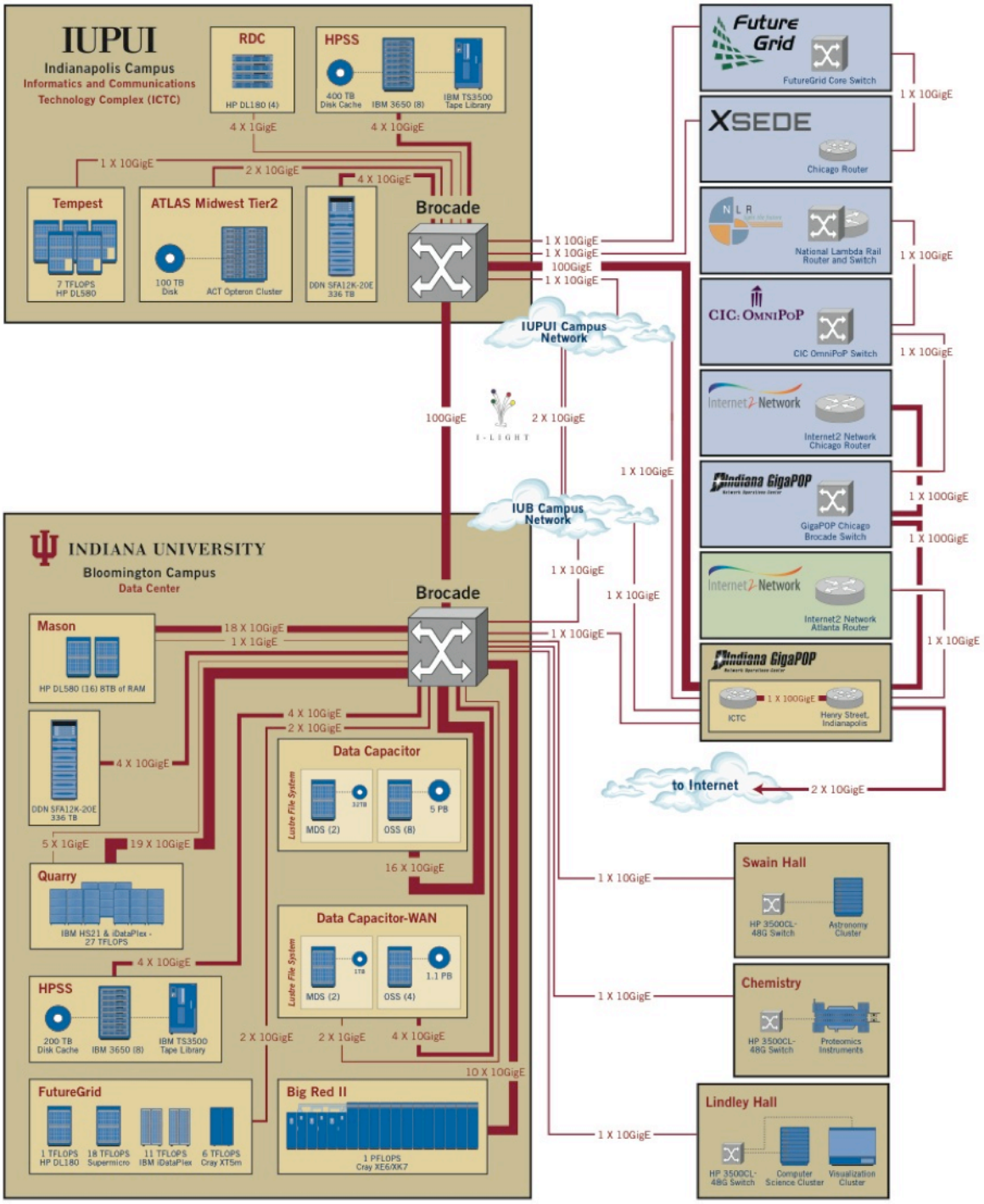
Indiana CTSI	IUSM	IUPUI	IU Biobank caTissue software deployment and support		✓			✓
VP Public Affairs & Govern-ment Relations	IUSM	IUPUI	Software support		✓		✓	
Regen-strief	RI	IUPUI	Access to infrastructure		✓	✓		
Regen-strief	RI	IUPUI	Grant development access to infrastructure		✓	✓		

Appendix 10B. Summary of extended consultations – work taking >4 hours of staff time – completed by RT groups outside of ABITC during FY 2013

Dept.	School	Campus	Service provided	Service status		Staff effort provided (FTE equivalent)			
				Done	On-going	4hrs- 1 wk	1-4 wks	>4 wks	>4 wks
Office of Graduate Medical Education	IUSM	IUPUI	Sharing AFS Shares with Other RFS Users		✓			✓	
Biostatis-tics	School of Public Health	IUPUI	IeDA Project Follow-Up	✓			✓		
ABITC	VPIT	IUPUI	Security scanning of NGVB Patient Sample LIMS	✓			✓		
Nursing	IU School of Nursing	IUPUI	Consult on Data Storage	✓			✓		
Dentistry-Oral Health	School of Dentistry	IUPUI	Enabling High Through-put Image Analysis in	✓					✓

			Dental Computing						
Bioinform-atics	IUSM	IUPUI	Request for data capacitor access	✓			✓		.
Radiology & Imaging Sciences	IUSM	IUPUI	File Recovery Request from SDA	✓				✓	
Biostatistic s	School of Public Health	IUPUI	RDC Performanc e Metrics	✓			✓		
Biostatis-tics	School of Public Health	IUPUI	Apex Application Migration	✓			✓		
Medical & Molecular Genetics	IUSM	IUPUI	CIFASD: Assist with order of new 3D Camera System	✓			✓		
Radiology & Imaging Sciences	IUSM	IUPUI	Using new features of hsi4	✓				✓	
Dentistry-Oral Health	School of Dentistry	IUPUI	u-CT image and lesion depth mapping project for NIH grant	✓					✓
Dentistry-Oral Health	School of Dentistry	IUPUI	Analysis, Visualiza-tion for IUSD Ando's NIH report	✓			✓		
Biostatis-tics	School of Public Health	IUPUI	Data Capacitor Application	✓			✓		
General Internal Medicine	IUSM	IUPUI	HIPAA aligned storage for Access research project database	✓			✓		

Appendix 11: Schematic diagram of IU cyberinfrastructure showing network connections within IU and between IU and other national networks


IUPUI
Indianapolis Campus
Informatics and Communications Technology Complex (ICTC)
RDC
HP DL180 (4)
HPSS
400 TB Disk Cache
IBM 3650 (8)
IBM TS3500 Tape Library
4 X 1GigE
4 X 10GigE
1 X 10GigE
2 X 10GigE
4 X 10GigE
Tempest
7 TFLOPS HP DL580
ATLAS Midwest Tier2
100 TB Disk
ACT Opteron Cluster
DDN SFA12K-20E 336 TB
Brocade
1 X 10GigE
1 X 10GigE
100GigE
1 X 10GigE
IUPUI Campus Network
100GigE
2 X 10GigE
I-LIGHT
1 X 10GigE
IUB Campus Network
1 X 10GigE
1 X 10GigE
INDIANA UNIVERSITY
Bloomington Campus
Data Center
Brocade
Mason
HP DL580 (16) 8TB of RAM
18 X 10GigE
1 X 1GigE
1 X 10GigE
DDN SFA12K-20E 336 TB
4 X 10GigE
4 X 10GigE
2 X 10GigE
Data Capacitor
Lustre File System
MDS (2)
32TB
OSS (8)
5 PB
5 X 1GigE
19 X 10GigE
16 X 10GigE
Quarry
IBM HS21 & iDataPlex - 27 TFLOPS
4 X 10GigE
Data Capacitor-WAN
Lustre File System
MDS (2)
1TB
OSS (4)
1.1 PB
HPSS
200 TB Disk Cache
IBM 3650 (8)
IBM TS3500 Tape Library
2 X 10GigE
2 X 1GigE
4 X 10GigE
10 X 10GigE
FutureGrid
1 TFLOPS HP DL180
18 TFLOPS Supermicro
11 TFLOPS IBM iDataPlex
6 TFLOPS Cray XT5m
Big Red II
1 PFLOPS Cray XE6/XK7
Future Grid
FutureGrid Core Switch
1 X 10GigE
XSEDE
Chicago Router
N L R
National Lambda Rail Router and Switch
1 X 10GigE
CIC: OmniPoP
CIC OmniPoP Switch
1 X 10GigE
Internet2 Network
Internet2 Network Chicago Router
Indiana GigaPOP
GigaPOP Chicago Brocade Switch
1 X 100GigE
1 X 100GigE
Internet2 Network
Internet2 Network Atlanta Router
1 X 10GigE
Indiana GigaPOP
1 X 100GigE
ICTC
Henry Street, Indianapolis
to Internet
2 X 10GigE
1 X 10GigE
Swain Hall
HP 3500CL-48G Switch
Astronomy Cluster
1 X 10GigE
Chemistry
HP 3500CL-48G Switch
Proteomics Instruments
1 X 10GigE
Lindley Hall
HP 3500CL-48G Switch
Computer Science Cluster
Visualization Cluster
1 X 10GigE

.

Appendix 12. Grant activities by researcher involving ABITC/RT support

PI	School	Title	Amount requested	Date submitted	Amount awarded
Shekhar, A.	IUSM	Indiana CTSI renewal	$30,000,000	May, 2013	$30,000,000
Cornetta, K.	IUSM	National Gene Vector Biorepository and Coordinating Center	$903,034	March, 2012	$903,034
Foroud, T.	IUSM	3D Facial Imagining in Fetal Alcohol Spectrum Disorder	$372,560	July, 2012	$372,560
Niculescu, A.	IUSM	Developing Blood Test for Mood Disorders	$2,310,000	September, 2010	$2,310,000
Shekhar, A.	IUSM	Clinical and Translation Sciences Institute	$25,000,000	August, 2008	$25,000,000
Shekhar, A.	IUSM	Administrative Supplement to support designated Topic Areas	$500,000	December, 2011	$500,000
Barnett, W.	RT	Informatics Core for Collaborative Initiative in Fetal Alcohol Spectrum Disorders	$802,815	December, 2011	$802,815
Stewart, C.	RT	ABI Development; National Center for Genome Analysis Support	$1,479,040	August, 2010	$1,479,040
Barnett, W.	RT	The Open Science Grid – The Next Five Years	$15,692,445	March, 2007	$15,692,445
TOTALS			$77,059,894		$77,059,894

Appendix 13. Publications and presentations during FY 2013 by ABITC/RT staff

The following works relate to or stem from ABITC and RT support of IUSM and CA researchers.

- UITS staff appear in bold.
- IUSM and CA faculty appear in bold italics.

Conference papers

Falk-Krzesinski, H., and **W. K. Barnett,** "Promoting Collaboration and Team Science Across the CTSA Consortium OR Now that you've VIVOed, what Next?" VIVO Conference 2012, Miami, Fla., Aug 2012.

Boyles, M., A. William, C. Frend, and C. Eller, "Using Stereoscopic 3D Videos to Inform the Public about the Benefits of Computational Science" XSEDE 2012, Chicago, Illinois, Jul 2012.

Boyles, M., A. William, C. Frend, and C. Eller, "Using Stereoscopic 3D Videos to Inform the Public about the Benefits of Computational Science" XSEDE (eXtreme Environment for Science and Engineering Discovery) 2012 Conference, Chicago, IL, Jul 2012.

Henschel, R., M. Leiber, L. - S. Wu, P. M. Nista, B. J. Haas, and **R. LeDuc,** Trinity RNA-Seq assembler performance optimization , Chicago. Illinois, Jul 2012.

Kohara, and ***M. Ando***, "Exploiting HPC Resources for the 3D-Time Series Analysis of Caries Lesion Activity" XSEDE 2012, Chicago, Illinois, Jul 2012.

Conference Proceedings

Zhang, H., M. Boyles, and ***M. Ando,*** "3D-Time Series Analysis of Caries Lesion Activity for Oral Health Care" 2012 Workshop on Visual Analytics in Healthcare: Open Health Data held in conjunction with IEEE VisWeek 2012, Seattle, WA, Oct 2012.

Henschel, R., M. Lieber, **L. - S. Wu,** P. M. Nista, B. J. Haas, and **R. D. LeDuc,** "Trinity RNA-Seq assembler performance optimization" XSEDE'12, Jul 2012.

Mukherjee, R., A. Thota, H. Fujioka, T. C. Bishop, and S. Jha, "Running many molecular dynamic simulations on many supercomputers" XSEDE (eXtreme Environment for Science and Engineering Discovery), Chicago, Il, Jul 2012.

Journal Articles

Christie, A. E., V. Roncalli, **L. - S. Wu, C. L. Ganote, T. Doak,** and P. H. Lenz, Peptidergic signaling in Calanus finmarchicus (Crustacea, Copepoda): In silico identification of putative peptide hormones and their receptors using a de novo assembled transcriptome , vol. 187, Jun 2013.

Foroud, T., L. Wetherill, S. Vinci-Booher, E. S. Moore, R. E. Ward, E. H. Hoyme, L. K. Robinson, **J. Rogers,** Ernesta M. Meintjes, C. D. Molteno, et al., "Relation Over Time Between Facial Measurements and Cognitive Outcomes in Fetal Alcohol-Exposed Children" Alcoholism: Clinical and Experimental Research, vol. 36, no. 9, pp. 1634-1646, Sep 2012.

Peer-reviewed Posters at Conferences

Hallock, B., Cyberinfrastructure Resources for Bioinformatics Research, Bio-IT World Expo Boston MA, Apr 2013.

Barnett, W. K., and R. LeDuc, Next Generation Cyberinfrastructures for Next Generation Sequencing and Genome Science , AMIA 2013 Translational Bioinformatics Summit San Francisco, CA. , Mar 2013.

William, A., C. Frend, M. Boyles, H. Zhang, ***E. Kohara, and M. Ando***, Visualizing the Dynamic Process of an Artificial Caries Lesion in Human Enamel, Visualization Showcase of XSEDE 2012, Jul 2012.

Presentations (not peer reviewed; generally seminars or training sessions)

Barnett, W. K., and **R. LeDuc,** Optimizing the National Cyberinfrastructure for Lower Bioinformatic Costs: Making the Most of Resources for Publicly Funded Research, RNA-Seq Conference, Boston, Massachusetts, Jun 2013.

LeDuc, R., and **L. - S. Wu**, Using Prior Knowledge to Improve Scoring in High-Throughput Top-Down Proteomics Experiments, American Society for Mass Spectrometry Annual Conference, Minneapolis, Minnesota, Jun 2013.

LeDuc, R., Leveraging the National Cyberinfrastructure for Top Down Mass Spectrometry, Annual Conference for the American Society for Mass Spectrometry, Minneapolis, Minnesota, Jun 2013.

Barnett, W. K., Research Networking, CTSA Communications Key Function Committee Face-to-Face Albuquerque, NM., Apr 2013.

Sheppard, R., "IUPUI Parallel Programming Workshop" Parallel Programming Workshop, IUPUI Campus, Indianapolis, In., Sep 2012.

Sheppard, R., "IUB Parallel Programming Workshop" Parallel Programming Workshop, IUB Campus, Bloomington, IN., Sep 2012..

Miller, J., Research Technologies' Storage Systems, IUPUI Campus - Indianapolis, Apr 2013.

Barnett, W. K., Presentation Skills, AAMC GIR Leadership Institute New Orleans, LA, Mar 2013.

Barnett, W. K., and **R. LeDuc**, Next Generation Cyberinfrastructures for Next Generation Sequencing and Genome Science , AMIA 2013 Translational Bioinformatics Summit San Francisco, CA., Mar 2013.

Barnett, W. K., Research at Academic Health Centers, AAMC GIR Leadership Institute New Orleans LA., Mar 2013.

LeDuc, R., Statistical Consideration for Identification and Quantification in Top-Down Proteomics, American Society for Mass Spectrometry - Sanibel Conference 2013, St Pete Beach, FL, Jan 2013.

Barnett, W. K., Business Intelligence in Translational Research: Research Networking as a Test Case, EDUCAUSE 2012, http://www.educause.edu/annual-conference , Denver, CO, Nov 2012.

LeDuc, R. D., and **W. K. Barnett**, The National Center for Genome Analysis Support and Galaxy, IEEE/ACM Supercomputing (SC|12), OpenSFS.org booth, Nov 2012.

LeDuc, R., Experimental Design for NGS-Based Transcriptomics for Non-model Organisms, World Genome Data Summit, San Francisco, Nov 2012.

LeDuc, R., Genomics, Transcriptomics, and Proteomics: Engaging Biologists, 8th IEEE International Conference on eScience 2012, Chicago, Illinois, Oct 2012.

Arenson, A. D., and R. L. Davis, REDCap: Easy creation of data management systems, plus a lot more, IU Statewide IT Conference 2012, Bloomington, In., Sep 2012.

Arenson, A. D., and R. L. Davis, REDCap: Easy creation of data management systems, plus a lot more, Indiana University Statewide IT Conference, Sep 2012.