Principal Investigator Meeting, Strategic Technologies and Software Development for CyberInrastructure
National Science Foundation – January 28-29, 2010

Award #0943559: STCI: OptIPlanet Cyber-Mashup

Persistent Visualization and Collaboration Services for Global Cyberinfrastructure

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SAGE, the Scalable Adaptive Graphics Environment, is a graphics streaming architecture that enables users to interactively access, display and share a variety of data-intensive information, in a variety of resolutions and formats, from multiple sources, with the same ease that the Web affords for accessing lower-resolution objects today. This requires 21st-century "personal computers;" that is, tiled display walls driven by computer clusters and interconnected over multi-gigabit optical networks.

As globally distributed research teams work more closely to solve complex problems utilizing high-performance cyberinfrastructure – from petascale computers to specialized instrumentation generating massive amounts of data – the need for high-resolution visualization is becoming more critical for analysis. This is propelling the worldwide adoption of tiled display walls, which enable the creation of "cyber-mashups," or juxtapositions, of data visualizations, enabling greater insight.



Our Nation already invests in network-connected, middleware-enabled cyberinfrastructure to generate and disseminate petabytes (ultimately exabytes) of data among researchers worldwide. What is needed, however, is a globally integrated collaborative work environment, or framework, to facilitate data analysis and high productivity. SAGE is cross-platform middleware that enables users worldwide to have such an

operating environment. SAGE is transitioning from a transformative research prototype to a hardened technology that provides production-quality, community-driven open services for persistent visualization and collaboration, to make national/international cyberinfrastructure accessible to broader communities of scientists and students, and to help maintain US leadership in high-performance computing.

The NSF-funded OptIPuter[1] project funded SAGE software development, tiled display walls (also known as "OptIPortals) was based on a 2002 NSF award to EVL for *LambdaVision*[2], a 100-Megapixel tiled display. As SAGE was designed to stream high-resolution images and animations over optical networks, EVL began prototyping network-based transport protocols and prefetching algorithms over optical networks accessible via StarLight, using the NSF-funded IRNC TransLight/StarLight[3] links to Europe as well as other circuits that are part of Global Lambda Integrated Facility (GLIF) optical fabric. Today, SAGE has many early adopters, as shown in the illustration above and the table below.

SAGE User Community – January 2010		
Australia • AARNet • Monash University - Caulfield • Monash University - Clayton • University of Melbourne • University of Queensland **Canada** • Nortel Networks, Canada • Simon Fraser University **China** • Chinese Academy of Sciences, Computer Network Information Center **Czech Republic** • Masaryk University, Advanced Networking Technologies Lab (2) **Germany** • Braunschweig University of Technology, Institute of Computer and Network Engineering **Japan** • Knowledge Graphics Technology, Inc. • Kyoto University • National Institute of Advanced Industrial Science and Technology (AIST) • National Institute of Information and Communications Technology (NICT) - Otemachi • Osaka University **Korea** • Gwangju Institute of Science and Technology (GIST), Networked Media Laboratory • Korea Institute of Science and Technology Information (KISTI)	**Mexico** • Ensenada Center for Scientific Research and Higher Education **Netherlands** • SARA Computing & Networking Services • University of Amsterdam, e-BioScience Laboratory • University of Amsterdam, System & Network Engineering Research Group **Russia** • Russian Academy of Sciences, Science and Innovation Center • Russian Academy of Sciences, Space Research Institute **Saudi Arabia** • King Abdullah University for Science and Technology (KAUST) **Taiwan** • National Center for High Performance Computing (NCHC) **United States** • Adler Planetarium & Astronomy Museum • Argonne National Laboratory, Transportation Research and Analysis Computing Center • Calit2, University of California, Irvine • Calit2, University of California, San Diego (3) • Florida International University, Center for Internet Augmented Research & Assessment • Louisiana State University, Center for Computation and Technology	• NASA Goddard Space Flight Center, Space Visualization Studio • Northwestern University, International Center for Advanced Internet Research • Purdue University, Envision Center • Rincon Research Corporation • Sharp Laboratories of America • Texas A&M University, Computer Science & Engineering • UCSD, National Center for Microscopy and Imaging Research • UCSD, Scripps Institution of Oceanography • University of Hawaii, Center for Microbial Oceanography: Research and Education • University of Illinois at Chicago, Electronic Visualization Lab (2) • University of Illinois at Urbana-Champaign, National Center for Supercomputing Applications • University of Michigan, Department of Atmospheric, Oceanic & Space Sciences • University of Michigan, Digital Media Commons • University of Michigan, School of Information/ Provost's Virtual Space Interaction Testbed • University of Texas at Austin, Texas Advanced Computing Center • University of Washington • US Geological Survey (USGS), National Center for Earth Resources Observation and Science

[1] NSF Information Technology Research (ITR) award OCI-0225642, October 1, 2002 – September 30, 2009. Larry Smarr (UCSD) was PI, Jason Leigh (UIC) was a co-PI, and Maxine Brown (UIC) was project manager.

[2] Jason Leigh (UIC), PI, received NSF CNS-0420477, September 15, 2004 – August 31, 2008, for LambdaVision.

[3] Tom DeFanti (UIC), PI, and Maxine Brown, co-PI, received NSF funding to provide network connectivity between the US and Europe. NSF cooperative agreement SCI-9730202, April 1999 – May 2005, established Euro-Link. NSF cooperative agreement OCI-0441094, Feb 2005 – Jan 2010, established TransLight/StarLight.