I am writing to provide some thoughts about the GENI project and its role in my NSF EAGER / US IGNITE grant "Digital Tele-Microscopy in Support of Teaching Biology," NSF grant number 1451220.

As background, as described on the NSF website grant summary, this project explores how to enrich high-school biology education by bringing university microbiologists and research-grade microscopy into the classroom via real-time, high-grade video. Research-grade microscopes have a variety of technologies not normally available in high-school classroom instruments. Professional microbiologists are able to provide expert commentary about specimens and answer questions in dialogues that can enrich student's experience and excite their sense of discovery. This project is using gigabit networks and ultra-high-quality video to bring research instruments and researchers into the classroom. The project links research facilities at the University of Southern California with the STEM School Chattanooga, a public high school. The project's technology will allow researchers at USC to place live biological specimens under a USC-developed microscope and capture ultra-high resolution (4k) movies of the microorganisms while simultaneously transmitting live, high definition images from the microscope system to the students. It takes advantage of Chattanooga's deployment of a city-wide gigabit network. The project provides students there the unique opportunity to collaborate with scientists a continent away.

The GENI system played a critical role in enabling this project to make the requisite high speed connection from USC in Los Angeles to STEM School Chattanooga. Conversely, this project also had an influence on pushing the installation of the GENI rack at UT Chattanooga forward to meet the looming deadline of the biology course. Having the GENI rack at the University of Tennessee, Chattanooga, and networking personnel there were essential in bringing the connection into existence, which was required for the remote course to take place.

The connection between the university and high school consisted of three components that functioned together over the network: a high definition video conference between the high school students in Chattanooga and the faculty and grad students at USC; a high definition video connection from the microscope at USC to a large flat panel display at the STEM School, and a remote desktop interface putting the computer at USC that controls the microscope under the control of the students in Chattanooga. This allowed human in the loop, remote control of a research microscope 1800 miles away, with simultaneous remote viewing through the microscope and conversation with microscopic domain experts, making for a compelling and engaging experience.

Although GENI had not been designed to facilitate the connection of a microscope from a research university to a distant STEM high school, it served

that function in this project, allowing us to create an ad hoc connection from an expensive scientific instrument, in this case a remotely controllable microscope with a digital cinema camera, to a distant STEM high school.

The path taken from USC to STEM School Chattanooga was as follows: network speeds (1, 10, 100)

USC School of Cinematic Arts (10)--> (10) USC TEN 2 Network router (100)--> Zayo fiber (100)--> CENIC (downtown LA) (100) --> AL2S (100)--> Atlanta SoX (10)--> (10) University of TN, Chattanooga GENI Rack (1)--> Chattanooga EBP (1)--> STEM School Chattanooga

An important function of the GENI project in our case was the ad hoc interconnection between the two sites involved in this NSF grant. As we imagine the future of our tele-microscopy project, being able to connect to distant sites is essential. Insofar as the GENI systems and the associated researchers can facilitate further connections, this will be critical in providing a growth path for tele-microscopy.

Perhaps this example could point the way to a potential new and important function of the GENI system, namely facilitating connections between colleges and universities nationwide and high schools, or perhaps community colleges in their vicinities. Once that high speed connection has been made for a project such as ours, then in addition to enabling this particular application, the whole world of high speed applications would now become feasible at the high school.

The project brought together four levels of people who otherwise would have had no reason or occasion to interact: high school students, high school teachers, university grad students and university faculty. This provided the high school students with an otherwise unavailable opportunity to interact with university faculty and to interact and control a piece of research equipment beyond their technological or financial reach. The impact was to generate new interest among high school students in the micro-world, and in microbiology that they never had before. In addition, the project was very educational for the high school teachers themselves, who were seeing the fine details of living microorganisms for the first time along with their students. And in fact it was quite educational for the university faculty and even grad students to see how high school education has changed since the days when they were high school students.

Why is this important? The optical microscope has been one of the most important scientific instruments ever invented, and continues to evolve. High schools don't have the research grade microscopes that allow students to explore and appreciate the fascinating and intricate living micro-world, along

with expert guides to answer their questions. Being able to see this for the first time can spark their interest in biology and other sciences, at a critical time in their education, when they are considering career and higher education choices.

We were only at the second week of the biology course when we presented this project at the NSF / GENI / US IGNITE conference in March, 2015. The project was selected as one of four for presentation in the VIP demo suites, out of about sixty GENI projects presented at the conference.

For this presentation, we essentially replicated the remote classroom, connecting to the microscope at USC, and did a live demonstration to senior NSF, White House Office of Science and Technology Policy members, Department of Education officials, and other VIPs. The Director of the NSF herself steered the distant microscope, and the project was widely thought to have been among the most compelling and understandable demonstration of what high speed networks can accomplish.

GENI aided this project in several ways: facilitating the hardware connection itself, providing a knowledgeable cohort of networking professionals, and providing the conference venue where the project could be presented.

One goal moving forward on this project is to reach more schools in other locations across the country. GENI's ability to foster previously unplanned connections will potentially allow us to reach more schools and students.

There is much remaining to explore in this project in terms of cyberinfrastructure. Although we have been focusing on the live, interactive streaming and remote control aspects of the network usage, once the images are in digital form, there are a wealth of other ways that the information could be processed, analyzed, stored, and further distributed. Connecting the project to the GENI grid holds the promise of using additional nationwide (or even international) resources, such as distant computing, graphics and distributed databases.

This project demonstrated that with GENI, US IGNITE, and NSF's assistance (along with national, regional, and local networks), a high speed network connection to a high school can be made to facilitate a new form of education dealing with microscopic organisms and phenomena. Once that high speed network is in place, a wealth of other opportunities could open up to that high school in addition to this one, highly compelling application. The big winners are the students at the high school who experience this new form of education, with the ancillary benefits of having the high speed connection for other educational and research uses.

Richard Weinberg, Ph.D.
Charles S. Swartz Endowed Chair in Entertainment Technology
Research Associate Professor
USC School of Cinematic Arts
930 West 34th St.
Los Angeles CA 90089-2211
weinberg@cinema.usc.edu
213-740-3239