

Geological Society of America 2006 National Meeting Professional Development Course Proposal

TITLE OF COURSE:

Using GPS data to study crustal deformation, earthquakes, and volcanism: a workshop for college faculty

PROPOSERS:

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DAY/DATE/TIME:

We propose a one-half day professional development workshop on-site with no field component. We would prefer that the workshop be held on Saturday, October 21 or Sunday, October 22, 2006 beginning in the morning. We would also like to request that our workshop not be held on the same day as the IRIS consortium's proposed workshop because we believe that the audiences will be similar for both, and we are working with IRIS to develop complementary materials.

SPONSOR: Geological Society of America

CO-SPONSOR: Geological Society of America Geoscience Education Division

ACCREDITATION:

Per the Geological Society of America's criteria for CEU accreditation, our workshop will have the following attributes:

- Clearly stated objectives.
- Clear instructional outline.
- Statement of course outcomes.
- Topic related to geologic education/training.
- Maximum of three faculty members.
- Minimum of four course hours.
- Proposal will be peer-reviewed by one of GSA's divisions. (Geo. Ed. Division)

- Anticipated outcomes stated in course description.
- Course notes available.
- Mechanism for evaluation of students during progress of course.
- Evaluation will be completed by students and course monitor.

CONTENT:

Introduction.

We propose a workshop to highlight new scientific discoveries related to plate tectonics based on high-precision GPS. The deployment of large numbers of continuous GPS sites has led to the identification of transient deformation (*i.e.*, deformation not associated with earthquakes, often accompanied by seismic activity.) It has provided evidence that such transient deformation may be much more common than previously realized. Since currently available GPS receivers can operate at high sampling rates, GPS investigators use these data in new applications in studying deformation associated with earthquakes, volcanoes, glaciers, ice sheets, continents, plate motion, and related phenomena.

UNAVCO is a non-profit, membership-governed consortium funded by the National Science Foundation and the National Aeronautics and Space Administration. Member organizations are primarily research universities that study crustal deformation, addressing mechanisms for large and small-scale tectonic features and processes such as earthquakes, volcanoes, plate motion, faulting and folding, and mountain building. To achieve UNAVCO's mission of supporting and promoting high-precision measurement techniques for the advancement of Earth sciences, UNAVCO scientists from member institutions are involved in cutting-edge GPS research. UNAVCO secured NSF funding in March 2005 for the Plate Boundary Observatory Nucleus project, a 3.5-year effort to operate, maintain, upgrade, and integrate 209 GPS stations from six regional networks in the western United States into the Plate Boundary Observatory.

A major goal of the Plate Boundary Observatory Nucleus project involves increasing public appreciation and understanding of Earth deformation processes and their societal relevance through education and outreach. To that end, UNAVCO is developing free instructional materials for a variety of audiences that involve middle school and undergraduate students using authentic GPS data. These resources will

provide educators at the secondary and post-secondary levels with concrete, problem-based ways to teach their students how Earth scientists measure crustal deformation using GPS and how these measurements are important to hazard prediction and infrastructure. In addition, the materials will draw attention to new discoveries yielded by high-precision GPS and provide students with case studies highlighting the scientific process. From this point on, we will refer to our instructional materials as “modules”, which we define as self-contained sets of curricular resources that include lecture materials, visual aids (photographs, illustrations, graphs), activities such as lab and homework exercises, data sets, an instructor’s manual with information on scientific content and instructions for module implementation, and internet resources. We are explicitly developing the modules to accommodate the implementation needs of different users. This way, instructors will be able to choose which portions of the module they wish to use in their classrooms based on their curricula, class size, access to technology, and student population.

One of the modules being created is for use in general education and/or introductory undergraduate geoscience courses. We wish to hold a professional development workshop at the 2006 Geological Society of America national meeting to introduce this module to college and university faculty from liberal arts colleges, community colleges, tribal colleges, historically black colleges and universities, comprehensive universities, and Research I universities.

General objectives.

Teaching geoscience to the introductory undergraduate population. Many undergraduates enrolled in a general education/introductory geoscience course are non-science majors. Although a significant number of these students will never work in a scientific field or conduct scientific research, fostering skills like critically assessing data, visualizing abstract concepts, and using multiple lines of evidence to evaluate an idea is important regardless of a student’s future academic and career path. Problematically, McConnell et al (2005) found that the majority of undergraduates in introductory geoscience courses do not think at an abstract level. Their research suggested that instructors must provide concrete examples of geologic phenomena and assist students in developing an understanding of abstract concepts. This process was best facilitated in an

inquiry-based learning environment rather than in a passive, lecture-based environment. Indeed, the National Research Council (1996) stated that teaching undergraduates to think scientifically can be accomplished in a classroom setting if problem-based activities in which the “real-world” importance of scientific concepts are implemented. In addition to conveying scientific concepts qualitatively, Shosha et al (2000) demonstrated that quantitative exercises can be effectively incorporated into introductory geoscience courses with non-majors and majors.

Addressing the barriers to teaching plate tectonics. Plate tectonics is a central theme in most general education/introductory geoscience courses, but the spatial, causal, and temporal aspects of plate tectonics are challenging concepts for a variety of reasons (Gobert, 2005.) Imagining Earth’s internal structure and mysterious physiographic features such as mid-ocean ridges and trenches is difficult for students because they have never seen them (Gobert, 2005.) The scales on which tectonic processes are measured with respect to size (for example, lithospheric thickness) and time (for example, rates of plate motion and crustal deformation) also present a barrier to understanding plate tectonics because they differ from the spatial and temporal reference frames that we encounter in every-day life (Jacobi et al., 1996.) Oversimplified or inaccurate representations of plate tectonics and Earth structure in films and books contribute to student misconceptions as well. Sibley (2005) found that of 600 general education students’ cross-section sketches of continental collision zones, only 25% of sketches on homework assignments and less than 20% of sketches on quizzes were correct. The same study revealed that a significant number of geology majors and first-year graduate students shared the same major misconceptions (Sibley, 2005.)

Challenging students’ understanding of plate tectonics through problem-based activities and frequent questioning (as opposed to passive learning strategies such as lecturing) is an effective method of identifying student misconceptions and replacing incorrect ways of thinking about plate tectonics with more accurate models (McConnell et al., 2005.) For example, Sawyer et al (2005) have developed a series of qualitative activities based on real data called “Discovering Plate Boundaries” in which students study world maps to investigate earthquake focal depths and locations, geographic

distribution of volcanism, age of Earth's crust, and global topographic/bathymetric patterns with respect to plate boundaries. High-precision GPS represents an additional technique that may be applied to tectonic problems, in this case by measuring crustal deformation.

The value of GPS: spatial and temporal aspects of plate tectonics. Because of its increasing use in transportation and recreation, many undergraduates have a peripheral awareness of the existence and applications of GPS technology. Several introductory geoscience textbooks (*i.e.*, Skinner et al., 2004; Marshak, 2001; Press and Siever, 2000) provide brief, general descriptions of GPS but do not elaborate on its applications, explain how to interpret GPS data, or convey the excitement of new discoveries that have been made as a result of the data. In addition, curricular activities using handheld GPS units have been developed and successfully implemented in introductory geoscience courses (*i.e.*, Weiss and Walters, 2004; Herrstrom, 2000.) However, these activities typically focus upon recording one's position at a given moment in time and use instruments with errors on the order of 1 m. In contrast, high-precision GPS instruments are accurate to within 1 cm and generate continuous data sets to measure position changes over days, months, and years. Because this deformation is expressed on Earth's surface over more familiar time scales and on easily visualized orders of magnitude, GPS data represent an effective method of illustrating the geomorphic effects of plate tectonics and in essence, allows students to "see" plate tectonics. In addition, linking small-scale deformation that can be observed on the surface to underlying tectonic processes may help students better understand more abstract, large-scale geologic phenomena. Finally, GPS data provide a means to study events like earthquakes and volcanic eruptions that are influential to humans and our infrastructure.

We aim to provide faculty with a module to help them teach their students how Earth scientists use high-precision GPS data to measure crustal deformation. The modules will be appropriate for a range of student populations, enrollments, and class structures and will be designed so that faculty will be able to choose the portions that best fit their curricular needs. For example, we will provide paper/pencil and computer-based exercises, in-class activities for large, introductory courses, lab exercises for low-

enrollment courses, and a mix of qualitative and quantitative activities. During the proposed workshop, we will:

- Offer a high-precision GPS primer for participants.
- Give concrete examples of quantitative skills (general examples: precision vs. accuracy, averaging, plotting vectors, calculating rates of change) that may be taught in conjunction with the module.
- Assist participants with downloading one or more high-level GPS data sets, constructing a time-series, and interpreting the results.
- Provide one or more case studies of geographic regions with a strong component of societal relevance in which high-precision GPS is being used to measure plate tectonics.
- Discuss potential barriers to implementing the module in the classroom and how to overcome them.
- Generate (with the help of participants) additional ideas for teaching plate tectonics from a geodetic perspective.
- Sufficiently prepare participants to implement the module in their courses by helping them develop plans for implementation and selecting which portion(s) of the module they will use in their teaching.
- Point participants to web-based UNAVCO resources.

Anticipated topics.

Our module is currently in development. Below, we briefly provide several examples of geologic case studies that we are currently incorporating into the module.

Episodic tremor and slip. The Cascadia Subduction Zone (CSZ) marks the North American- Juan de Fuca plate boundary (Figure 1.) In addition to a myriad of volcanic hazards, significant seismic hazards exist for residents of the Pacific Northwest as the CSZ has generated numerous magnitude 8+ earthquakes. Until recently, it was assumed that slip on the fault occurred consistently, but in the 1990s, an idea that would eventually be known as episodic tremor and slip (ETS) was proposed. Scientists first characterized ETS in response to anomalous GPS station displacement on southern Vancouver Island.

In contrast to the interseismic eastward deformation in response to the compressional regime, they observed an abrupt shift in displacement every ~14 months during which slip occurred ~4-8 mm to the *west* for approximately 14 days (Figure 2; Dragert et al., 2001, Miller et al., 2002) and was accompanied by low-frequency seismic events that were dubbed “tremors” (Figure 3, Dragert et al., 2001.) Subsequently, nine ETS events have been observed since 1992 using high-precision GPS instrumentation (Miller et al., 2002, Johnson et al., 2005.)

The discovery of these “slow earthquakes” using high-precision GPS represents a fundamental shift in the way that Earth scientists think about subduction zones and provides an opportunity to build students’ critical thinking and quantitative skills using GPS data sets. For example, the data in figure 3 could be used to pose questions about patterns (How often do the cycles occur? When would we expect to see the next event?), rates of change (What is the magnitude and direction of change during each event? What is the average rate of change since the events were first observed?), and data integration (How does the movement at this station compare to plate motion vectors that you see on a map? Do earthquakes occur near the station? Are there volcanoes near the station?) With respect to societal relevance, the implications for seismic hazard determination are significant because the probability of large earthquakes increase during the events (Mazzotti and Adams, 2004.) In addition to gaining a deeper understanding of subduction dynamics, this case study provides a meaningful look into the scientific process and formulation of cutting-edge scientific theories. Because slow earthquakes are a relatively recent discovery, this is an exemplary case study by which to convey to students the questioning nature of science and the process by which new theories are developed.

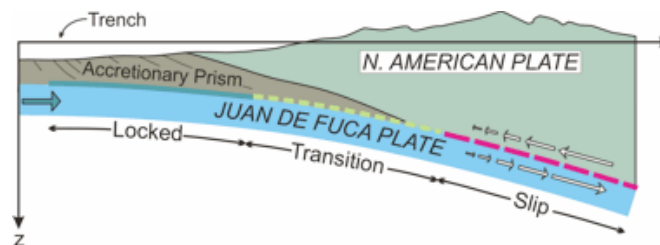


Figure 1. Sketch of Cascadia Subduction Zone. The pink, dotted lines denote the portion of the thrust fault that is believed to slip episodically. Illustration courtesy of Geological Survey of Canada, URL http://www.pgc.nrcan.gc.ca:80/geodyn/docs/slip/slip_info_1.html.

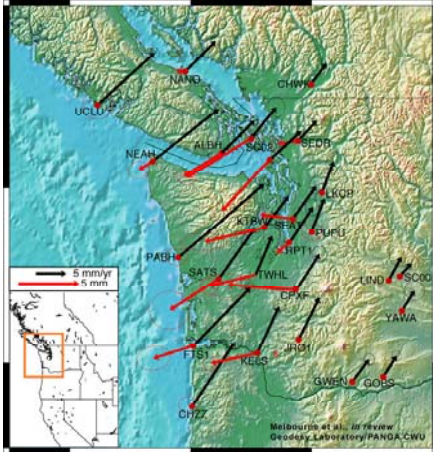


Figure 2 (left.) Comparison of interseismic deformation vectors (in black) and displacement vectors during the 2003 Cascadia ETS event (in red.) Note westward displacement during the ETS event. Figure courtesy of PANGA, Central Washington University.

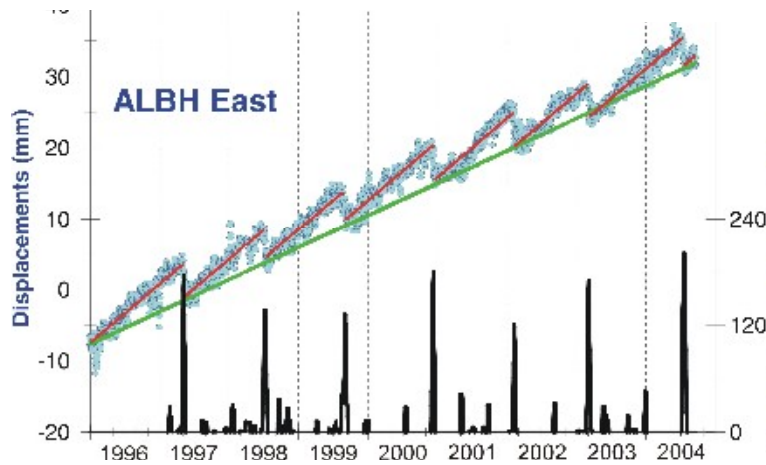


Figure 3. Illustration of relationship between deformation and seismicity in Victoria, British Columbia in response to ETS. The blue time series depicts changes in the eastward component of motion at a GPS station. Red lines within the GPS data show 14-15 month intervals of eastward motion, followed by shorter intervals of westward motion. The green line denotes long-term eastward motion. The black time series represents the number of hours (within a sliding 10-day window) of tremor activity. Note the strong correlation between the tremor and slip events. Figure and caption information courtesy of Geological Survey of Canada, <http://www.pgc.nrcan.gc.ca:80/seismo/ETS/ETS.htm>.

Postseismic deformation. Studying postseismic deformation provides insight into fault zone mechanics and the crustal recovery that occurs after large earthquakes (Hudnut et al., 2002.) For example, GPS time series for the Hector Mine (1999), Denali Fault (2002), and San Simeon (2003) events have constrained the spatial and temporal extent of postseismic deformation. For example, in the case of Hector Mine, Hudnut et al (2002) calculated displacement on the order of centimeters per several months. By utilizing GPS time-series from postseismic deformation related to the Hector Mine event, students will

have the potential to qualitatively and quantitatively compare coseismic and postseismic deformation (*ie*, How much deformation took place on the day of the earthquake? How much additional deformation occurred over the next two months?) and relate small-scale displacement to relative motion of a large-scale structure (What does the relative motion in the study area tell us about the relative motion of the fault?).

Monitoring volcano deformation. Ground deformation in volcanic systems measured by GPS has important implications for regional tectonics, magma recharge, and volcanic hazard mitigation. Plate Boundary Observatory Nucleus stations were installed at Yellowstone caldera in 1996 and have produced continuous data sets showing regional extension and caldera subsidence and uplift (PBO Nucleus proposal, p. 18.) The 2004 eruption of Mount St. Helens and the recent unrest at Augustine volcano in Alaska are other examples of potential GPS case studies. In the case of Augustine volcano, UNAVCO installed five continuously operating GPS stations on the volcano in September 2004. The data obtained from these stations will allow students to compare ground deformation that occurred on the volcano in 2004 and 2005.

Methodology.

Authentic data. Using data in undergraduate science courses is becoming increasingly widespread because of its numerous benefits. Incorporating data sets into undergraduate curricula provides students with insight into the scientific process; specifically, developing questions and hypotheses, understanding how data are collected, evaluating the quality of data, and formulating conclusions based on the data and their science content knowledge (Manduca et al., 2003.) However, it is imperative that data-rich activities for introductory geoscience courses be designed at audience-appropriate levels. Designing activities that are problem-based and integrate effectively into an introductory curriculum is time-consuming and challenging for faculty. Logistical issues include finding specific data products, gaining access to the appropriate software to allow students to view, manipulate, and interpret the data, and selecting appropriate data sets that clearly illustrate the scientific problem being addressed. Once the data have been found, educators must determine how to guide students—many of whom have never

worked with a data set—through the process of viewing and interpreting the data, making connections between the data and the large-scale problem (for example, relating centimeters of surface displacement to large-scale subduction zone processes that are occurring at depth), and understanding the importance of the problem. We are addressing these development and implementation issues as we design the module and will be discussing these barriers with participants during the workshop.

Identifying user needs. To assess the needs of our users, we are conducting telephone interviews with over twenty geoscience faculty from the liberal arts, community college, tribal college, HBCU, comprehensive university, and research I communities to elicit their opinions about the proposed module. To date, the majority of faculty felt as though both qualitative and quantitative material would be useful at the introductory level but remarked that quantitative data sets should be cut and dried and show clear patterns. Most thought that a laboratory or homework exercise would be best suited to their students. While respondents did not express a strong preference as to whether the module should be paper and pencil-based or a mix of paper/pencil and computer activities, only one person preferred a purely computer-based module. The majority expressed an interest in a professional development experience related to the module, and all respondents to date have agreed that a strong component of societal relevance should be included in the module. We have taken this feedback into consideration and are designing our module accordingly.

Timeline for pilot testing. We plan to complete several versions of the module over the course of its development. The first iteration will be completed in April 2006 and will be evaluated individually by several faculty members. We will work informally with a different group of faculty during summer 2006 to make additional modifications. Subsequently, three faculty members will test the module in their classrooms during the fall 2006 semester. Although the module will already have been through three stages of pilot testing when it is presumably unveiled at the fall 2006 GSA meeting, we plan to elicit feedback during and after the workshop to determine whether or not additional changes will be made. We are also working with an external evaluator.

Tentative agenda.

- 7:30-8:00: Sign-in, computer checks, refreshments
- 8:00-8:15: Welcome and icebreaker
- 8:15-8:45: The science: current GPS research, new discoveries, limitations
- 8:45-9:30: Using and understanding GPS data
- 9:30-9:45: Break
- 9:45-10:45 Introduction to module and module content
- 10:45-11:30: The pedagogy: discussion about teaching plate tectonics, the benefits and challenges of teaching using real data, accommodating diverse student populations and learning styles
- 11:30-12:15: Summary and discussion. Possible topics: participants work to develop individual plans to implement the module in their classrooms, discuss technological considerations, discuss where to go to find support and additional resources for teaching using GPS data
- 12:15-12:30: Course evaluations

Anticipated outcomes.

As a result of our proposed workshop, participants will:

- Increase their familiarity with high-precision GPS and its application to tectonic problems.
- Discuss the benefits and pitfalls of developing and implementing data-rich activities for their courses.
- Have an awareness of and access to resources related to high-precision GPS. Examples of resources include the module itself, UNAVCO web resources to support their implementation of the module, external GPS web resources, high-level GPS data sets, GPS-based internship opportunities for undergraduates, and a schedule of future UNAVCO professional development programs.
- Have a stand-alone resource to allow them to incorporate real data and quantitative exercises into their teaching.
- Field-test the module in their course and report on its efficacy.

As a result of our proposed workshop, workshop conveners will:

- Disseminate UNAVCO data products to a diverse group of educational users.
- Assess the effectiveness of the workshop and module by conducting an end-of-workshop evaluation.
- Find participants to use the module in their classrooms.
- Identify participants to assist in continuing to develop instructional materials.

Audience.

We hope to recruit a diverse audience of faculty from the liberal arts, community college, tribal college, historically black college and university (HBCU), comprehensive university, and Research I communities. Workshop participants should be involved in teaching at the 4-year or community college level and teach general education, introductory, and/or lower-level geoscience courses in which plate tectonics and crustal deformation are course topics. Faculty from other disciplines (for example, geography and environmental studies) who address plate tectonics in their undergraduate courses are also encouraged to attend. Through promotion of the workshop, we aim to recruit faculty who teach underrepresented student populations.

The workshop content will be appropriate for a range of academic backgrounds within Earth science. Participants should hold at least an M.S. in geosciences or a related field. While individuals with experience using GPS in research or teaching settings are welcome, the technical portion of the workshop will be geared toward faculty with an awareness of GPS but little or no background using GPS in their teaching. In addition to instruction on implementing the module in their classrooms, background information on high-precision GPS and the study areas mentioned above will be provided during the workshop.

With respect to technology, participants should be comfortable with basic Microsoft Excel applications (*ie*, downloading, entering, and plotting data.) Participants should also be able to provide their own laptop for the workshop. (Note that we offer both computer and paper-based instructional materials. Thus, while we will be using computers during the workshop, computers are not required for implementing the materials in the classroom.)

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Publications since 2000

Eriksson, Susan C. and G. Anderson, 2005, Incorporating Plate Boundary Observatory and other EarthScope Data Products in Broader Objectives for Geoscience Education and Outreach, EarthScope National Meeting, March, 2005, Invited plenary speaker, Abstract volume, p. 111.

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Eriksson, S.C., 2000, Making metaphors to enhance geological understanding: Journal of Geoscience Education, 5, 600-601.

- Percentage teaching during workshop: 40%

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M.S., Geosciences, University of Arizona, Tucson, AZ, 2005
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Publications since 2000

Walker, B.A., Hall, M.K., and Regens, N.L., 2005, Building effective scientist-teacher partnerships: a case study investigation, Eos Trans. AGU, 86(52), Fall Meeting Supplement, Abstract ED13F-02.

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- Percentage teaching during workshop: 40%

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Publications since 2000

Taylor, F.W., P. Mann, M.G. Bevis, R.L. Edwards, H. Cheng, K. Cutler, S.C. Gray, G.S. Burr, J.W. Beck, **D.A. Phillips**, G. Cabioch, J. Recy, Rapid forearc uplift and subsidence caused by impinging bathymetric features: examples from the New Hebrides and Solomon Arcs, accepted to Tectonics June 2005.

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estimates of crustal motion in the Tonga-Lau system (in prep for Geochemistry, Geophysics, Geosystems).

LIMIT:

Although we have established a minimum enrollment of 5 and a maximum enrollment of 20, our preferred range is 10-15 participants.

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COURSE NOTES:

The proposers will be responsible for printing and collating course materials, which are currently in development and will meet the publication specifications outlined by the Geological Society of America.

PROMOTION:

In addition to promotion in GSA publications, it would be helpful to promote the workshop via the following organizations:

- AGI (American Geological Institute)
- NAGT (National Association of Geoscience Teachers)
- CESE (Coalition for Earth Science Education)
- ESE (NASA's Earth Science Enterprise)
- SACNAS (Society for the Advancement of Chicanos and Native American Students)
- AISES (American Indian Science and Engineering Society)
- NABGG (National Association of Black Geologists and Geophysicists)
- AWG (Association for Women Geoscientists)

BUDGET ITEMS:

Catering:

At this time, we do not anticipate holding a pre-function event. We request beverages (water, coffee, tea, and juice) and appropriate condiments at the beginning of the workshop. We will schedule a mid-morning break, during which we would like beverages (water, coffee, tea, and juice), condiments, and snacks (fruit and baked goods) available. Refreshment quantity will depend on the number of registrants.

Audio-visual:

At this time, we anticipate the following AV requirements: digital projector, overhead projector, two screens, two lecterns, three laser pointers, three lavalier microphones, wipe boards.

Computers:

Participants will be asked to provide their own laptop computers. We will need the room to be equipped with numerous outlets for participants' power cords, internet connections and cords for each participant (including proposers), and wireless internet capability.

Transportation:

No transportation is required.

Labor:

We would like a student assistant to assist with initial set-up (*ie*, connecting the projector to the proposers' laptop, confirming that the internet connection is operating properly, troubleshooting if any problems arise during set-up.)

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