Project Description

Introduction and Background—Survey Findings and Conclusions

The Welding Industry: As an industry, welding is large with $34.1B/year gross revenue and provides an enabling manufacturing process for $3.1T of manufactured products, or approximately one-third US GDP (ref.1 and Appendix A for "Major Findings"). Welding is also diverse, in terms of processes [arc, high energy beam (laser and electron), resistance, solid state, brazing, soldering, cutting, and thermal spray (coatings)] and materials (metals and nonmetals). Welding depends on manual skills for basic processes (welders); increased intellectual skills to set up and operate highly automated systems (technicians - ref. 3, 4); design and analyze products (technicians and engineers); and perform basic investigations into materials and processes (research scientists). All are necessary and all have shortages of qualified personnel—but the greatest need is for technicians where manufacturers are focusing their resources on productivity by increasing automation and decreasing labor and/or implementing new materials and processes. Investment in intellectual capital is a priority for the industries that survive global competition and continue manufacturing operations in the US. The Center will substantially improve the return on this investment.

The American Welding Society (AWS) partnered with the Edison Welding Institute, US Department of Commerce, and US Department of Defense in sponsoring a comprehensive independent survey on the economic importance of welding to the US economy (ref.1, available online). This survey was sent to 5848 companies in seven industry sectors including automotive, aircraft & aerospace, electronics & medical, light industrial manufacturing, heavy industrial manufacturing, construction, and capitalized repair and maintenance (mining, et.al.) with 2218 responses distributed fairly evenly over these sectors. Major findings relevant to education include "labor represents more than 70% of total costs"; "industry experts reported that the need for qualified welders extends to all welding related professions, including technicians and engineers"; "over 50% listed a shortage of qualified personnel as limiting productivity"; "nearly one-half of establishments studied reported that their welding-related training needs were not being adequately met"; and "improved educational opportunities" to facilitate automation, better product design, improved quality control, and continued development of standards, assessment, and certification were critical to productivity improvement. Survey data leading to these findings were analyzed for each industry sector. Needs assessed in this 2002 survey are more likely to have increased in the last four years than not, since there has been no national response to the problems highlighted and, reported separately, the welding workforce is continuing to age with an average age of 54 (ref. 5).

Personnel Shortages: The AWS "Welding Shortage Fact Sheet" (ref. 5) compiled additional data on the shortage of welding personnel at all levels. "According to the U.S. Department of Labor's Bureau of Labor Statistics (BLS) (ref.6), there will be nearly 450,000 welding jobs available in 2014. Although this is approximately the size of the current workforce, the average welder is in their mid-fifties and many of these people will retire within the next 10 years, creating a tremendous need for skilled and experienced workers to replace them. The BLS also projects that the annual growth rate of workers 55 and older will be four times that of the overall labor force through 2014. It is therefore not surprising that according to the U.S. Department of Labor's Occupational Outlook Handbook for 2006-07 (ref. 6), job prospects in the field of welding should be excellent as employers report difficulty finding enough qualified people. According to the article, '*Change Creates Opportunity,'* published in the summer of 2006 in the Hobart Institute of Technology newsletter (ref. 7), '25,000 students will begin their welding careers this year while 50,000 experienced welders are expected to retire'. One difficulty in performing a quantified needs assessment is lack of relevant data, such as that collected by BLS, on the number of open jobs (welding technicians in this case). A recent National Association of Manufacturers (NAM) survey (ref. 8) indicated 83% of the manufacturing sector listed education and training as a factor limiting their current and future ability to compete. Manufacturers will need as many as 14 million new skilled workers by 2020, in part to replace the aging baby boomers that make up nearly half of manufacturing jobs today. According to the National Tooling and Machining Association, 40% of member companies are turning

away business due to lack of skilled welders."

An excellent summary article "Where Have All the Welders Gone, As Manufacturing and Repair Boom?" appeared in the Wall Street Journal August 15, 2006 (ref. 9 and Appendix B). This article offers short case reports on the shortage of welding personnel from the trades to engineers covering a broad assortment of industry sectors (400 ton mining trucks to fabricating French fry baskets) and geographical locations. Premium wages, benefits, and even signing bonuses are cited as evidence of the competition for skilled employees. Note that regional partner Ferris State University was a quoted source for this article.

Skills Gap: A "Manufacturer's Survey" (ref. 10 and Appendix C) provides skills gap information for welders, welding technicians, and welding engineers. For technicians, the top five problem areas were metallurgical knowledge (41%), writing skills (37%), welding process knowledge (30%), problem solving skills (25%), and testing (24%).

A survey performed by the Consortium for Alabama Regional Center for Automotive Manufacturing (CARCAM - 0501328) indicated that welding and robotics was important to the automotive industry (ref. 11), which is in agreement with the economic impact survey (ref.1). "Must have" areas included various aspects of robotics/automation, welding techniques, materials, and safety practices. This survey also included many other "must have" employability skills such as "work ethics, basic job skills, and mathematical skills".

The Ohio Department of Education and Ohio's Project Lead the Way (PLTW) affiliate (ref. 12) has developed "Emerging Engineering Technologies—Technical Competency Profile (TCP) (2005), which lists "Materials Joining Technology" and "Computer Integrated Manufacturing" (i.e. robotics) as two out of the seven TCP's. These profiles are an excellent resource for curriculum development and are based on extensive industrial needs assessment.

PLTW is a national organization that has created a sequence of courses, which are delivered in high school, and, when combined with college preparatory mathematics and science courses, prepares students for eventual careers in engineering and engineering technology. Upon completion of these PLTW courses, students are better prepared for the demands of engineering and engineering technology programs at various colleges and universities. PLTW is implemented on a state-by-state basis usually through a statewide career and technical education program. An important feature of the PLTW program is the teacher-training model that is associated with each PLTW course, including elective courses. Every educator teaching a PLTW course is required to attend the two-week training module for the specific course they will be teaching.

Education Needs: The "Educator's Survey" (ref. 2 and Appendix D) indicates that college faculty would offer new courses in automated/robotic processes, laser welding, fabrication layout and design, specifications/codes/standards, advanced materials, and other topics identified as important to productivity increases if educational materials were made available. Secondary instructors indicated similar needs.

In terms of numbers of students impacted, there are 608 schools, secondary, and community colleges, registered in the AWS Schools Excelling through National Skills Education (SENSE) program. In the web search done by the AWS Education Committee in 2003, 604 "other" schools were identified as candidates. Given that some schools were unavoidably missed, at least 1200 schools offering secondary and community college level programs is a conservative estimate. AWS estimates that on average, each school will have 20 students in the welding program and 1.5 faculty members. AWS also estimates that 20% of the schools will offer an undergraduate program. Therefore, it is estimated that 24,000 welding students of which 19,200 are pre-college and 4800 are in undergraduate programs will be potentially impacted by the work in this grant proposal. In addition, 1800 faculty of which 1440 are pre-college teachers and 360 are college faculty will also benefit. An estimate of 50-100 graduate students being impacted is also realistic.

Student Needs: An indication of student career goals is provided in the "Educators Survey" (ref.2 and Appendix D), which documents that most of the new courses instructors would teach if they had the resources are in the area defined by the technician job description. It is believed that individual faculty members have a very good understanding of student needs and this understanding reflects their need for

new educational materials. Students educated in a contemporary curriculum will be much more employable.

Professional Development: It is of the utmost importance that the National Center for Welding Education and Training (NCWET) provides professional development opportunities for teachers, instructors, professors, and facilitators of welding and related education. Faculty capabilities have a direct effect on availability and quality of personnel entering the workforce. In considering the professional development needs of educators, the program will address training, licensure, and the enhancement of resources for educators in carrying out their role in secondary, post secondary and private technical welding education. Currently, there are not enough applicable and affordable professional development opportunities for welding educators to meet increasing requirements.

Federal and state mandates requiring accreditation of programs and certification of teaching faculty to industry standards are increasing. The welding industry cannot rely on self-motivation of educators alone to meet new standards and incorporate an increased emphasis on science, technology, engineering, and math (STEM) into traditional vocational and technical education courses. Typically, instructors rely on their trade experience to guide them in their role as instructors with little opportunity to shape this experience into a well-defined array of pedagogical skills. This dependence on trade experience, while insufficient, is even less available to women and minorities entering non-traditional roles of education.

Helping instructors meet new skills criteria is a priority goal of the Center and will include instruction that improves the effectiveness of teaching while enhancing technical skills and exposure to new and improved technology. The implementation of this program will upgrade faculty capabilities and eventually decrease the shortage of skilled labor in the United States. It will indirectly improve the image of welding and related manufacturing skills as a viable career and improve student recruitment. A synchronized nationwide effort, using regional partner colleges, will standardize welding and related program objectives in career and technical skills education.

Summary: Extensive survey findings that benchmark a large cross-section of US industry indicate the current state of welding education is uneven in scope, quality, ability to recruit students, and geographic distribution as the best programs are not necessarily located close to the industries that need the personnel. There is a significant need for progressively more skilled welding personnel at all levels for the foreseeable future. A national center that actively recruits more students into the field will solve the skills gap issue if the students are educated in programs that follow the curricula developed in the Lorain County Community College (LCCC) – The Ohio State University (OSU) grant and the tenets of PLTW. These educational needs, unless addressed soon, lead to practical limits on productivity improvements and competitiveness of US manufacturers. Generally, the only case where industry is getting properly trained personnel is the one in which they make substantial investment in the local community college or an in-house school using educational consultants or contractors. Small business cannot compete well in this arena.

The foregoing survey findings indicate reform of welding technician education is just as important as any other manufacturing discipline and is needed by the entire manufacturing enterprise in the US. PLTW and results from the LCCC-OSU NSF ATE grant (NSF 0302792 & 0302803) provide the curricular foundation to launch this reform. The number and quality of technicians will also benefit from the application of national capabilities and resources to national problems, which previously have been addressed locally with attending limits in capabilities and resources. Education reform in welding is specifically addressed by implementing national skill standards, including the AWS Certified Welding Educator, (ref. 13) and Manufacturing Skills Standards Council (MSSC) assessments (ref. 14); the tenets of PLTW to insure students are prepared for college; collaboration with the National Association of Workforce Boards (NAWB) to reach the 652 “One-Stop Centers” funded by the Workforce Investment Act (WIA) for retraining personnel; and facilitating instructor networking and professional development with minimal travel requirements.

Prior Support

LCCC, MVCC, OSU, and AWS received an NSF-ATE planning grant (NSF 0402242 for $70,000) on July 1, 2004 to plan a National Center of Excellence for Welding Education. The partners collected compiled, and reviewed extensive survey results, formed a Center Advisory Board (CAB) from stakeholders in industry, education (including two other ATE centers), and the government, conducted teleconferences, and produced the plan set forth here. The project will culminate in a final proposal for an ATE Center of Excellence by October 12, 2006 and a final report to NSF by December 31, 2006. Other than this proposal, there are no publications to date. Survey data from AWS, NAM, and others are available.

LCCC and OSU received a collaborative NSF-ATE project (NSF 0302792 and 0302803 for $256,274 & $238,357, respectively) on "Collaborative project for the preparation of the 21st Century Welding and Materials Joining Technician" with a period of July 1, 2003 to June 30, 2007. LCCC and OSU began collaboration on this project to improve educational opportunities for technicians in the welding / materials joining field. This project is the initial step towards addressing educational curriculum, materials, and learning opportunities for both students and educators.

In the past two years, this project has met its goals and produced a modular curriculum that focuses on the topics commonly associated with standard arc welding processes as well as associated topics such as metallurgy, physics of welding, heat flow, design, materials testing, and safety. The Ohio Department of Education supported this curriculum through its Tech Prep efforts and it was made available to secondary schools as an elective course in Ohio's PLTW program. Efforts are underway to receive permission from National PLTW headquarters to allow other states to also use this same curriculum as an elective course in their respective state's PLTW program. In keeping with the PLTW model, there is a required two-week teacher training module (professional development) for this welding / materials joining curriculum. In the training module, educators learn about the specifics of the curriculum as well as how to best utilize the technological components of the curriculum in the most beneficial manner. In the summer of 2006, the program graduated its first teachers from the teacher-training module. These educators are now educating thirty students on the concepts included in this curriculum. The same curriculum and training is available to community college instructors for use in their programs as well. Currently, there are several colleges that are investigating the applicability of the course to their programs. Development and implementation of this curriculum is a direct indication of the quality of the work.

In addition to this curriculum, supplementary materials have been created to assist in the recruitment of students from all potential sources including women, minorities, and persons with disabilities. These materials describe the industry as a whole, working conditions, personal attributes required of those in the industry, typical position descriptions, pay rates, employment figures, and other information necessary to assist individuals with career decisions.

The activities of this project are showing positive feedback that underrepresented populations are being exposed to the welding / materials joining field. At LCCC, over 30 middle school aged girls have participated in an activity that introduces them to welding / materials joining concepts. These girls learn how to use copper sheet and brazing rod to create a rose. They have expressed great interest and excitement that they can make an attractive piece of art from ordinary materials.

Publications to date: "Welding - trade or profession" C.E. Albright and Kenneth Smith – ACTE Techniques March 2006, pg. 38. Numerous presentations related to the work of the grant have been made. These include 2004 Welding Educators Conference, 2004 NSF-ATE PI conference, 2005 NSF-ATE PI conference, 2005 Ohio PLTW Conference, 2005 Ohio Association of Two Year Colleges (OAYTC) Conference, 2005 AWS National Show, 2005 Association of Career and Technical Education (ACTE) national conference, 2006 National TechPrep Conference, and several local AWS section meetings.

Among the research products that have been created include survey data of educators regarding their needs and comments on existing teaching challenges; and survey data from industry personnel regarding feedback on the utilization and effectiveness of welders, welding technicians, and welding engineers.

Thus far, the following are statistics on the numbers of educators, guidance counselors, students, and other interested parties who have expressed interest in the work of the project:

- Secondary and post-secondary educators surveyed about their perspective of the status of welding education, quality of existing curricula and materials, their educational needs, and problems they see in educating students – 300
- Welding professionals in the manufacturing setting surveyed about the effectiveness of existing welders, welding technicians, and welding engineers; what they see as strengths in these individuals; weaknesses; and do they perceive adding new technology that would require these individuals to seek out professional development seminars on this technology – 730
- Number of community college and university faculty throughout the country informed of the work of the project and it's deliverables – 5000+
  - Number of these individuals responding directly to the PI for more information – 30
- Number of hits to the www.weldingedu.com web site:
  - 2005 - 750
  - 2006 ≈ 500
- At the 2005 Ohio PLTW conference, the number of Ohio educators and guidance counselors directly exposed to the curriculum and what the field of welding / materials joining is really like – 150
- Number of educators participating in various summer workshops thus far - 24
- Number of educators expressing interest in training thus far – 32
- Number of educators actually trained and now implementing the curriculum presently – 2
- Number of students participating in welding experience exercises – 28

Other previously funded NSF projects include one at Portland Community College (PCC). Several years ago PCC was awarded a grant to develop welding seven courses to train individuals transitioning between careers. When approached by the planning grant team to participate as a regional partner in the NCWET, they declined. PCC did however share with the planning grant team some information regarding the "Women of the Arc" program they implemented specifically for women in the field of welding. This program has ceased to exist however the information shared by them can be used in the efforts of the Center.

What is a Welding Technician?

According to AWS B5.6: 200X, "AWS Specification for Qualification of Welding Technicians" (ref. 15), "a welding technician is a person with the ability to weld and understand and apply welding and related technologies including design, materials, processes, quality and economic considerations. The welding technician either prepares or reviews written instructions for the production of weldments. The welding technician must be thoroughly familiar with various codes, standards, specifications, base materials, filler materials, heat treatment, mechanical properties, welding processes and procedures, welding equipment, inspection methods, acceptance standards, tests, welding qualification requirements, fabrication tolerances, and other aspects of fabrication and assembly with which the welding technician may be involved. The welding technician shall also prepare and produce reports, which reflect professional judgments. For the welding technician to be effective, the activities performed shall be consistent with specified requirements, technical and ethical principles. The welding technician should be able to work with the engineer, welder, and others involved in the project and appreciate the role of each in the development of weldments." This definition is consistent with BLS Standard Occupation Classification (SOC) code 51-4122 Welding, Soldering, and Brazing Machine Setters, Operators, and Tenders ("set up, operate, or tend welding, soldering, or brazing machines or robots that weld, braze, solder, or heat treat metal products, components, or assemblies. Include workers who operate laser cutters or laser-beam machines") (ref. 4).

Motivating Rationale

The motivation for creating this center is industrial competitiveness—essentially the same as the ATE program goal of producing more science and engineering technicians and PLTW goals of increasing the number and quality of engineers (technicians are often one step on the career pathway to engineer). The need to support national security by providing both civilian and military technicians for rapid response to damaged infrastructure caused by natural or manmade disasters provides additional motivation. Other factors include the need to improve the image of the industry and strengthen student recruitment, particularly of underrepresented groups.

Vision

The Center's vision facilitates education that is driven by industry needs and student career goals through a network of regional partners. The regional partners, in turn, will serve other community colleges and secondary schools that support local industry. "Teaching the teachers" will be a guiding policy. Workshops at convenient regional locations and online courses will be supplemented by national conferences, print media, and web casts, eventually utilizing Internet 2 locally available to the main partners. Instructors will be exposed to state of the art equipment via demonstrations at their institutions where possible; web casts of live demonstrations or simulations; and travel to modern factories where their students will eventually work.

To achieve this vision, the Center will play a major role in increasing manufacturing productivity by leading education reform in welding, creating a culture of life-long learning for students and faculty, and providing for excellent educational opportunities wherever manufacturing chooses to locate. This vision requires articulation between levels to avoid barriers to employee mobility, transfers, or continuing education.

Industry partnerships will be crucial to success of the Center. Industry associations including Welding Equipment Manufacturers Committee (WEMCO), Resistance Welders Manufacturers Association (RWMA), Gases and Welding Distributors Association (GAWDA), and National Council for Advanced Manufacturing (NACFAM) have committed staff to represent their needs on the Center Advisory Board (CAB) and logistical support in industry surveys. Their membership represents a broad and crosscutting slice of manufacturing. These associations will also provide a forum for the NCWET to publicize activities and a market for its products. Their members will utilize contacts at local colleges and persuade them to adopt NCWET educational materials and participate in the professional development program. Major corporations such as Northrop Grumman, Lockheed Martin, Caterpillar, and Mitsubishi will provide similar support and facility tours as part of professional development. Small and medium size businesses such as RoMan Engineering Services and Nelson Stud Welding are especially committed to the NCWET as they have increasing difficulty competing with major corporations for new graduates. Lincoln Electric Company has committed to directly assist train-the-trainer workshops with Lincoln personnel and equipment. Lincoln currently provides direct equipment support to OSU, AWS and several of the regional partner colleges. Finally, the AWS Foundation has committed to seek a new endowment as part of its capital campaign to generate support for NCWET curriculum development, thus ensuring sustainable programs after NSF support ceases. (Please see Appendix F for letters of commitment).

Goals, Objectives, Activities, Deliverables, and Outcomes

A tabular representation of these goals is included in the "Supplementary Docs" section.

Goal 1: Increase the number of welding technicians to meet workforce needs

Objective 1.1: Accurate workforce assessment and forecast
Activities: NCWET will update industry, institutional, and student surveys biennially to insure center activities remain on a critical path that addresses industry skill gaps due to technological or workforce

changes. Technician requirements in different geographical regions will be included. We will maintain direct communication with a broad cross section of industry through industry associations and members of the Center Advisory Board (CAB). Root causes of skill gaps will be determined and provide an opportunity for a fast response. Regional partner colleges will provide data on enrollments, graduates, certifications, recruitment and retention.
Deliverable: Statistically valid biennial workforce assessment
Outcome: Increased welding technicians available to industry

Objective 1.2: Improve existing welding technology associate degree programs located near employment opportunities
Activities: The Center will market improved curricula and meet with stakeholders such as community college deans and workforce boards to discuss the job market for welding technicians in their area. We will also encourage them to adopt the Center's educational materials and utilize our professional development program.
Deliverables: Geographic assessment of existing programs; benchmark for improved curriculum
Outcome: Improved results of benchmark assessments of welding programs; adopted usage of NCWET curricula

Objective 1.3: Increase effectiveness of student recruitment
Activities: A broad spectrum of outreach activities will be conducted including career fairs, meetings with guidance counselors, web site presentations, and collaboration with other ATE centers. The Center will also utilize the best practices of ATE centers documented by the Evaluation Center at Western Michigan University (ref. 16) and the "Recruiting Toolkit" offered on the NSF-AACC "Pathways to Technology" web site (ref. 17). NCWET will conduct industry and trade union led workshops at the various regional partner facilities targeted at attracting industrial partners into scholarship, internship, apprenticeship, and job placement opportunities for students. By making industry a partner in education, they will gain confidence and be able to support the schools in pursuit of graduates to fill the projected vacancies.
Deliverables: baseline enrollment and graduation demographics report; recruitment plan by student population demographics; marketing plan
Outcome: Increased enrollment in welding technician programs and graduation of welding technicians

Objective 1.4: Significantly increase workforce diversity
Activities: In keeping with the goals of NSF, the Center will focus a great deal of time and attention towards issues related to the recruitment and retention of women, minorities, and persons with disabilities. Collaboration with associations supporting underrepresented populations will be established to obtain needs and best practices. Efforts will include designing marketing materials appropriate for the audience, i.e. pictures depicting individuals from these demographic groups at work in industry, profiles of successful individuals representing these groups, and multi-lingual materials. Specific facility needs for women and persons with disabilities will be documented. Support systems and networks (counseling, mentoring, professional groups, re-training, child care, and transportation) will be established. Courses that enable the workforce to deal with specific issues (cultural, religious, gender, and humanities) will be developed. Summer camps will be held to recruit students from these groups. Physical limitations preventing persons with disabilities from experiencing a career in welding / materials joining will be mitigated with work stations or equipment designed for wheelchair access. The CAB will be utilized for input and evaluation of these designs. LCCC has experience with addressing the educational and supportive needs of underrepresented populations. Programs such as WomenLink (support services for women), CORE (Creative Opportunities Reaching For Excellence – women and minority support), Micro Enterprise Program (Women's Development Center - access to personal and financial independence through entrepreneurial education, advocacy and support, primarily for economically disadvantaged women), and the Office for Special Needs (resources and assistance for people with disabilities) will serve as models for other institutions and organizations to replicate. The Center will disseminate

information about these services as appropriate. Partnerships will be sought with specific demographic groups with welding programs, such as Esperanza Unida - an organization that provides counseling, representation, job training, and job placement to minority, injured, and unemployed workers in the Milwaukee, WI area (ref. 18). Organizations such as the Society of Women Engineers (SWE), the Society of Black Engineers (SBE) and DO-It (representing the needs of people with disabilities) have been approached to partner with the NCWET to increase recruitment and retention figures in those demographic areas. Additional organizations with similar focus will be approached for maximum impact.
Deliverables: Marketing plan for student recruitment; participation in career fairs; meetings with counselors; plan for increasing workforce diversity; and collaboration with student organizations
Outcome: Increase enrollment and graduation of women, minorities, and people with disabilities

Goal 2: Comprehensive reform of welding education

Objective 2.1: Provide educators a contemporary welding curriculum, including upgraded STEM and other core courses, cataloged and available for dissemination
Activities: NCWET will collect and evaluate curriculum from partners; perform gap analysis with input from CAB and National Visiting Committee (NVC); develop courses to address curriculum gaps; beta test new educational materials in classrooms and labs; and develop forecasts of curriculum needs.
Deliverables: Assessment tool for evaluation of curricula; curricula gap analysis
Outcome: Dissemination of NCWET supported curricula

Objective 2.2: Establish a national network of regional partner institutions
Activities: The Center will negotiate agreements that articulate roles, responsibilities, intellectual property ownership, and remuneration with regional partners named in this proposal.
Deliverables: Regional partner network plan, articulation agreements per regional partner
Outcome: National impact of NCWET with comprehensive regional representation

Objective 2.3: Implement advanced laboratory techniques
Activities: OSU will procure vision equipment and produce dynamic educational materials. Video, DVDs, and/or high-speed photographs that demonstrate process fundamentals will be produced in a form suitable for broad dissemination. A template model for applying advanced technology to instructional courses in which the Center provides research and college faculty design the application parameters will be produced. Instructors will receive assistance in utilizing these materials by organizing forums with other instructors such as the AWS Instructor's Institute. This activity will not only provide faculty with much improved educational materials, it will help them compete for resources and recruit students by demonstrating real education reform.

Broad use of this specific instrumentation for development of educational materials is an original concept in welding technician education and deserves additional discussion as it provides for integration of applied research and associate degree level curriculum. While high-speed photography has been used previously for demonstration purposes, curriculum at all levels needs to be modified with greatly enhanced laboratory learning experiences, including the ability of the student to visualize welding processes and comprehend the scientific basis for procedures. Modern technology can provide that improvement and enhance current teaching methodology. This project will adapt use of a welding vision system, originally used for basic welding and other process research, for development of more informative and interesting educational materials for arc and laser welding processes. High-speed video images are needed so students can visualize and understand effects of arc welding process (machine) settings on weld wire melting, droplet transfer, and weld pool size and fluid motion. An understanding of these effects is critical for process optimization, quality, and troubleshooting. The video images are useful for both qualitative and quantitative analysis. Please see Appendix E for technical details.
Deliverable: Educational materials detailing advanced welding techniques available in various accessible media

Outcome: Demonstrated increased use of advanced welding techniques

Objective 2.4: Provide for efficient and effective dissemination
Activities: NCWET will produce educational materials in common media as soon as materials are complete. The Center will develop advanced web-based dissemination methods utilizing high-speed Internet. Regional partners will play a principal role in dissemination to educational institutions in their region.
Deliverable: Educational materials and laboratory methods in the hands of regional partners
Outcome: Curriculum utilization

Objective 2.5: Creation of a central repository for welding educational materials
Activities: NCWET will create a library, predominantly digital, of all educational materials collected and developed in the program. The Center's web site will be created and maintained as appropriate. The Center will collaborate with national digital libraries funded by NSF as needed.
Deliverable: Central repository
Outcome: Educators accessing materials for use; clearinghouse for welding education information

Objective 2.6: Infuse national skill standards into curriculum and professional development
Activities: The Center will utilize the MSSC certifications for general manufacturing foundational skills (ref.14), AWS SENSE (ref. 19) for basic, advanced, and expert skills in welding, AWS Certified Robotic Arc Welding Technician (CRAW) (ref.20), and AWS B5.6:200X Welding Technician Qualification Standard (ref.15) in curriculum development. The latter standard will require five years of experience in technician related duties. A two-year associate degree may be substituted for two years of experience.
Deliverable: Faculty certification to national standards
Outcome: Increase numbers of certifications awarded to educators

Goal 3: Enhanced faculty professional development and continuing education

Objective 3.1: Develop faculty professional development courses and materials and disseminate to regional partner organizations
Activities: NCWET will develop course materials and organize equipment/application demonstrations for presentation in workshops. The Center, with assistance from Lincoln Electric Co. will conduct a series of summer train-the-trainer workshops at regional partner facilities targeting faculty training to specified certification levels and standards. Industry application needs (both current and evolving) will be featured. These workshops will also disseminate current information on new concepts in technology education as well as relevant government initiatives and legislation.
Deliverables: Professional development plan; curriculum; course materials
Outcome: Educational course materials available through all regional partners

Objective 3.2: Conduct Faculty Training and Continuing Education through Regional Partners
Activities: The Center will develop a welding educator workshop that can be delivered at a regional partner facility in the form of a three day seminar, as an online course, or as a comprehensive self study program to enhance welding instructor pedagogical skills and obtain a nationally recognized technical teaching licensure.
Deliverable: Faculty offered annual professional development workshops at convenient locations, consistent with Standards for Technological Literacy (ref. *Standards for Technological Literacy: Content for the Study of Technology* (*STL*) (ITEA, 2000/2002; http://www.iteawww.org) (ref. 21)
Outcomes: Ongoing training and development of faculty

Objective 3.3: Enable technologically current faculties
Activities: NCWET will develop externship opportunities for faculty who have completed a summer workshop series and seek to obtain industrial experience structured to specific industries and applications; organize demonstrations of the latest welding technology at regional partner campuses or in industry for non-portable equipment
Deliverable: Faculty trained and certified to current manufacturing technology; initiate faculty externship program
Outcome: Continuing certification and awareness of contemporary manufacturing technology

Objective 3.4: Utilize the AWS Welding Show educational program and establish a long-range plan for professional development activities
Activities: NCWET will conduct an annual national conference in conjunction with the AWS Show. In year 1, it will feature general topics in welding education and NCWET activities. In year 2, the program will provide a best practices curriculum symposium with faculty sharing curricula, laboratory equipment, and teaching methodology. In year 3, it will provide faculty a symposium covering emerging issues, the latest trends in the science and technology of welding, and both current and emerging industry needs. In year 4, the conference will provide a workshop format with breakout sessions on relevant topics for future conferences and long-term Center planning. Travel will be provided to regional partners.
Deliverable: Presentations by engineers, scientists, technologists, managers, and educators to assist in development of faculty expertise and continuous improvement; continuing education courses relevant to industry skills standards
Outcome: National education conference for educators

Project Timeline
The activities timeline is located on the last page of the narrative.

Major Partners
LCCC and OSU, both in Ohio, are collaborating on a current NSF grant (0302792 & 0302803) to develop a curricular model that can be emulated by other two-year colleges for the training of welding technicians and OSU has the largest and oldest ABET accredited welding engineering program in the country. Moraine Valley Community College (MVCC) in Illinois is a leading community college in the Chicago area with a recognized welding program and performs unrelated work on other NSF grants. AWS serves as the leading international professional society for welding and related processes. AWS provides members the services one would normally expect from a large professional society (~50,000 members) such as conferences and publication capabilities for educational materials, technical journals, handbooks, and textbooks. LCCC, MVCC, and OSU have the curriculum development and educational materials expertise to provide the intellectual foundation for the center. AWS drives national skill and manufacturing standards and their Education Committee represents an ideal network of educators for collection and dissemination of educational materials.

These four partners, along with other individuals mentioned later, will form the Center Board of Directors (CBD) whose role is to guide the center toward its intended functions. The CBD will receive advice and guidance from a Center Advisory Board (CAB) with members representing regional partner educational institutions and industry members from the planning grant (see Management Plan). Collectively, the CBD and CAB groups have the desire, commitment, and capability to create and operate the NCWET that both forecasts and meets the educational needs of industry.

Regional partner roles

Regional partners will represent NCWET in their respective regions by marketing and distributing educational and promotional materials; recruiting students including outreach to underrepresented groups; organize new technology demonstrations developed by the Center; and teach customized courses to industry (on request). Furthermore, the regional partners will provide advice to the CBD through teleconferences, meetings, and document review; collect and provide industry needs and student data in support of surveys; conduct professional development program for colleges in region using center supplied materials; conduct continuing education program for industries in region (on request); utilize center educational materials; provide curriculum to center; and perform relevant certification examinations after qualifying as an AWS Certified Test Lab (optional).

Regional Partner Institutions & Principal Faculty Member

Northwest:	Walla Walla Community College; Michael Haggard
West Coast:	College of the Canyons; Jack Compton
Intermountain West:	Weber State University; Mark Baugh
Southwest:	Texas State Technical College; Frank Wilkins
Midwest:	Milwaukee Area Technical College; Larry Gross
Northeast:	Pennsylvania College of Technology; Donald Praster
Mid-Atlantic:	Chattanooga State University; Jack Sample
Southeast:	Yet to be determined

(Please see Appendix F for a synopsis on these institutions and their faculty members.)

NCWET Collaboration with other ATE centers

Mr. Dale Cox at the Consortium for Alabama Regional Center for Automotive Manufacturing (CARCAM) has expressed interest in having the NCWET provide welding / materials joining curricula specifically tailored for their automotive workforce. NCWET will also partner with the Center for Nondestructive Evaluation and The Nondestructive Testing Resource Center (NDT) www.ndt-ed.org (NSF-ATE) for information on nondestructive testing and evaluation of materials. NCWET will provide links to the NDT web site so educators can locate necessary information and will encourage educators to utilize their materials and services. The NDT center will reciprocate with similar links to NCWET. The Center will partner with Edmonds Community College and their Mat-Ed Resource Center (NSF-ATE) to help educators locate materials in materials science topics. The National Center for Manufacturing Education (NCME) and its MERC online feature will be a source for educators to locate various NCWET materials. Other NSF supported centers that have been contacted about the creation of partnerships include New Jersey Center for Advanced Technological Education (NJCATE) and the National Aerospace Technical Education Center (SpaceTEC). Letters of commitment are included in the "Supplementary Docs" section.

Management Plan

The grant PI, Mr. Ken Smith, will be directly in charge of the grant and project as required by NSF, and will serve as the Project Director (PD). He will interface directly with NSF and the NVC. Along with staff members provided by the project, he will manage the Center on a day-to-day basis, carrying out the goals and objectives as prescribed by the grant. As the main host college, LCCC will serve as the fiscal agent. A Center Board of Directors (CBD), consisting of Co-PI's and other named senior personnel from partner organizations, will assist the PI/Project Director in oversight of the project. Management of the Center will utilize a Center Advisory Board (CAB) with many of the same members that advised the planning grant. The current planning grant CAB members are:

Dr. Nancy Carlson	AWS Board of Directors and Chair, AWS National Education

	Scholarship Committee, Idaho National Laboratory (ret.)
Mr. Scott Chapple	Consultant and former AWS Board of Directors (training & education expertise)
Dr. Mert Flemings	Professor Emeritus, MIT; formerly director of MIT-Singapore Project, a $100M project to provide synchronous Internet 2 web casts of the MIT materials science curriculum to two Singapore universities.
Mr. Kurt Hofman	President, RoMan Engineering Services
Mr. Jesse Hunter	Senior Staff Engineer, Mitsubishi, AWS Board of Directors, and Vice Chair, AWS Education Committee
Ms Joanna Kile	Director, CAPT (ATE Process Technology Center); general advice on ATE Center management
Mr. Dennis Klingman	Director, Lincoln Electric Welding School and Chair, AWS Education Committee
Mr. Lee Kvidahl	Sector Manager Welding Engineering, Northrop-Grumman (ship building); AWS past president
Mr. Ernest Levert	Senior Staff Manufacturing Engineer, Lockheed Martin; AWS past president; Federation of Materials Societies president-elect; recipient of Lockheed Martin outstanding Black engineer award
Ms Elizabeth Miles	Division Manager, Advanced Production Technology, Caterpillar
Ms LeeSa Page	Executive Director, National Council for Advanced Manufacturing (NACFAM)
Ms Monica Pfarr	Director, NCME ATE center
Mr. Oren Reich	Texas State Technical College welding faculty (retired) and AWS Board of Directors
Dr. Herschel Smartt	Fellow Scientist, Idaho National Laboratory (Department of Energy); Chair AWS Welding Research and Development Committee
Staff Sergeant Adlene Wilks	United States Marine Corps; Training and Education Ground Ordnance Maintenance Center of Excellence
Mr. Dean Wilson	President, Wilson Industries and Past Chair, AWS Welding Equipment Manufacturers Committee

Roles and Responsibilities of Co-PI and Senior Personnel

Kelly Zelesnik – Co-PI, a faculty member at LCCC, will assist in the overall management of the center and guide activities focused on women, minorities, and people with disabilities.

James F. Key, Ph.D. – Co-PI, former president of AWS and the Federation of Materials Societies (FMS), will provide guidance on strategic planning and industry collaboration, develop other funding sources for the Center, and utilize an extensive network of contacts to publicize, market, and support the Center.

Professor Charles Albright (OSU) – Co-PI, will focus on curriculum articulation with engineering degree programs at OSU and provide curriculum assistance in advanced welding process technology.

Richard DePue (AWS) – Co-PI, will be responsible for the professional development task making use of AWS' infrastructure of publications, conferences, and committees. He will also support dissemination and adoption of national skill standards utilizing this infrastructure.

Professor David Dickinson (OSU) - senior personnel, AWS past president, is generally responsible for curriculum. He will oversee the training of instructors in course material and teaching techniques to assure instruction requirements are met, continue course improvements in currently available courses (particularly in the use of virtual laboratories), continue development of course content in technician and engineering programs, and will provide liaison with the national Project Lead The Way.

Professor James Greer (MVCC) – Co-PI, AWS past president, will provide curriculum consultation and focus on reform in laboratory courses utilizing high-speed vision systems and simulation.

Professor Dave Farson (OSU) - senior personnel, will develop high-speed vision systems to supplement curricula and supervise a graduate student who will apply advanced vision systems to reform of laboratory instruction.

Plan for Sustainability

A sustainable business model (plan) requires the following elements at a minimum: 1) educational products that anticipate technological change; 2) rapid dissemination and instructor professional development; and 3) a cash flow philosophy based on increased use of center products rather than increased unit cost. There is a definite international market for these products that will be tapped once effective operations in the US are established. AWS has standards translated into Spanish by a sister society in Spain. NSF has funded Internet 2 lines to countries served by AWS. Much of the expensive infrastructure is in place to provide the center a global reach, thus providing additional means to amortize development and operating costs. Finally, the AWS Foundation has committed to seek a new endowment as part of its capital campaign to generate support for NCWET curriculum development, thus ensuring sustainable programs after NSF support ceases.

Project evaluation

The Center Advisory Board (listed above) will provide general advice and oversight to the project. The committee will meet as required the first year and at least annually during the second, third and fourth years to advise the Center management team. The Center will use both internal and external evaluators. The external evaluator will interface with the National Visiting Committee to provide an annual formal assessment of progress with respect to plans and guidance for the following year. Together, these advisors will provide Center management and PIs with experience-based recommendations that will insure successful operations. The external evaluator will also update the evaluation design and specifics, develop/adapt the needed instrumentation, and manage data security and analyses. Evaluation will involve both formative and summative evaluation methodologies using NSF handbooks and best practices guidelines.

Evaluation plan

To adequately evaluate the success of the Center, the PD, and Co-PIs, will measure the progress of each goal and objective both during the project and at its end. The evaluation plan will follow the criteria established and guidelines set for planning, formative, and summative evaluation in the NSF "User-Friendly Handbook for Project Evaluation: Science, Mathematics, Engineering and Technology Education".

Together, the internal and external evaluators will evolve the evaluation design and specifics, develop/adapt the needed instrumentation, and manage data security and analyses. The internal evaluator – The Public Services Institute, affiliated with LCCC, will be responsible for data collection, analysis, and writing formative evaluation reports. The external evaluator—Dr. Richard Hinckley, Executive Director of The National Coalition of Advanced Technology Centers (NCATC), will be responsible for overall summative evaluation. Dr. Hinckley will review data collected, documents and work products, and will use a protocol to interview staff, customers, students, and partners. The NCATC is a network of 150 institutions of higher education that advocates and promotes the use of technology applications that enhance economic and workforce development programs and services. The Coalition provides professional evaluation services to other NSF ATE projects. Dr. Hinckley will coordinate the evaluation and use faculty and administrators from member colleges to conduct the evaluation site visits to LCCC, OSU, other partner institutions, and write evaluation reports.

Project goals, objectives, and activities will be measured on three levels: 1. Operation/Processes - this will be a formative ongoing review of activities implemented to achieve each of the goals and outcomes associated with the Center, addressing whether or not planned procedures were carried out. 2. Outcomes - this evaluation will measure project outcomes to determine if planned products were actually

produced and to assess their quality. 3. Impact - this evaluation will examine the goals and actual outcomes and analyze the discrepancies.

Evaluation will involve the components of planning, formative, and summative methodologies. First, planning evaluation will be conducted to assess partner understanding of the project goals, objectives, activities, and timelines. This will take place in the first month of the Center's funding. Second, formative evaluation will assess and assist in steering the project implementation, including its operations and processes. This will take place quarterly with reports forwarded to the external evaluator for review and consultation as needed. Third, summative evaluation will be used to assess the project outcomes and impact. NCATC will compile all evaluation data annually and reports will combine both formative and summative evaluation data.

Instruments for each evaluation level and type will be developed using the examples in the evaluation handbook. In all cases, appropriate methods of data collection will be utilized, including focus groups, survey instruments, test results, and personal testimony. Results of evaluation will be reported to the PI for transmittal to the NVC and NSF as appropriate.

National Visiting Committee (NVC)

As required by NSF, the following is a listed of proposed individuals for NVC membership:

Professor John Lippold	Ohio State University; Department Chair
Professor Yoni Adoni	LeTourneau University; Welding Engineering
Professor Dave Olson	Colorado School of Mines; Welding Metallurgy
Dr. Angie Price	Texas A&M University; Welding Engineering
Professor George Cook	Vanderbilt University; Automation
Mr. Dennis Blunier	Caterpillar (retired); Heavy Manufacturing
Mr. Denis Clark	Idaho National Laboratory; Chair AWS Safety and Health Committee and active in education
Mr. Harvey Castner	Edison Welding Institute, Vice President, Government Programs Office
Mr. John Mendoza	CPS Energy; AWS Board of Directors and active in Hispanic education in the southwest

Dissemination Plan

In addition to dissemination activities described in the Goals section, the Center will develop and support accessible website repositories of curricula. The Center will collaborate with ATE Resource Centers, mentioned previously, to increase availability of educational materials. It will solicit, research, document, and write articles on best practices in welding and related processes for publication and use at conferences and workshops including those of the American Welding Society, the American Association of Community Colleges (AACC), and affiliated professional groups in secondary and postsecondary education. The Center will seek out and publish articles on models of excellence in education and training in both academic and industrial settings. The Center will make full use of the extensive infrastructure of AWS in publications, conferences, instructor institutes, and committees (both education and industry).

Project Timeline

This project timeline provides a quick glance at the activities the Center will undertake and the time frames they will be completed.

Activity	**Year 1**	**Year 2**	**Year 3**	**Year 4**
Recruit and hire staff				
Execute agreements with regional partners (revenue sharing, intellectual property, project assignments/commitments)				
Design and initiate survey of unique needs of underrepresented groups				
Outreach to underrepresented groups & associations				
Collect student data from regional partners				
Design and conduct survey of student career needs				
Update skills gap and workforce needs survey and create database				
Conduct curriculum collection, categorization, and review				
Update design of comprehensive welding, joining, and related processes curriculum based on LCCC-OSU curriculum and existing skills gap survey data				
Plan and implement articulation activities to implement the 2+2+2 model				
Complete comprehensive curriculum that covers welding, joining, and related processes				
Procure equipment and develop advanced vision techniques for improved laboratory demonstrations				
Complete laboratory demos and supplements, i.e. simulations, video, vision systems				
Initiate dissemination of individual courses and beta test delivery methods				
Plan and conduct first phase of general dissemination (workshops and conferences)				
Complete beta test of curriculum disseminated to regional partners				
Complete dissemination of educational materials				
Plan, initiate, and conduct faculty professional development program				
Conduct annual conference on welding education and Center activities				
Identify advances in technology and develop new educational materials				
Design, implement, and maintain internship program				
Complete annual report and meet with National Visiting Committee				