BUDGET JUSTIFICATION

Using continuation pages if necessary, describe the specific functions of the personnel and consultants. Read the instructio all costs requested.

The key PSI participants are: R. Scheer, Principle Investigator. Dr. Scheer is the scientist on the Lableless Lab™ product line, a series of experimental kits for university lev which do not have a regular laboratory component. The Lableless Lab™ product line will als important in science and technology telecourses and in the so-called virtual university develo

Dr. Sheer will be assisted by R. Van Wagenen, who has considerable experience in optically-based instrumentation and will work principally on the art approach to interest base

Dr. Phil Triolo is an accomplished jazz musician, as well as a biomedical engineer, interdisciplinary experience and interests. He will work principally on the music-based scienc

All three individuals have a strong background in the biological sciences and, worki with the University of Utah team, will develop the strong biological sciences connection, wh major goal of this project.

The University of Utah effort will be led by J. Andrade, Co-Director for the Universit for Integrated Science Education and Program Co-Chair for the Utah Science/Art Center proj unique Leonardo on Wheels Project. Joe has worked for the past four years with elementar throughout the state of Utah and developed a set of unique biological science teaching mater on bioluminescence and marine phytoplankton. He is a bioengineer with nearly 30 years of e and a wide range of areas dealing with medical devices, diagnostic products and biosensors.

He will be assisted by Mr. Paul Dryden, Mary McDonald, the Staff Director of the Integrated Science Education, who is obtaining a degree in Informal Science Educati University of Utah, and Melinda Steadman, who is completing her bachelor studies in Hi Italian, and has a strong personal interest and experience in Leonardo da Vinci and his contri art and technology. Mr. James Biggs, a Bioengineering graduate student, and an accomplishe and artist in his own right, manages the University's unique Leonardo Laboratory, the facilit many of the studies proposed will be carried out and the implementations tested and evaluated

RESOURCES AND ENVIRONMENT

1. FACILTIES: Describe the facilities to be used and briefly indicate their capacities, pertinent capabilities, relative proximit of availability to the project. Include laboratory, clinical, animal, computer, and office facilities at the applicant organizati performance site listed on the FACE PAGE, and at sites for field studies. Using continuation pages if necessary, include of any consortium arrangements with other organizations.

PSI has 1,200 square feet of research space at 350 West 800 North, Suite 218, Salt L Utah 84103-1441. Laboratory, computer, and office facilities are adequate for the work propo is a member of the Center for Biopolymers at Interfaces at the University of State/University/Industry consortium, and as a member has access to specialized laborat equipment at the University. The equipment is available on a fee for service basis.

2. MAJOR EQUIPMENT: List the most important equipment items already available for for this project, noting the location capabilities of each.

Computer, incubator, optical microscope, plasma glow discharge apparatus, necessary is available at PSI's facility. SEM and SPS services are to be provided through the Universit where a goniometer is available for contact angle measurements.

3. ADDITIONAL INFORMATION: Provide any other information describing the environment for the project. Identify support as consultants, secretarial, machine shop, and electronics shop, and the extent to which they will be available to the pro

Surface analysis and SEM are available through the University of Utah.

PRINCIPAL INVESTIGATOR:

ABSTRACT OF RESEARCH PLAN

NAME, ADDRESS, AND TELEPHONE NUMBER OF APPLICANT ORGANIZATION

Protein Solutions, Inc.
350 West 800 North, Suite 218
Salt Lake City, Utah 84103-1441
(801) 596-2675

YEAR FIRM FOUNDED	NO. OF EMPLOYEES *(include all affiliates)*
1988	7

TITLE OF APPLICATION

Science by Seduction -- Education Via Interest-Based Kits.

KEY PROFESSIONAL PERSONNEL ENGAGED ON PROJECT

NAME	POSITION TITLE	ORGANIZATION
R. Scheer	PI - Research Scientist	PSI
P. Triolo	Research Scientist	PSI
J. Andrade	Professor	University of Utah

ABSTRACT OF RESEARCH PLAN: State the application's long-term objectives and specific aims, making reference to the health-relatedness of the project, describe concisely the methodology for achieving these goals, and discuss the potential of the research for technological innovation and commercial application. Avoid summaries of past accomplishments and the use of the first person.

The abstract is meant to serve as a succinct and accurate description of the proposed work when separated from the application. Since abstracts of funded applications may be published by the Federal Government, do not include proprietary information. DO NOT EXCEED 200 WORDS.

"Just as eating against one's will is injurious to the health, so study without a liking for it spoils the memory, and it retains nothing it takes in." This quote is attributed to Leonardo da Vinci, but it is particularly appropriate in modern K-12 science education, and especially at the grade 5-10 range.

Everyone is interested in *some*thing. This is the assumption behind our Science by Seduction approach, pioneered by the Center for Integrated Science Education at the University of Utah, and the basis of several unique and novel courses now offered through its Liberal Education program. Interest-based science via inquiry is also the basis of the Utah Science/Arts Center, a modern science museum/science center now being developed in Salt Lake City.

Protein Solutions, Inc. proposes to work closely with these two entities to assess the feasibility of a set of experimental science kits based on two topics of major interest to the upper elementary/jr. high student population: music and art. An interest-based approach to science facilitates the involvement of the student in topics and activities in which they are already interested and makes it easy and straightforward to increase their interest spectrum and so doing to make them aware of much of the great breadth of science and thereby the opportunities available to them. We will connect their interests to the basic sciences, mathematics, and technology, with particular emphasis on topics relevant to biology and biotechnology.

The kits would be expected to eventually sell in the $45 price range.

Provide key words (8 maximum) to identify the research or technology.

Science Education, Biology Education, Biotechnology Education, Music.

Provide a brief summary of the potential commercial applications of the research.

Hobby and Interest-based science kits are an important component of the multi-billion dollar market for science-based educational products. The marketing strategy and experience for PSI's line of bioluminescent science kits, the Science in the Dark product line, and for its product developments in the Lableess Lab™ area provide an efficient and effective marketing mechanism for hobby and interest-based kits.

Robert J. Scheer
390 Wakara Way, Room 31
Salt Lake City, UT 84112
Ph. (801)585-3128
e-mail (rob.scheer@m.cc.utah.edu)

EDUCATION

Ph.D. in Materials Science and Engineering, September 1993, University of Utah, Salt Lake City, UT. Dissertation emphasis: Mechanical, interfacial, and surface study of composite materials.

B.S. in Mechanical Engineering, 1989, Duke University, Durham, NC. GPA 3.76.
Emphasis: Fracture mechanics and failure analysis of polymeric materials.

UNIVERSITY HONORS

National Science Foundation Fellow,
University of Utah Graduate Research Fellow,
Dean's List Duke University, Academic All American
Duke University Magna Cum Laude,
Scholastic Societies: Tau Beta Pi and Pi Tau Sigma.

COMPUTER SKILLS

Systems: DOS, UNIX
Languages: FORTRAN and True Basic (BASIC).
Software: Autocad, Claris Cad, Excel, and Lotus 123.
Applications (test equipment): MTS, Instron.

EXPERIENCE

Principle Investigator
Protein Solutions, Inc. Salt Lake City, UT. 1994 - present. Directed research for the design and implementation of novel science education materials.

Research Assistant
University of Utah, Salt Lake City, UT. 1989 - 1994. Tested mechanical properties of polymers and composites, studied surfaces and interfaces, tested adhesive bonds on the microscopic scale, and developed stress analyses related to materials testing.

Instructor/Tutor
University of Utah and Salt Lake Community College, Salt Lake City, UT. 1991 - present. Planned, instructed, and graded for undergraduate physical science classes. Served as tutor and teaching assistant.

Engineering Technician
Sandia National Laboratory, Albuquerque, NM. Summer, 1989. Designed engineering experiments for failure analysis of ceramic materials, and extensively researched current experimental techniques for determining material fracture toughness.

Engineering Technician
Sandia National Laboratory, Albuquerque, NM. Summer, 1988. Designed engineering experiments for strength testing of brittle materials, and performed CAD. Interacted with diverse engineering disciplines on a major research project.

AFFILIATIONS

American Society for Mechanical Engineers
ASM International
The Minerals, Metals, and Materials Society
American Physical Society
The Center for Biopolymers at Interfaces

PUBLICATIONS

Scheer, R.J. and J.A. Nairn. "Variational Mechanics Analysis of Stresses and Failure Analysis in Microdrop Debond Specimens." *Composites Engineering*, Vol. 2, No. 8, pp. 641-654, 1992.

Scheer, R.J. Ph.D. Dissertation, "An Energy Based Analysis of Fiber-Matrix Adhesion." University of Utah, 1993.

Andrade, J.D. and R.J. Scheer. "Applying 'Intelligent' Materials for Materials Education: The Lableess Lab™." *Proc., 2nd Annual Conference on Intelligent Materials*, Tech. Publ. Co., 1994, in press.

RESEARCH PLAN

A. Specific Aims:

1) *To assess the interest, motivations, and aptitude of jr. high, high school, and undergraduate students in the general areas of music and art.* This will be accomplished by discussions with instructors and educators in those areas, by assessment of the books and other curriculum materials available, including key periodicals in art and music education, and by discussions with socio-economic experts who systematically assess interests and activities of these age groups. This task is the principle responsibility of the University of Utah Center for Integrated Science Education (CISE), the subcontractor.

2) To review commercial products related to *art and music education, hobbies, and other activities* with respect to their science content, and particularly with reference to biology and biotechnology. This will be done by monitoring of activities and trends in art stores, music stores, hobby stores, museum gift shops, and related outlets. This task will be performed by Protein Solutions, Inc., the major contractor.

3) To establish *the connections and extensions between art and music and the various sciences, particularly the biological sciences,* to identify a set of appropriate books and models with which to establish and expand these connections, including the availability of existing books, kits, and other materials which develop such connections. This task will be accomplished by the Center for Integrated Science Education, University of Utah.

4) Working through the American Association for Museums and the Association of Science and Technology Centers to *establish the role of art and music in science museums* and the role of science (particularly the biological sciences) in art and music museums; use this informal education community to develop expanded and enhanced connections between the various fields. A good example is the Exploratorium, the hands-on science center in San Francisco, which has a small and active art and music program. This task will be accomplished primarily by the Center for Integrated Science Education at the University of Utah in collaboration with the Utah Science/Arts Center and its Leonardo Project.

5) Determine the feasibility of, and begin the development of, *a set of popular experimental music activities* which can begin to develop the connections and extensions with the biological sciences (Figure 1). This will be a joint effort of the Center for Integrated Science Education and Protein Solutions, Inc.

6) Same as above, but with respect to *art and its connections and enhancement with the sciences*. Tasks 5 and 6 will also lean on the connections developed by Leonard Shlain in his remarkable book, *Art and Physics*, which draws the parallels and interconnections between art, music, and the sciences, from the pre-Renaissance to the present. Shlain, incidentally, is a physician (4).

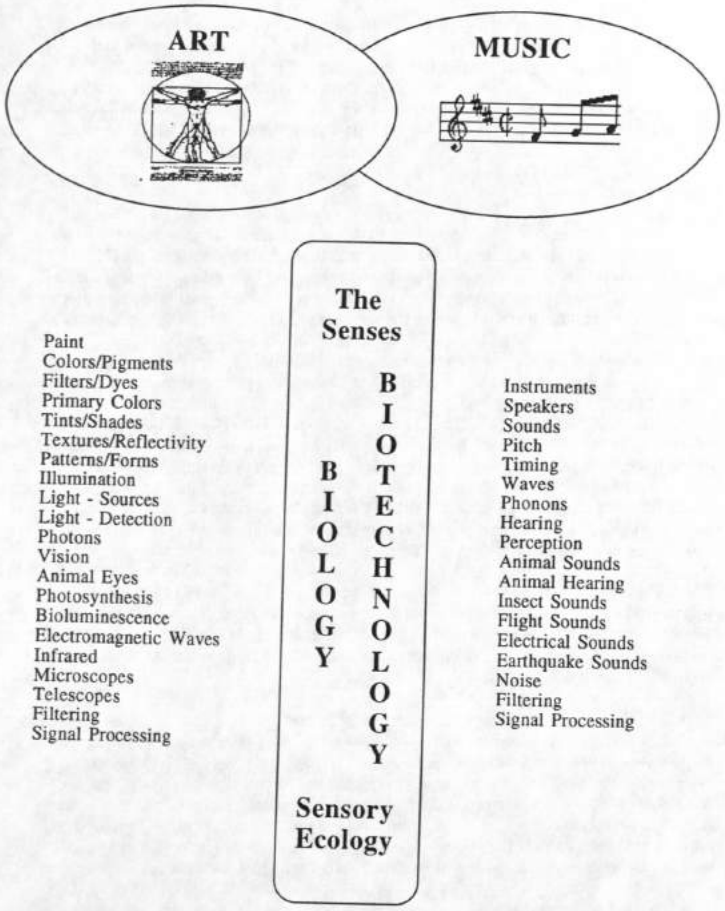

Figure 1: Flow and Connection Diagram for Interest-Based Science Using Art and Music

U.S. Patent 5,135,876, August 4, 1992, "Method and Apparatus for the Regulation of Complex Binding," (J.D. Andrade and J. Herron).

U.S. Patent 4,368,047, January 11, 1983, "Process for Conducting Fluorescence Immunoassays Without Added Labels and Employing Attenuated Internal Reflection," J. D. Andrade, and R. A. VanWagenen, assigned to University of Utah Research Foundation.

Medical and Biological Engineering in the Future of Health Care, J.D. Andrade, ed., University of Utah Press, 1994.

Artificial Organs, J.D. Andrade, et al., eds., VCH Publication, 1987.

Surface and Interfacial Aspects of Biomedical Polymers, Vol. 1 - Surface Chemistry and Physics, Vol. 2 - Protein Adsorption, J. D. Andrade, ed., Plenum Press, 1985.

Hydrogels for Medical and Related Applications, J. D. Andrade, ed., Amer. Chem. Soc. Symp. Series No. 31, (1976).

*"Purification and Preservation of Firefly Luciferases," C.Y. Wang and J.D. Andrade, J. Biolum. Chemilumin. 9 (1994) 336.

*"Air-Water Monolayer Studies of Bioluminescent Enzymes," D.J. Min, C.Y. Wang, J.D. Andrade, J. Biolum. Chemilumin. 9 (1994) 344.

"Proteins at Interfaces: Principles, Problems, and Potential," (J.D. Andrade, V. Hlady, L. Feng, and K. Tingey), chapter in Interfacial Behavior of Bioproducts, J. Brash and P. Wojciechowski, eds., Dekker, 1994, in press.

"Polyethylene Oxide and Protein Resistance: Principles, Problems, and Possibilities," in J.E. Glass ed., Hydrogels, Biocompatible and Biodegradable Polymers and Associating Polymers, Adv. in Chem Series No. ???, Washington D.C. 1994, in press.

"Fibrinogen: Its Structure and Surface Properties," L. Feng and J.D. Andrade, in T. Horbett and J. Brash, eds., Proteins at Interfaces - II, Amer. Chem. Soc. Symp. Series (1995), in press.

"Plasma Protein Adsorption on Model Biomaterial Surfaces," V. Hlady, J.D. Andrade, C-H Ho, L. Feng, K. Tingey, Clin. Materials, 13 (1993) pp. 85-93.

"Proteins at Interfaces: Principles; Multivariate Aspects; Protein Resistant Surfaces; and Direct Imaging and Manipulation of Adsorbed Proteins," J.D. Andrade, V. Hlady, A-P Wei, C-H Ho, A.S. Lea, S.I. Jeon, Y.S. Lin, E. Stroup, Clin Materials, 11 (1992) 67.

"Adsorption of Complex Proteins at Interface," Pure.Appl.Chem. 54 (1992) 1777-81.

"Needs, Opportunities, and Problems in Biomaterials and Biocompatibility," J.D. Andrade Clin. Materials, 11 (1992) 19

"Manipulation of Proteins on Mica by Atomic Force Microscopy," A. S. Lea, A. Pungor, V. Hlady, J. D. Andrade, J. N. Herron, E. W. Voss, Jr., Langmuir 8 (1992) 68.

"Immuno-Biosensors: The Clinical Chemistry and Coagulation Laboratory on a Chip," J. D. Andrade, J-N Lin, V. Hlady, J. Herron in Y. Sezai, ed., Artificial Heart: Biomation in the 21st Century, Saunders, 1992, p. 89.

"Bioengineering: A Model for Engineering Education," Biomedical Engineering Society Newsletter 15 (1), (1991) 3-6.

"Vroman Effects, Techniques, and Philosophies," J. D. Andrade and V.Hlady, J. Biomaterials Sci: Polymer 2 (1991) 161-172.

"Comparison of Site-specific Coupling Chemistry for Antibody Immobilization on Different Solid Supports," J. N. Lin, I-N Chang, J. D. Andrade, J. N. Herron, D. A. Christensen, J. Chromatography, 542 (1991), 41-59.

"Interaction of Plasma Proteins with Heparinized Gel Particles Studied by High Resolution 2-D Gel Electrophoresis," C-H Ho, V. Hlady, G. Nyquist, J. D. Andrade, K. D. Caldwell, J. Biomed. Mat. Res. 25, (1991) 423-441.

"Immunosensors: Remaining Problems in the Development of Remote, Continuous, Multi-Channel Devices," J. D. Andrade, J-N Lin, V. Hlady, J. Herron, D. Christensen, and J. Kopecek, chapter in R. B. Buck, et al., eds. Biosensor Technology, Dekker, Publ., (1990) pp. 219-239.

"Real Time Imaging of an Immunoglobulin Adsorption Using the Atomic Force Microscope," Langmuir 6 (1990) 509.

Students Graduated Last Four Years:

A-P Wei, MSc, 1990
C-H Ho, MSc, 1990
Li Feng, Ph.D., 1993
I-N Chang, Ph.D. 1994

Current Students:

K. Tingey, Ph.D. defense, June, 1995
J. Zhang, Ph.D. defense, December 1994
E. Stroup, Ph.D. defense, June 1995
C.Y. Wang, Ph.D. defense, June 1995

Collaborators:

Dr. Vladimir Hlady, University of Utah
Dr. James Herron, University of Utah
Dr. Karin Caldwell, University of Utah
Dr. Douglas Christensen, University of Utah
Dr. Jindrich Kopecek, University of Utah
Dr. Sung Wan Kim, University of Utah

Dr. Andrade's Ph.D. supervisor (1966-1969) was Dr. Paul Predecki, University of Denver, Colorado. Other collaborators live and work in Europe or Asia.

7) Assess the effectiveness of the availability and application of *music based and/or art based biological sciences kits* in the development of science interests and professional goals among students initially uninterested in the biological sciences. This is indeed *the goal of the entire project*, but will require the availability of at least prototype kits, *the goal of the Phase I component*. During *Phase II* these prototype kits will continue to be developed, tested, and evaluated in appropriate student and general public populations.

B. Significance:

There has been considerable concern in the past decade in the growing disinterest in science studies and careers among high school, college, and university students (1,2). Although there has been an increasing number of programs designed to interest students in the sciences, there has been little concerted effort in directly addressing those populations which express considerable *disinterest* in the sciences.

The Science by Seduction approach, now being actively pursued in the University of Utah's Center for Integrated Science Education, is based in large part on Howard Gardner's *Frames of Mind: Theory of Multiple Intelligences* (3). Fundamentally, the approach accepts the fact that different segments of the population have different aptitudes and interests, and may even be wired differently. Rather than ignoring this fact or trying to change it, courses and workshops have been developed which build on it (16,17). There is a great deal of science in music, for example, and many famous scientists have been outstanding accomplished musicians. Although examples in the arts are not as common, Leonardo da Vinci is always given as an example of an individual with incredible accomplishments and skills in the arts, the sciences, and engineering/technology.

The so called right vs. left brain model, which is often employed to "explain" or rationalize the different interests and aptitudes of various individuals, was well analyzed by Shlain (4) concluding in part that the real goal of education ought to be to show students how they can indeed synthesize or connect their right and left brain to achieve enhanced levels of creativity and productivity.

Shiela Tobias, in her important study, *They're Not Dumb -- They're Different* (18), showed that Arts and Humanities students are not necessarily disinterested in the sciences, but they are put off by the way the sciences are presented and taught. David Evans, sometimes called the "father of computer graphics" and former Chairman of the Department of Computer Science at the University of Utah, and former President of the Evans and Sutherland computer corporation, once said in rationalizing why he took totally "unprepared" artists into his graduate student program in advanced computer science, "It's far easier to teach engineering to an artist than it is to teach artistic creativity to an engineer."

We propose to take students with interests and aptitudes in the arts and music and enhance and expand their interests to include science, particularly biological science -- *not* to substitute for their interest in art and/or music, but rather to enhance those interests, and to *employ* their art and music skills, modes of thinking, and creativity *in the biological sciences*. We feel that this will be far more important than just inducing a small number of art and music majors to now major in the biological sciences. Rather, it will produce a small group of individuals with levels of creativity and perception enhanced (4) over those

who, however smart and accomplished, take the more traditional, direct route into the through the sciences.

The Project 2061 report, *Science for All Americans*, argues strongly and persuasively for an integrated approach to the sciences (1,2). We feel that it is important that at least some small subset of the population go even beyond that report and consider an integrated approach to education in general (19).

C. Relevant Experience:

Protein Solutions, Inc. is a small education products company founded in 1988 by J. Andrade, Professor of Bioengineering and Co-Director of the Center for Integrated Science Education at the University of Utah. Joe has almost no skills, and up until recently had little interest, in the arts and music. Reputed by his wife to be completely tone deaf , he does enjoy listening to music, and has occasionally made some limited, but futile, attempts to produce some.

With the founding of the Center for Integrated Science Education, and the realization and adoption of Project 2061's goals and guidelines, Joe began to develop a set of courses and workshops designed initially for elementary teachers, called Integrated Science Concepts and Themes (16). As he got into these workshops, and began to study the work of Howard Gardner and other educational psychologists (3,19), he began to realize that the people which we must interest in science are *dis*interested because they are really very interested in something else, and the only way to effectively and successfully interest them and involve them in science is to find out what does interest them and to connect through that interest. We call it interest-based science, or *Science by Seduction.*

In working with elementary teachers in Utah Joe found that what really interests them are the things that they would rather be doing if they could be doing anything at all. Some of those topics include: gardening, cooking, outdoor activities, sports, dance, sex, music, and art, as well as many others. We have adopted two of those interests for this STTR proposal, *music and art.* We hope to address the other ones in subsequent proposals and activities.

The Center for Integrated Science Education has thus embarked on a major effort to develop interest-based science courses for the university undergraduate population. Joe is now teaching a two quarter liberal arts course, Science Without Walls: Science for the Science Resistant, which is an interest-based approach. He regularly gives workshops for elementary teachers which, although called Integrated Science Concepts and Themes (16), are based on the teacher's personal interests

CISE consists of an Executive Committee representing each basic science department, the College of Engineering, the Graduate School of Education, and the College of Earth and Mineral Sciences, as well as the informal science education museum community. The Co-Director of CISE is Joe Dickinson, Professor of Biology. There is close coordination with the Howard Hughes Medical Institute education programs, and with other education and outreach activities throughout the campus.

The National Science Teachers Association meeting, December 15-17, 1994 in Las Vegas is expected to draw some 3,000 to 5,000 attendees, at least 1,500 of which will participate in a survey questionnaire (in exchange for a bioluminescence freebie), thereby obtaining marketing information on educator interests and needs. These marketing studies are not part of the budget of this STTR project, but they are important to the information and data gathering required to most effectively design interest-based science projects and kits.

Task 3) The education community, in general, does not know the connection between the arts, music, and the sciences. By working with groups of teachers responsible for each of the three major age groups targeted, that is, jr. high, high school, and college, we will begin to understand the hesitations, misconceptions, prejudices, and related hurdles which must be overcome in implementing an integrated, interest-based approach. We will use focus groups with which to facilitate such interaction and to develop such information. These same groups will then be utilized later in the project to help evaluate and assess the methods and preliminary kits developed, i.e., to assess the *feasibility* of our proposed approach.

We will also work closely with the authors of books and materials which have developed such connections and have developed science courses for non science students based on an interest-based approach (6,10,11,12,14).

Task 4) This task will involve the staff and program committee of the Utah Science/Art Center Project, as well as other members of the Association for Science and Technology Centers (ASTC). There are a number of museums which are starting to draw connections between the sciences and the arts, including the Exploratorium in San Francisco (12,20) and a new science center in Albuquerque, New Mexico. In this task we will identify those groups, make initial contact with them, and begin to involve them as advisors in this project.

Of particular interest is the Leonardo Project of the Utah Science/Art Center. The Leonardo Project is a science center on wheels which will roam the state of Utah in 1996 and the Intermountain west region of the United States in 1997-'98. It is designed to bring a science/art center experience to this large geographic region consisting of primarily rural environments. Since Leonardo will actually be on the road during the last half of this STTR Phase I grant, it will be utilized as a test vehicle with which to assess the feasibility of our concept and approach (see enclosed letter from R. Millar, Utah Science Center Authority).

Task 5) We certainly do not propose to fully develop a music-based approach to the biological sciences in this Phase I grant, but rather to assess the feasibility of such a development and to put together *a preliminary prototype of such a kit.* A more comprehensive kit, or kits, and their testing and evaluation will be a major part of the Phase II activities.

Almost everyone is interested in music, at least in listening to certain types of music. Some people have wide and diverse musical tastes, others are interested

Protein Solutions, Inc. now manufactures bioluminescence science kits, the Science in the Dark product line. It is also developing the Lableless Lab™ product line, using National Science Foundation SBIR support (DMI 94-23708). It expects its third major product line, based on this Phase I and Phase II STTR, and subsequent R & D activities, to be *Science by Seduction, interest-based kits* to be sold and distributed not only through the conventional science education products outlets, but directly through arts, music, and hobby stores and related outlets. PSI is well aware of hobby and science product marketing and distribution.

D. Experimental Design and Methods (in order of Specific Aims):

Task 1) CISE works closely with the science and math curriculum coordinators in the Utah State Office of Education and, through them, with the National Science Supervisors Association. It also has very close connections and interactions with the Salt Lake City School District, The Granite School District and the Davis District, three major urban districts in Utah.

CISE is also working closely with the Utah Science/Arts Center Authority and with the Utah Arts Council to design and construct the Gateway Center, Utah's 21st Century Science/Art Center, a hands on, interactive celebration of personal creativity (see letter from R. Millar, Technical Director). Building on the experience of major hands-on science centers, such as the Exploratorium in San Francisco, the Ontario Science Center in Toronto, the Cite de Science in Paris, and other interactive science centers around the world, Utah is planning the first of the 21st Century Science/Art Centers. Using Leonardo da Vinci as an icon and a guide, this particular center will enable the visitor to not only experience the sciences, the arts, and engineering/technology, but even more importantly to experience the connections between them and the enhancement which each one provides for the others.

Joe Andrade, PI of the University side of this STTR application and Co-Director of CISE, is also Program Co-Chair for the Utah Science/Art Center. Thus, indirectly, the entire 200 plus member Program Committee for this unique facility are available and accessible for this Science by Seduction project. Working closely with the Utah Arts Council and the Utah Alliance for the Arts and Humanities Education, CISE will be able to readily accomplish Task 1 (Specific Aims). We will also work closely with our education colleagues in the National Science Foundation and the National Endowment for the Arts, and with their grantees and contractors appropriate to this study.

Task 2) Will be conducted largely by PSI through exhibits, shows, and workshops at the major science, arts, and music educational conferences, for example, the National Science Teachers Association (NSTA) annual meeting. PSI will survey the existing arts, music, and science education communities with respect to their responsiveness to and interest in interest-based science. PSI is already conducting such surveys within the science educator community for its new Lableless Lab™ product line.

in performance, others in composition. Music is an almost ubiquitous hook, and historically has been widely used for the teaching of science (11, 12, 21, 22). Often the most popular exhibits and activities at science museums involve personal, interactive music: talking or singing into a microphone and directly seeing the amplitude and frequency of your audio output -- the use of various delay lines or echo lines in the output, intentional distortions of the sound, merging of voices -- these are common exhibits and activities in every major science museum in the country. There is absolutely no problem in connecting music to the physical sciences -- the physics of waves, sound generation, acoustics, sound transmission, the synthesis of sound, and its production are all popular and well developed topics.

For the purposes of this STTR, however, it is *the connection to the biological sciences* which we want to emphasize. That can be accomplished in several ways. One is through the sense of hearing itself: the mechanism of hearing among different components of the animal kingdom, hearing disorders, the threshold of pain or of hearing damage -- all are very popular topics. The generation of sound by other members of the animal kingdom, the exquisite versatility of the human voice, the anatomy and physiology of the human vocal system, the repair of hearing defects, the generation of sounds by other animals, the diversity and beauty of bird calls, the entire sensory ecology and sensory physiology of the various species and their predators (7,8). We can develop these connections easily and straightforwardly by simply working our way through fundamental high school and college freshman biology textbooks, developing the connections which tie music, sound, and hearing to the disciplines of biology, chemistry, and physics.

Putting all of this into a kit is a bit more challenging. This will involve recording capability, sound and music analysis capability, and a number of simple tools and activities, including tuning forks, simple instruments, bird calls, etc.

Task 6) *Our art-based activities will rely upon two excellent texts:* Falk, et al.'s *Seeing the Light: Optics in Nature, Photography, Color, Vision, and Holography* (9), and Williamson and Cummins', *Light & Color in Nature & Art* (10). From the preface of the Williamson book: "This book is an introduction to the science of light and color in its applications to photography, art, natural phenomena, and other related areas. It is intended primarily as a text for a one semester or one quarter college course for students with little or no background in science or mathematics." In the case of the Falk preface, many students "came with a definite interest -- art, vision, photography, ho illusions, the visible world around them -- a large variety of spe was already there before we said the first word." Althoug connect a range of physical and biological concepts to art a really begin with interests and aptitudes related to art. C We choose to *start with art* -- those activities and in would naturally choose and through those a discover a range of scientific concepts, perhaps cent colors

of a butterfly, and thereby getting into the optics of butterfly wings, for example.

This will require working closely with art educators and with a variety of physical and biological scientists who have personal interests in painting and art. A good, although unfortunately dead, example is the famous physicist Richard Feynman, who became quite interested in artists and art and became a fairly accomplished artist in his own right. The best example, of course, is Leonardo da Vinci, who basically studied human anatomy and the human form in order to be able to perfect his art. We will, of course, borrow heavily from Leonardo's sketchbooks and his own treatise on art (28), as well as the Feynman example (27). We will also draw heavily on the Thompson's On *Growth and Form* (24), and related books dealing with design and symmetry in biology. This will also be connected closely to mathematics, particularly geometry and topology based on the arguments and methods presented in the recent mathematics education study, *On the Shoulders of Giants* (25).

The kit components here are straightforward, involving a set of light sources, filters, a variety of paints and other media, experiments related to perspective, two vs. three dimensions, symmetry, texture, use of various computer *Paint* programs, etc. Those of use involved in this project are excited to begin.

Audience: We will particularly target women and other minorities in our focus groups and in our target populations. Working closely with the MESA (Minority Engineer and Scientist Achievement program), and also with the universities' and the local school districts' programs to encourage women in science, we will see to it that these populations are not only appropriately represented, but particularly involved and encouraged (26).

E. Human Subjects:

There are no substantive human subject issues to be addressed. Rather, we will work through teachers and others who work with the appropriate student populations.

F. Vertebrate Animals: Not applicable.

G. Consultants: No formal consultants are budgeted.

H. Contractual Arrangements:

Protein Solutions, Inc., and the University of Utah have an active Technology Transfer Agreement in the area of "bioluminescence and other science educational materials." This agreement has been in place for over four years, and the current term continues for an additional two years. Copies of the agreement are available upon request.

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UTAH SCIENCE CENTER AUTHORITY

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November 29, 1994

J.D. Andrade, Professor
Department of Bioengineering
2480 MEB
University of Utah
Salt Lake City, Utah 84112

Dear Joe:

I was pleased to learn of your NIH-STTR grant application, via Protein Solutions, Inc., on hobby and interest-based science kits to encourage jr. high students to develop interests in the biological sciences and biotechnology.

Your proposal will be an important asset to public education, and to furthering the goals of the Utah Gateway Center and its Leonardo on Wheels science center outreach project. We look forward to working with you and in directly involving students benefiting from your science kits in our projects.

Thank you for your important involvement in the Utah Gateway Center.

Sincerely,

Rod Millar
Technical Director

USCA/29Nov94

PSI and the University of Utah are now collaborating on an existing STTR Phase I from the National Science Foundation, effective 8/15/94, R. Scheer. PSI and the University of Utah have a strong and highly effective working relationship. The University of Utah subcontract activities will be conducted primarily through its space and resources, including the space assigned to the Center for Integrated Science Education and its Leonardo Laboratory, a 1,200 sq/ft four room complex in which the Science by Seduction approach using art and music is presently being employed in the Science Without Walls Liberal Education Course, now under way.

PSI's activities will be conducted at its corporate space at 350 West 800 North, Suite 218, and surrounding rooms. This space is a ten minute drive from the University of Utah campus. Rob Scheer, the PI on this STTR, and J. Andrade, PI for the University of Utah portion, have a close working relationship and are also the respective PIs on the existing NSF STTR. Roughly half of the activity on this Phase I STTR is through the University of Utah subcontract and the remaining half is through PSI.

The approximate task breakdown was described above under Specific Aims.