APPENDIX B

Utah Small Business Innovation Program

PROJECT SUMMARY

UTFC AWARD NO.

NAME OF FIRM

Protein Solutions, Inc.

ADDRESS

6009 Highland Drive
Salt Lake City, Utah 84121

PROJECT LEADER (NAME AND TITLE)

J.D. Andrade, President, Chief Scientific Officer

TITLE OF PROJECT

BIO-LITE: The Living Night Light

TECHNICAL ABSTRACT (LIMIT TO 200 WORDS)

BIO-LITES are spheres ("balls") or cylinders ("tubes") containing a concentrated suspension of bioluminescent micro-algae. When the product is tapped, rolled, inverted, or otherwise mechanically agitated, the algae produce light -- that is, they bioluminesce. The culture recharges itself by photosynthesis by day and can "perform" its bioluminescent feats in the dark. The startling bioluminescence (light production) is an intense blue color and occurs upon mechanical stimulation. The product is designed to last 6 weeks. It will be disposable. It will be initially sold in pet, fish, and hobby stores, and in high end adult novelty outlets, including airport and museum gift shops.

Protein Solutions, Inc. is developing unique science education products which will motivate children and adults to observe and experience scientific phenomena. PSI's first product, NIGHT COLONY, consists of a transparent container with a culture of bioluminescent marine microalgae. Local test marketing of NIGHT COLONY should begin in early November, 1991. Additional products include NIGHT LAB -- a complete science education kit using bioluminescence. PSI is working with the Davis County, Jordan, and Salt Lake school districts to use bioluminescence in their science curricula.

The proposal focuses on Bio-Lites, tubing and spheres designed for the pet, aquarium, and science novelty markets -- for both children and adults. Imagine the fish in your aquarium intentionally jostling a BIO-LITE sphere at night -- in the dark!. Imagine a cat with a BIO-LITE ball at night -- in the dark.

KEY WORDS TO IDENTIFY TECHNOLOGY (8 MAXIMUM)

Aquculture, Aquarium Products, Pet Accessories, Bioluminescence, Science Education, Toys, Children's Products, Biotechnology.

POTENTIAL COMMERCIAL APPLICATIONS OF THE INNOVATION

Science Education, Children's Toys & Novelties.

1-89

TABLE OF CONTENTS

IDENTIFICATION AND SIGNIFICANCE OF THE INNOVATION

Protein Solutions, Inc. (PSI) intends to develop, manufacture, and market a new line of educational, innovative products, NIGHT LIFE PRODUCTS, which use the phenomenon of bioluminescence to motivate and entertain children, their teachers, and their parents. This proposal specifically addresses the second product of this line, BIO-LITE, a *living* night light.

A new awareness is emerging in the literature and public opinion that the 90's will be a decade of increased emphasis on education. Most states have already adopted programs to enhance education at all levels, in both public and higher education. The National Science Foundation's budget for science education has increased dramatically in recent years. This has resulted in a significantly increased demand for products which have an educational component, including gifts and novelties for children and more serious products purchased by parents and teachers to enhance the education of their children and their students. There has also been a proliferation of science and nature stores. Local examples include the Chem Shop (Crossroads Plaza Mall) and the Great Basin Nature Company (Foothill Mall). In addition, many toy stores and book stores now feature science products and kits (Gregory's Toys & Adventures and A Woman's Place Bookstore -- both in Foothill Mall). PSI will be addressing this expanding interest with products that stimulate a child's natural curiosity and eagerness to learn.

PSI is focused on the development and application of bioluminescence as an educational and product development tool. This is a unique technology which has never been utilized in educational products or toys. Children (and their parents!) are fascinated by bioluminescence. It is a new, "magical", mystical, and stimulating experience for them.

NIGHT COLONY, a transparent container of bioluminescent marine micro-organisms which produce a brilliant blue light upon mechanical stimulation, is the first NIGHT LIFE PRODUCT. A marine microalgae, Pyrocystis lunula, has been cultured to high density (5,000 organisms/ml) and placed in an attractive container. The NIGHT COLONY prototype will be launched and test marketed later this year. PSI has invested $60,000 in the research and revelopment of this first product. The bioluminescent microalgae can be seen upon close scrutiny with the naked eye. With a small magnifying lens (provided with the product) they can be discovered and observed. With the use of a low power microscope (which will also be available through PSI), internal structures, cell division, and other behavior may be observed. A fascinated child will want to take his "companions" to bed and explore their brilliant night light.

Successful development and manufacture of NIGHT COLONY will provide a new, exciting introduction to the joy of discovery and exploration, and the impetus for developing questions and curiosity.

The National Council on Science and Technology Education recommends introduction to the nature of the scientific enterprise in our education curricula , including how science, mathematics and technology relate to one another and to the social system in general. Educational reform to integrate the various divisions of science is now recognized as a critical step which must be taken if the US is to compete with other nations[1]. NIGHT COLONY provides an excellent introduction to the interplay of biology, chemistry, physics, and environmental science (Figure 1).

Equally important, NIGHT COLONY, provides a teaching aid which may be used in classrooms from kindergarten through grade 12. Consider the fascination of the traditional Ant Farm used in classrooms throughout the country and extrapolate to the increased fun in

observing organisms which produce their own light! PSI has had very positive responses from the Salt Lake City and Davis County school districts, and from the State Office of Education; there is strong interest in adding the exploration of bioluminescence into their curricula[8].

J. Andrade, PSI's Chief Scientific Officer, is also Director of the University of Utah's new Center for Integrated Science Education (CISE). CISE is working with the University of Utah School of Education and with local school districts to use bioluminescence as an integrated science discovery tool.

Thus, successful development and commercialization of the proposed NIGHT COLONY and other NIGHT LIFE TOYS will increase the interest and enthusiasm of children through the process of discovery, thereby enhancing science education. .

This proposal is for the Research and Development needed to launch PSI's second major product, BIO-LITE: The Living Nite Lite.

Although much of the technology is in place for BIO-LITE, this product has some additional requirements:

- It will be completely sealed;
- It will be a maintenance-free product;
- It will be available in 3 different shapes (cylinders, spheres, and plates);
- It will be designed and formulated to last at least 6 weeks and possibly for up to 6 months; and,
- It will be disposable.

BACKGROUND, APPROACH AND ANTICIPATED RESULTS

Background

Flashing fireflies on summer evenings, glowing ocean surf, and other forms of natural bioluminescence have always generated interest and curiosity. Although investigated for many years, biologists have been slow to exploit bioluminescence in the laboratory. Now scientists are using bioluminescence to study biology, medicine and agriculture[2].

Nearly everyone who discovers and observes bioluminescence is impressed and motivated to see and learn more. In these times where children and adults have their senses constantly stimulated to near exhaustion, bioluminescence is a relatively unknown, unexperienced phenomenon which can readily compete for people's attention and interest.

Bioluminescence is the light produced by certain plants and animals. It is not only fascinating to observe, but can be packaged and discovered in ways which entertain a child while teaching the basic principles of biology, chemistry and physics via an integrated, multi-disciplinary approach to science education[3] (Figure 1).

The so-called phosphorescence of the sea is due to the bioluminescence of dinoflagellates, fascinating microalgae which are the basis of PSI's NIGHT LIFE PRODUCT line. . The light emitted when the water is disturbed is characteristically emitted as a rapid flash which occurs upon stimulation and lasts only a fraction of a second [2]. Individual cells, depending on the species, will flash repeatedly with repeated stimulation. Pyrocystis

lunula, a dinoflagellate, is used in NIGHT COLONY to produce light when agitated or mechanically stimulated.

Approach

We are developing integrated science educational toys using bioluminescence as the "discovery" and observation vehicles. NIGHT COLONY consists of a transparent container of "sea pets", an owner's manual, food packets, a sampling pipet, and a NIGHT SLIDE for observation.

The technology involved in the development of NIGHT COLONY will be applied to the newer BIO-LITE product. Additional efforts are needed, however, in the culture, growth and handling of the bioluminescent microorganisms in supplemented sea water The technology further includes means to stimulate the bioluminescence by physical and chemical means. One major advantage of bioluminescence over chemiluminescent products* is the ability to control the light emission, essentially to induce light on command.

PSI has developed culture techniques for production of the microorganisms. PSI also has substantial experience and knowledge as to the temperature, salinity and nutrient requirements, including trace metals and vitamin supplements, of the Pyrocystis noctiluca, Pyrocystis lunula and Gonyaulax polyedra bioluminescent organisms[12]. This work has been targeted for the current product development -- NIGHT COLONY, which is not sealed, is open to the air, required periodic maintenance , and is *not* designed to be rolled on the floor! Growth of the organisms to the high densities needed for BIO-LITE requires selection of the best organism, optimization of the culture conditions, and optimization of the sea water composition.

In addition, we propose to select the appropriate materials and design the product configuration for BIO-LITE which would have the greatest visual and tactile appeal to generate interest in children, their parents, their teachers, and their pet fish, cats, etc.

The requirements for shipping and storage of the BIO-LITE must be defined. For example, questions such as how much carbon dioxide and carbonate gravel to be stored in the BIO LITE to maintain an adequate shelf life and product life.

PSI is uniquely positioned to enter the bioluminescence product market. We have had extensive interaction with experts in the field, including those knowledgeable about dinoflagellates and other bioluminescent organisms[10]. J.D. Andrade, President of PSI, has been involved in the field of bioluminescence for nearly 3 years. One of our staff has attended a workshop on marine phytoplankton culture and techniques at the Provasoli Guillard Center for the Culture of Marine Phytoplankton in Maine.

In addition, we have been actively working with educators and administrators from the Davis County, Jordan, and Salt Lake City school districts to introduce bioluminescence into an experimental science curriculum[8]. We are also working with the Children's Museum of Utah to develop an interactive, hands-on bioluminescence exhibit[9]. We sincerely believe that the development of this technology will result in an expanding, successful and profitable business venture which will stimulate fascination and interest in bioluminescent products.

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* The Lite Stiks sold by American Cyanamid are based on chemiluminescence and do not involve living organisms.

Anticipated Results

The proposed R&D project has been planned and organized to test the feasibility of developing and maintaining a viable, sealed, robust, and maintenance-free dinoflagellate culture for use as a science educational toy, a "toy" for pets, and a general novelty product. We anticipate successful demonstration of feasibility by growing cultures of these microorganisms and placing them in suitable containers. We propose work leading to:

1. High density cultures of single and mixed populations of dinoflagellates which may be maintained viable for up to six months with little care or attention. We expect to identify specific feeding and CO2 requirements for their viability and to design optimum product configurations.

2. Containers which include a polymer membrane capable of providing the necessary gas requirements for these organisms. The gas needs of the dinoflagellates will be a function of temperature and lighting conditions and must be determined. Several gas permeable polymers are commercially available which should satisfy these requirements[11].

3. Testing and selection of product configuration, size, physical characteristics, and bioluminescence properties suitable for aquarium, pet, and novelty products (see below).

After feasibility is demonstrated and prototypes constructed in this Phase I project, we will immediately move into Phase II to further develop and optimize BIO-LITE and to move into production and commercial sales. We anticipate no difficulty in obtaining funding for the follow-on Phase II (optimization and test marketing -- see letter, page 14) and Phase III (full commercialization) of the project.

Several novelty products are currently on the market which generate light through chemiluminescence, such as "light stiks" (see footnote on page 6). However, these do not address the educational market or attempt to stimulate scientific interest. These products lack the flexibility, versatility, efficiency and control available with bioluminescence. To our knowledge, no other product is available or under development which can compete with NIGHT LIFE TOYS or BIO-LITE.

PROGRAM OBJECTIVES

The proposed R&D project is aimed at accomplishing the following specific objectives:

A. Select the optimum dinoflagellate organisms.

B. Develop methods to produce high densities of different dinoflagellates and their mixtures for optimum bioluminescence consistent with long-lived cultures (6 weeks to 6 months).

C. Develop optimum container/membrane combinations for appropriate CO_2 requirements for each of the 3 product shapes and for the 3 different marketing ideas.

D. Establish shipping and storage requirements to maintain a viable culture of the dinoflagellates.

E. Develop product accessories to enhance customer interest and science education.

PROGRAM PLAN

The program objectives will be reached by the performance of 14 specific tasks (keyed to Objectives A-E above):

Task A-1. Selection of robust dinoflagellates which can function for long times in sealed cultures- There are many species of bioluminescent dinoflagellates. PSI has selected Pyrocystis lunula for its NIGHT COLONY products. Although this organism appears to be suitable for the BIO-LITE products, we want to select the best organism for the job. The organisms are available from the Center for the Culture of Marine Phytoplankton in Maine. We can easily obtain, culture, test, and screen the various organisms. We will also further explore the literature and consult with experts in the field[10]. The organisms will be identified and final selections made based on availability, bioluminescent intensity and duration, ease of culture, ease of transport, and long term viability in a sealed product.

Task B-1. Design, fabrication and installation of incubators and lighting systems- Dinoflagellates maintain normal circadian rhythms and are sensitive to fluctuations in temperature and light. Following consultation and based on our current experience, incubators and lighting systems will be designed, built and installed in our laboratory. Different organisms respond differently to light/temperature cycles so it may be that several incubators will be needed to maintain the different species. PSI has investigated the possibility of acquiring floral or restaurant chillers which may prove appropriate for our needs. These techniques are needed to generate the high densities and volumes of organisms for use in the BIO-LITE products.

Task B-2. Identification of division rates- Each species of dinoflagellates has a specific life cycle and division rate. Obviously it will be important to select those organisms which will provide the maximum division rates for culture while minimizing any fouling of the media from cell death or metabolites. The culture media has an influence on the rate of division and will be explored in efforts on Task C-1 below.

Task B-3. Maximization of cell densities for maximum bioluminescent intensity- Currently, PSI has developed sufficient expertise to maintain moderate density cultures of the Pyrocystis strains. Experiments will be conducted to maximize the cell densities of individual species by altering light cycles, temperature and availability of CO2. These experiments will again be explored simultaneously with efforts to optimize the artificial sea water (Task C-1).

Task B-4. Influence of temperature/ light on long term stability- Using the optimum cell densities determined above for each species selected, experiments will be conducted to determine the influence of varying light cycles and temperatures for the purpose of long term stability and product life issues. These factors are critical in design of the product itself as well as in the development of packaging and shipping containers to maintain a viable, dense culture of dinoflagellates.

Task B-5. Product lifetime considerations- Questions which must be answered include: How long can the culture live (assuming adequate CO2) without the depletion of

nutrients? Do the organisms degrade their own environment with metabolites or decay products? By proper formulation of the culture media, we hope to enhance product lifetimes from an initial value of 6 weeks to as long as 6 months.

Task B-6. Mixed cultures- Experiments will be conducted to determine if mixed cultures, i.e. more than one species present, will provide a more favorable product, either in terms of intensity or duration of light, or longer term stability of the culture. Since the different species of dinoflagellate respond differently to stimulation, it may be that a BIO-LITE consisting of a mixture of organisms will prove more optimal. Each of the selected organisms will be cultured in combination with the others and observations made as to light intensity, duration, long-term viability of the culture and growth rates. The dinoflagellates are plants and should therefore coexist without problem (they can't eat each other!)

Task B-7. Optimization of artificial sea water and supplements- Several commercially available sea waters are under investigation for use in the current NIGHT COLONY PRODUCT. Examples of these include Guillard F/2 Supplement® and Instant Ocean®. We will do extensive testing to develop formulations for optimization of growth, and bioluminescence emission. Additives to increase the viscosity of the medium will be explored for purposes of forming a homogeneous suspension of the organisms. An example of a material which may be considered is polyethylene glycol, a non-toxic, inert polymer. The optimum media will be proprietary and possibly patentable.

Task C-1. Optimization of container configuration/materials- We wish to develop *three* container configurations, each targeted for different markets.

The cylinder configuration is the simplest; most of the initial effort will be focused on the cylinder. This will be analogous to a simple plastic test tube with a screw cap, except that the screw cap will contain a silicone rubber membrane. The cap will contain a few grains of carbonate gravel to help provide an agitation source and to help deliver and maintain a CO_2 balance. The tube will be completely filled with the high concentration dinoflagellate solution. The cap will then be screwed down and sealed, probably with a simple solvent weld. There will be a small air bubble to permit gas exchange, and also to be used as an agitation source when the tube is inverted. This will be a completely sealed and disposable system.

The container design must consider volume, diameter and length of the tube, size and thickness of the silicone membrane, and the particular cap geometry and sealing process. The material will probably be an impact resistant polystyrene, although that has yet to be determined. The cylinder tube geometry actually fits most of the markets we are now considering. It would be appropriate for floating on the top of either a fresh water or salt water aquarium.

The second priority will be given to the sphere geometry because this has the potential to function as a ball, which would probably be more attractive as a children's toy or as a toy for nocturnal pets. This would be a more difficult product to manufacture. Again, we would want to have the transparent sphere almost totally filled with solution, with just a little bit of gravel and air to provide the agitation and turbulence to stimulate the bioluminescence. In all likelihood we would have a two part molded sphere, which would then be sealed around the diameter. One of the hemispheres would contain a small hole onto which a tiny plug, containing the gas permeable silicone membrane, would be solvent welded.

This configuration will need to be studied in much more detail, particularly from the point of view of the costs of manufacturing and assembly. It clearly is the ideal shape for market applications which involve a ball or ball-like expectation.

A third shape, which will *not* be developed as part of this SBIP project but is described here for completeness, is a flat card or sheet. Imagine something the size of a credit card, which is completely transparent and contains a very thin solution of the dinoflagellates. One edge or one corner of this card would be the gas permeable membrane. The rest of the card would be a transparent semi-rigid plastic. In this case, the card would be kept in a shirt or jacket pocket and brought out for demonstration at the appropriate time. In this form it would simply be more of a novelty and a curiosity. However, one can envision that this would become popular and could be used together with a printed logo on one side of the plastic, then the logo would be backlit by stimulating the bioluminescence. One could even imagine giving these away as expensive business cards, much as is done today with small, cheap calculators on which a business card is printed. Clearly the major cost and concern here would be in the costs of the card and the cost of manufacturing and assembly.

In all three cases the costs of the organism and the filling material is almost negligible compared to the cost of the container and the manufacturing process.

Task C-2. Determination of CO_2 requirements- Dinoflagellates use CO_2 and expire O_2 as part of their photosynthetic processes in the day. The rate per cell will determine the surface area and permeability of the materials used in the culture. Experiments will be performed to determine gas exchange requirements and limits. For example, is it possible to carbonate with CO_2 for shipping and storage without hurting the organisms? The CO_2, HCO_3, pH equilibria will be carefully studied. The respiration of the organisms will also be studied -- can carbonate minerals be used to deliver CO_2 at a slow rate, thereby extending the life of the product?.

Task C-3. Identification of appropriate gas transfer membranes-When CO2 requirements are established for particular cell densities, various materials will be evaluated for permeation rates of CO2, O2, and water.. Examples of materials which may be evaluated include siloxane polymers. The manufacturability of these polymers in the desired configuration will be evaluated.

Task C-4. Design and fabrication of container- Following selection of the appropriate material, ultimate designs and configurations for BIO-LITE products will be developed. Some of this work may be subcontracted to a local design engineering firm.

Task D-1. Stress testing of cultures for limits of viability- Experiments will be conducted to determine limits of viability which will be critical in shipping and shelf life. Parameters which will be tested include temperature, partial and total darkness, and CO2 storage capacity.

Task E-1 We will continue the development of supporting teaching and educational materials which will be available as product accessories for inquisitive customers and for teachers and schools.

It is emphasized that the over-all objectives of the tasks described above, including testing to be carried out, is to establish feasibility of growing dinoflagellates and designing and building BIO-LITE products.

POTENTIAL PROBLEMS

No serious or insurmountable difficulties are anticipated. Areas of potential concern are listed below with appropriate discussion and possible solutions.

1. Contamination of culture- It may be possible, if careful handling and transfer techniques are not used, that other organisms may contaminate the culture media. It may be necessary, if this is determined to be a problem to suppress such growth by composition adjustment of the culture media. However, it is likely that the unique nutritional requirements of dinoflagellates will themselves act as inhibitors for bacteria, diatoms, or other algae. The media used for reproduction and maintenance of dinoflagellates are inhibitory to many other microorganisms.

2. Safety testing- Because of the high safety expected of toys and related products, safety and toxicity testing of the media and of the organisms will be carried out. Nelson Laboratories, located in Salt Lake City, is a contract laboratory for toxicity testing and will be used to test product safety. No allergic or toxic indications have been reported for these dinoflagellates.

3. Cycle Maintenance- Dinoflagellates respond to light and dark cycles. The cultures and products will have their light-dark cycles adjusted to synchronize with the end user's needs and expectations. The only required "maintenance" will be to expose the products to normal room or office lights for 8-10 hours during the normal day. The light is required for the photosynthesis which maintains the organisms.

FACILITIES

The work on this project will be carried out by PSI, Inc. in its laboratories located at 390 Wakara Way in the University of Utah Research Park in Salt Lake City. PSI is a member of the Center of Biopolymers at Interfaces at the University of Utah, one of the State's Centers of Excellence (Appendix B). PSI is a key corporate participant in the University's new Center for Integrated Science Education (CISE). PSI has a Technology Transfer agreement with the University of Utah Research Foundation (Appendix B). PSI's laboratories are equipped to perform the necessary biological, chemical, engineering, and evaluation studies. Sophisticated equipment which may be required may be used by our team on a time-sharing cooperative basis at the University of Utah.

CONSULTANTS AND SUBCONTRACTS

PSI anticipates utilizing other bioluminescence and marine biology experts for consultation, in particular, Professor W.G. Hastings, Department of Biology, Harvard University. Dr. Hastings is internationally recognized for his work on bacteria and dinoflagellate (photoalgae) bioluminescence. He and his co workers have worked out the basic chemistry of dinoflagellate bioluminescence. He has applied these systems for the study of biological circadian rhythms, and is published widely on the subject.

PSI expects to involve an outside design engineering in the development of the final configuration of BIO-LITE products.

PSI expects to contract the design and production of packaging and shipping containers to the Utah Paper Box Co., Salt Lake City.

KEY PERSONNEL

Joseph D. Andrade, Ph.D. Chairman, Department of Bioengineering, University of Utah, and President of Protein Solutions, Inc., has been studying bioluminescence for over 3 years, primarily for science motivation and education. He has taught high school general science, chemistry, and biology and has assisted in elementary school science instruction on a regular basis for a 3 year period. He has a strong interest in integrated science education. Dr. Andrade has been working on biomaterials and biotechnology problems for the past 25 years (Appendix A).

Suzanne Winters, Ph.D., will serve as a consultant. Dr. Winters has worked in technology development for the past 4 years with CardioPulmonics, Inc. as Director of Membrane Technology, where she was responsible for materials development of a gas transfer membrane. She holds a Bachelors Degree in Zoology and and Ph.D. in Pharmaceutics from the University of Utah (Appendix A).

Mr. John Tobler is an undergraduate biology major at the University of Utah and has been working full-time for Protein Solutions, Inc. for the past year. John is experienced in the culture and growth of dinoflagellates and is basically responsible for PSI's phytoplankton culture facilities.

PSI expects to engage the services of a part-time business student for aid with market analysis and test marketing. We also expect to engage the services of a design and plastics molding engineer with experience in small plastic parts. Several individuals with considerable experience in the local disposable medical plastics industry are now being considered.

Joe Andrade will be directly responsible for the project. He is on sabbatical leave from the University of Utah through September of 1992. He has also arranged his duties at the University of Utah so that he is working with PSI over 50% of the time during that time period, which includes the time course of this SBIP (see letter on next page).

Joe is directly and heavily involved in all aspects of Protein Solutions, Inc., and in all aspects of the study, development, and marketing of its bioluminescence products.

By using part-time personnel and consultants during this early start-up stage, PSI expects to keep its labor costs to a minimum until sales and investment income are appropriate to hire permanent full-time staff

CURRENT AND PENDING SUPPORT & FOLLOW ON FUNDING

PSI recently (June 17, 1991) submitted two Phase I SBIR Applications to the National Science Foundation, Topic 26: Education and Human Resources:

NIGHT COLONY: Science in the Dark, and

LIGHT CRAWLERS: Bioluminescence-Based Discoveries for Science Education.

These applications involve single organism cultures and products based on dinoflagellates (Night Colony) and terrestrial earthworms (Light Crawlers). There is no overlap with this SBIP application.

THE UNIVERSITY OF UTAH

August 1, 1991

To Whom It May Concern:

J.D. Andrade, Professor of Bioengineering and Materials Science and Engineering at the University of Utah, is employed 64% of full time by the University of Utah. In addition, Dr. Andrade is on sabbatical leave from September, 1991 through August, 1992, so his time is flexible. The activities he has proposed in this SBIR are consistent with his sabbatical leave goals.

As University of Utah policy is to pay only 80% of the state salary during a sabbatical, his full time percentage effort during the '91-'92 year is only 52%.

It is our understanding that his commitment and responsibilities with the University of Utah will be reduced to 50% or lower during the course of the SBIR project, to enable him to spend 50% or more time with Protein Solutions, Inc.

We are in support of his plans.

Sincerely,

R. Normann, Acting Chair
Department of Bioengineering

R. Boyd, Chair
Department of Materials Science and Engineering

D. Pershing, Dean
College of Engineering

mm/ag1

Department of Bioengineering
2480 Merrill Engineering Building
Salt Lake City, Utah 84112
(801) 581-8528
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On August 1, PSI submitted an SBIR to NASA's "Bioregenerative Life Support Using Microorganisms topic:

- Bioluminescent Closed Ecological Systems.

There are no overlaps between the NASA SBIRs and the SBIP application.

In addition to the anticipated Federal SBIR funds, PSI has already invested $60,000 (provided by its founders and major stock holders) in the initial studies and product development. PSI is now discussing significant equity investments by a number of local investors and investment groups. A follow on commitment from a local private investor is in place (see letter below).

* * * * *

Joseph D. Andrade
6009 Highland Drive
Salt Lake City, Utah 84121
(801) 227-1259

August 21, 1991

To Whom It May Concern:

I have invested $50,000 in Protein Solutions, Inc. over the past two years. I am convinced that PSI will be a leader in a new and rapidly emerging market for science related products and am convinced that major markets exist for science education materials in the public schools, as well as for informal science education products in the public sector, which includes consumer products and consumer novelties.

I am also convinced that Protein Solutions, Inc.'s emphasis on novel products derived from living organisms will mesh with the growing public interest in ecology and environmental awareness, and therefore an interest in learning more about biology and its living creatures.

I am convinced that bioluminescence in particular is an intriguing, mystical, magical, and generally attractive phenomena, which sparks considerable interest, motivation, and desire.

Protein Solutions, Inc. has the technical skills, the commitment, and the vision to develop these products, to guarantee their market penetration, and to grow and expand the company.

I am frankly convinced that they will be a very major player in the next three or so years. For this reason I expect to match SBIP and SBIR funding with continued private equity investment in PSI over the next several years at a level of at least $25,000 per year. I also frankly expect that as soon as their first product, Night Colony, is test marketed in early November, that they will be successful in getting additional and significant investment.

Sincerely,

J.D. Andrade, Ph.D.

PRE-EXISTING RELEVANT PATENTS AND INVENTIONS

PSI has already developed several proprietary culture media formulations, used with existing commercial artificial sea waters. PSI expects to patent a unique technology, now under development, which will permit the product to be shipped and maintained with minimal damage to the organisms. This technology should have market potential in aquaculture and biotechnology. PSI would then license the technology for suitable royalties to one or more companies involved in aquaculture and/or biotechnology.

FINANCIAL/LEGAL INFORMATION

PSI's lawyer is Mr. Jay Sheen with Moyle and Draper, Salt Lake (phone (801) 521-0250). PSI's accounting firm is Peterson, Silar, and Stevenson, P.C., Salt Lake City (phone (801) 328-2727).

MARKET ASSESSMENT

The initial market for PSI's bioluminescence products are children, their parents and their teachers. With the recognition that our educational system must increase the emphasis on science and mathematics, a dramatically increased demand for products which have a significant educational component will be seen during the 90's[1,3].

Although PSI has not had the resources to do a complete market analysis, it is clear that the market is large. For example there have been over ten million Ant Farms sold by its original inventor and developer, Milton Levine. There at least two other manufacturers of ant farms who have a significant fraction of the market. The estimated sales volume for these ant farms and accessories is $25 million. PSI's new NIGHT COLONY product should easily surpass such figures.

Market assessments performed by Toy Manufacturers of America estimates sales of Activity Toys, which include educational toys, for 1989 to be $1.4 billion. The segment of this market specifically addressing educational and scientific toys was $45 million in 1989[5]. PSI is working with the Davis County, Jordan, and Salt Lake school districts to use bioluminescence in their science curricula. We anticipate a market as large as $100M/year in the public and private education sector -- Grades K-12 (the national market for science education materials in K-12 public schools is over $2 Billion/year!).

A key target for PSI's marketing emphasis will be museum and science center gift shops. According to a recent ASTC Science Center Survey[6], museum stores represent a substantial source of revenue. Numerous articles are appearing in journals across the nation from flight magazines to Business Week describing museum shopping and the emporiums for unique gifts[7].

PSI has been in contact with The Children's Museum of Utah and has agreed to work with them to erect a display dedicated to bioluminescence. The museum has indicated a strong interest for the exhibit as well as items for the gift shop (Appendix B). A joint proposal to NSF's Informal Science Education Program will be submitted in February, 1992.

PSI is now obtaining information as to the total volume and subcategories of sales in museum gift shops nationally. Additionally, PSI is investigating the total budget and

budget subcategories for science-related supplies and equipment in elementary, junior high and high schools throughout the nation. The National Science Teachers Association wields tremendous buying power and hosts shows and exhibitions for manufacturers of science-related products. Other groups to which ads and mailings can be specifically targeted include the School Science and Mathematics Association, The National Education Association, and related groups.

PSI's competitors would be manufacturers of scientific educational toys. However, no other bioluminescent toys or science kits are currently on the market.

It is expected that PSI's bioluminescence educational products will retail in the price range from roughly $15 to $100. The Bio-Lite products, the subject of this SBIP, should sell in the $3-10 range. They will be initially marketed through pet and hobby stores, science stores, and toy stores with a science component.

We are now in the process of doing a market analysis of the pet and home aquarium markets.

In summary, the educational toy and pet markets are already very large and are likely to be expanding in the next decade, based on the recognition of need for a renewed emphasis in science education. The ability to produce bright light in various patterns and under various degrees of stimulation will attract potential buyers to PSI's bioluminescent products. That attraction and novelty, coupled with the educational potential of the product, should guarantee a strong and loyal clientele.

MARKETING PLAN

It is PSI's intention to develop and manufacture BIO-LITE in Salt Lake City as the second of a line of products based on bioluminescence. BIO-LITE falls into PSI's division of liquid products. Follow-on products in the dry category involve technology consisting of a powder containing the protein and the chemicals required for efficient bioluminescence, derived from a marine crustacean. When the powder is wet with water, the enzyme is reactivated and a brilliant bioluminescence results. This dry technology lends itself to the development of products such as paper, inks and paint. The market for these types of toys was over $200 million in 1989. LIGHT CRAWLERS, a bioluminescent earthworm farm, analogous to the ant farm, is under consideration, as well as a more sophisticated teaching toy, NIGHT LAB, a complete laboratory with accessories for more in-depth exploration of the phenomenon of bioluminescence.

Initial test marketing of all of these products will be in local specialty shops such as Gregory's Toys and Adventures. Managers of these businesses have expressed significant and enthusiastic interest in these products (Appendix B) Direct marketing via the publications of the National Science Teachers Association and related groups will be used at a later date.

The second market segment on which PSI will concentrate is the museum shops[6,7]. As mentioned previously, The Children's Museum of Utah has shown interest in a bioluminescence exhibit with bioluminescent products in their gift shop (Appendix B).

PSI intends to have its first product, NIGHT COLONY, on the market by late 1991, with extensive marketing and distribution planned to follow. The second product, BIO-LITE, should be launched by late 1992.

PRODUCT PROTECTION

These products will incorporate a wide range of proprietary innovations and components, including the design of the container, the selection of highly bioluminescent strains, the particular nutrient compositions, and the development of various chemical enhancers for bioluminescence. The particular formulations, designs, and innovations are all patentable and proprietary. PSI expects to have a significant technological lead over any competition which may attempt to copy its creative products. That technological lead will be protected by patents and by trade secrets.

UTAH OPERATIONS

Anticipated growth of the new business resulting from the development of NIGHT LIFE TOYS is summarized as follows:

ANTICIPATED BUSINESS GROWTH	1991	1992	1993	1994	1995
Utah employees:					
Scientists	1	1	2	5	10
Technicians	1	2	4	12	25
Sales and Admin	1	1	4	6	15
Payroll: (annual) in $1,000	50	120	300	1,500	2,000
Sales Forecast: (annual) in $1,000	1	150	500	2,000	5,000

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BUDGET JUSTIFICATION

Personnel: Although J. Andrade will be working on PSI projects at least half time, he is budgeted only a small amount. He will also be compensated in stock options. A full-time technician will be working closely under Dr. Andrade's supervision. He/she is fully budgeted.

Permanent Equipment: Incubators are required in order to have a controlled, reliable environment for the extensive culture studies proposed. It is far cheaper to control the environment in an incubator than to contract for highly sophisticated research space with expensive environmental controls. Partial support of a computer is also budgeted for computerized design, data analysis, and record keeping.

The consultants category is for advice and services of experts in dinoflagellate culture. This includes Dr. Woody Hastings, Department of Biology, Harvard University, and a number of other individuals with whom we have been in contact[10]. Their compensation will be limited to the Utah SBIP maximum rate of $320 per day. Their travel is budgeted separately. We anticipate sharing the travel expenses of these consultants with the appropriate components of the University of Utah, as they are all highly respected biologists and biotechnologists and would probably give lectures on campus as well.

$4,000 is budgeted for engineering and design services for prototype product development and for consultants.

We have also budgeted $4,000 towards memberships in the University of Utah Center for Biopolymers at Interfaces and Center for Integrated Science Education. Such memberships provide us with a unique range of facilities and expertise at very minimal cost.

Travel funds are also requested to permit the project director to attend at least one meeting of the National Science Teachers Association and of the Association of Science and Technology Centers. Both of these groups have industrial exhibitions, and this travel is essential in developing an appropriate marketing analysis and marketing plan. Travel is also budgeted for the consultants.

Indirect Costs are 25% of total costs: The indirect costs are primarily for the support of an office manager, for accounting and legal services, and for space rental.

APPENDICES

VITA
Letters

Joseph Andrade
VITA Summary

Joe Andrade, President and Chief Scientific Officer of PSI, also serves as Chairman of the University of Utah Department of Bioengineering and as Director of the University of Utah's Center for Integrated Science Education. He was born in Hayward, California on July 13, 1941, received a B.Sc. degree in Materials Science and Engineering from San Jose State University in 1965 and a Ph.D. in Metallurgy and Materials Science from the University of Denver in 1969.

From 1969 to the present he has been on the faculty of the University of Utah. Joe served as Dean of the College of Engineering from 1983 to 1987. He has over 150 publications and has edited 5 books in the area of materials in medicine, biocompatability, and surface chemistry. He is Professor of Bioengineering, Materials Science and Engineering, and Pharmaceutics. During his 22 years at the University of Utah he has directed a large interdisciplinary research program averaging roughly $300,000/year in external funds. His 40 graduate students have positions in academia, industry, and government.

In 1981, together with Sung Wan Kim and a group of former students and coworkers, he founded Biomaterials International (Albion Instruments), a manufacturer of medical anesthesia monitoring equipment. Albion Instruments (now Ohmeda-Salt Lake) employs about 75 people in a site at the Salt Lake International Center.

In January 1988, together with Peter Gerity and Jim McRea, Joe founded Protein Solutions, Inc. (PSI), a biotechnology firm focused on applying proteins to a wide range of consumer products and bioluminescent products for the toy and education markets.

Joe holds 5 patents. In 1983 he co-founded the Center for Biopolymers at Interfaces, a University/State/Industry consortium which now has 24 corporate members and sensors. The Center is directed by Dr. Karin Caldwell of the University of Utah. He recently formed the Center for Integrated Science Education (CISE).

Joe Andrade has a long and strong track record of working with industry. He has lectured at -- and consulted for -- numerous biomedical and health care companies and has been awarded many industrial fellowships and research contracts.

He has worked closely with the State of Utah Department of Community and Economic Development, with the Board of Regents, and with the Utah Legislature in fostering University-Industry interactions and economic development.

He has an international reputation in the medical device/biomaterials research and industrial communities.

GREGORY'S
TOYS & ADVENTURES

March 15, 1991

Joseph D. Andrade, President
Protein Solutions, Inc.
6009 Highland Drive
Salt Lake City, Utah 84121

Dear Joe:

I was pleased to learn that Protein Solutions, Inc. is proceeding with its plans to develop a range of children's discovery products based on bioluminescence. I have reviewed your description of the proposed NIGHT-COLONY product and feel that it would be very popular with our customers.

As you know, Gregory's Toys and Adventures provides toys and related products for a broad audience. We also have a very significant educational component in our stores. As I am sure you are aware, the science area is one that continues to draw more interest from consumers as well as educators. It is a real growth category. Our clientele prefer products which are safe, sound, educational, and entertaining. Your proposed NIGHT-COLONY product meets all of these requirements.

We look forward to participating in the initial test marketing of NIGHT-COLONY, which I understand may be available as early as late in 1991, hopefully in time for the pre-Christmas season.

We will be happy to display and to feature your product in our local and out of state stores. We look forward to your continued progress.

Sincerely,

Greg A. Gohlinghorst
President, Gregory's Toys & Adventures

THE CHILDREN'S MUSEUM OF UTAH ™

Office of the Executive Director

26 August 1991

Dr. J. D. Andrade, President
Protein Solutions, Inc.
6009 Highland Drive
Salt Lake City, Utah 84121

Dear Joe,

I was pleased to review your BIO-LITE Proposal to the State SBIP Program. The availability of the technology which will be generated as a result of this project will greatly help you and me in our efforts to develop an interactive bioluminescence-based science exhibit in The Children's Museum of Utah.

The availability of this exhibit will of course provide exposure for your product and product ideas. We would also expect to be able to sell and distribute the product via our gift shop mechanism.

I look forward to continuing to work with you in the development of a complete set of bioluminescence interactive exhibits at The Children's Museum of Utah.

Good luck.

Very truly yours,

Richard R. Morris
Executive Director

RRM:bw