Department of Agriculture, Trade and Consumer Protection
Division of Agricultural Development
Agricultural Development & Diversification Program (ADD)
Grant Project Final Report

Contract Number: **ADD Grant File # 22053**

Grant Project Title: DATCP ADD Grant for Market Development for the Midwest BioLink Incubator

Amount of Funding Awarded: $38,000

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Please use the following questions as a guide for writing your grant project final report. In your final report, please answer each question as it relates to your grant project.

1) What was the original intent of the grant?

- **What did you want to accomplish with the grant?**
- **How was it expected to benefit Wisconsin Agriculture?**
- **What makes this project work important or significant?**

The original intent of PLANET LLC's DATCP grant was to provide market education, promote application acceptance, and create customer relationships that would result in revenue-generation for the first test rooms (Figure 1) of the future "Midwest BioLink Incubator" facility. The proposed project encompassed the tasks to continue the development and implementation of the Midwest BioLink Incubator (MBI) facility. The MBI will be a unique controlled environment facility that provides a biosecure setting for the development, test, and validation of high efficiency growth and production of plants modified to produce human, animal, and industrial proteins and commercial bio-agricultural manufacturing systems and protocols.

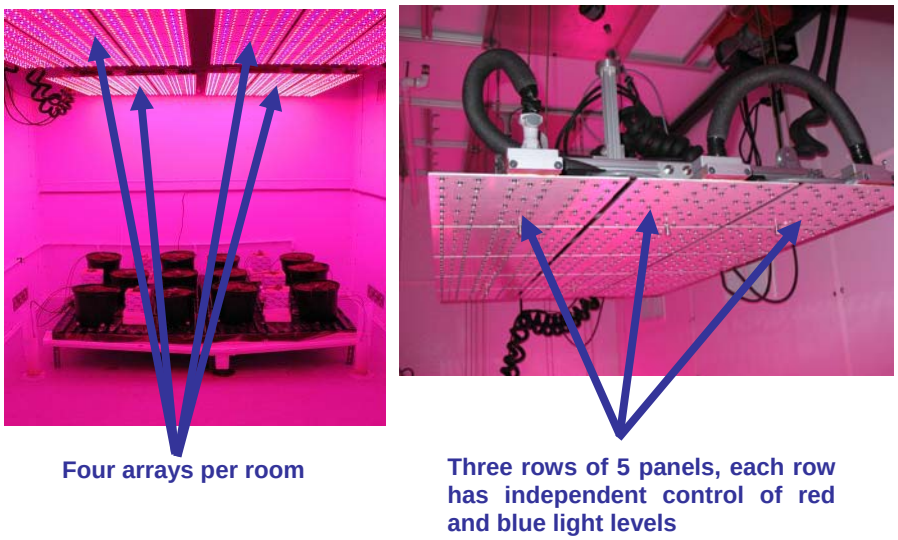


Figure 1. Layout of the LED lighting systems in the test rooms for the Midwest Biolink Incubator facility.

The vision for the MBI is to help develop a new category of Wisconsin industry focused on plant-made products in controlled agricultural manufacturing facilities. The estimates of total economic activity resulting from the MBI range from $50M to $150M within ten years. We believe that this activity will occur whether MBI exists or not; however, the MBI would help focus and sustain a large segment of this activity in Wisconsin.

The opportunities presented by the MBI are: (1) a self-sustaining operation, (2) new commercialized plant-made products, and (3) new commercially available agricultural manufacturing systems and services. The capabilities and knowledge base surrounding these activities, including the University of Wisconsin, are projected to spawn a focal point that lures businesses large and small to begin testing, launching, and producing new plant-made pharmaceuticals and industrial proteins in Wisconsin.

The specific tasks to be completed during this project included:

- Assignment of full-time resources to market and customer development, focused on creating partnerships with pharmaceutical and other bio-based product development companies and academic institutions that will result in the first customers for the Midwest BioLink Incubator. This ADD grant would enable expansion of these efforts to create more Wisconsin partnerships.
- Identifying and outlining the protocols that will allow the MBI to facilitate FDA approval for pharmaceutical customers.
- Develop the operating specifications for the first controlled environment rooms now being completed at Planet and ORBITEC, and finish necessary installations so they can be marketed as fully operational facilities for controlled environment agriculture.

With the assistance of the ADD Grant Program, PLANET LLC expected to be able to devote full-time resources to the launch of the test room phase of the MBI. This would significantly decrease the time-to-market for the future MBI facility, resulting in revenues for the state in advance of the proposed timeline in the business plan. The first test bed rooms could be marketed as world-unique controlled environment facilities for the pharmaceutical and bio-based plant manufacturing markets.

2) What steps did you take to reach your goal?

- **What worked?**
- **What challenges did you face?**
- **What would you do differently?**

Work on each of the three assigned tasks was conducted during the six month project; however it quickly became apparent that the development of FDA protocols was premature. PLANET was still in the process of completing, filling and testing the initial test bed rooms during the early portions of the project timeline, and until these tests were complete, authoring specific operations protocols for specific FDA substances was not going to be feasible. PLANET therefore focused a greater amount of time on Tasks 1 and 3.

Task 1

Task 1 was strictly to begin marketing and potential customer development. During the first month we updated our presentation of controlled agricultural manufacturing concept and accompanying slip sheet marketing materials. These materials were forwarded to two potential MBI users for review and feedback. We then completed a first pass market research report on manufacturers and developers of orphan drugs, with an emphasis on those that use plants for research or produce plant-made pharmaceuticals (PMPs, our initially perceived first target market).

With supporting materials prepared, one of PLANET's focuses early on for business development of the MBI was to find partners in protein extraction and processing. These capabilities will not be available within the MBI, but are important for customers for the downstream processing of the plant materials they produce in the facility. Our first customer visit was therefore to two protein extraction companies to review our capabilities and outline a future working relationship. Since these customers are also potential distributors of our technology products, they were interested not just in our services, but in discussing use of controlled environments with some of their select customers. Both were quite interested in helping PLANET co-locate a new controlled environment facility on their property or to place the facility in their state. They also provided information on attaining funding from a number of states outside of Wisconsin. This was not pursued at this time.

Over the course of the project, these two customers were visited again, and many teleconferences were held. Three months into the project PLANET and ORBITEC also accompanied a protein extraction company on a customer

visit, and jointly contacted another. Overall, they will provide continuing business opportunities and they show great promise for systems sales.

Our second marketing step in this task was to target potential users of the facility, rather than downstream processing partners. First we created a potential customer list for direct mailing from the attendee roster from the Plant Biology and Botany 2007 conference. PLANET exhibited at this conference in the summer of 2007 (prior to the start of the DATCP grant award period). We also researched the purchase of commercial market studies on PMP and plant-made industrial products (PMIPs) as another method to obtain direct customer contact information. Two months into the project we received a significant market research report from BCC Research on plant-derived drug products, technology and applications. This data was used to update our market pitch, and was combined with past research to produce a working list of top 10 potential customers. Work began on contacting these top customers, with the goal to receive letters of support to use for future investment meetings. Feedback was generally positive about the concept, but IP protection and location away from their R&D centers of greatest concern for use of the test bed rooms at PLANET. The technologies (LED lighting, control systems for minimizing energy consumption) received positive feedback, along with a high level of interest in PLANET/ORBITEC's own effort to produce plant-made spider silk protein in a CEA production system.

PLANET also attended the Bio Mid-America VentureForum in Milwaukee, Wisconsin on September 24-26, 2007 to present the concept for controlled agricultural manufacturing and the Midwest Biolink Incubator to three large pharmaceutical firms. These discussions, as well as our market research, unfortunately pointed away from this type of customer. Our research had showed that the best targets for this type of facilities will be university researchers and small biotech start-up companies in need of productivity gains and infrastructure support. This hypothesis was validated in our discussions at the VentureForum, where we learned that, for the most part, the big name pharmaceutical companies are too far downstream in the product development cycle to work on embedding proteins in plants for future delivery systems.

PLANET therefore decided to target local research firms. We created a mailing to over 70 plant biologists, botanists and bio-product researchers at the UW-Madison. The goal was to find a partner willing to provide case study information on the test-bed rooms at the PLANET/ORBITEC facility to begin in late 2007. This mailing produced no interest, so we scheduled instead a series of three meetings with Dr. Molly Jahn, the Dean of the University of Wisconsin College of Agriculture and Life Sciences (CALS) and other CALS representatives. The discussions centered on partnerships between PLANET and ORBITEC's efforts and the College. We made tentative plans to supply a controlled environment room into the Wisconsin Institute for Discovery that will align in the future with an offsite plant-based product production facility. These meetings will continue past this project timeline, and would be a major success in our implementation.

Another major market development effort focused on marketing to investors that could finance the real MBI facility. In October we prepared a business plan overview for controlled agricultural manufacturing technologies and submitted it to the Wisconsin Angel Network Investors' Track for consideration at the 2007 Wisconsin Early Stage Symposium. PLANET LLC was accepted as a presenter on October 25, and we had the opportunity to present our business plan on November 14 at Madison's Monona Terrace. During the two day event, PLANET LLC received both excellent investor contacts and valuable feedback on our presentation materials, executive summary and investor pitch. We collected a number of very promising leads and are continuing follow up with several. Directly following the event we also completed a submission for Pfizer's visit to Wisconsin (lead from the Wisconsin Early Stage Symposium) and updated our presentation materials and executive summary pitch based on feedback from the conference.

Our new summary and product pitch focused more on the "products" from the MBI compared with the facility itself. The message that is now shared with customers highlights the power savings and economic impact of solid state lighting for controlled environment systems. Using this approach, PLANET met with and received two requests for quote from two different potential customers late in 2007. One quote was for a prototype subsystem, and the other was for a large-scale implementation of subsystems with an option for a full system installation. Securing our first order for controlled environment subsystems would have been a success for this project and our own business plan goals. Both were submitted in late December with customer negotiations continuing into the spring, however neither orders were landed at the time of this report. We also continue to work with several component suppliers to find reduced pricing for larger quantity orders in an effort to become more competitive against current technologies in the marketplace we are trying to supplant. This also includes work that was done to create new unique payment terms and lease options for customers interested in purchasing our systems.

In the final month of the contract, PLANET exhibited at the 2008 Controlled Environments meeting held in Cocoa Beach, Florida on March 10-13, 2008. This is an annual meeting of two large communities in our target market, and provided excellent sales potential for our subsystems. At the conference PLANET displayed its two new commercial lighting systems for research and CEA, shown below in Figure 2. The Clip Light was released just prior to the start of the DATCP project, and the product development for the Twin Panel began in October 2007 for release in the spring of 2008. We received excellent pricing feedback during the conference, as well as several requests for a new series of plant lighting that expands the wavelengths into the far red. These new product developments will continue after the project is complete.

Figure 2. PLANET's new Sunbow Lighting Systems, the Twin Panel (left) for plant growth chambers and the Clip Light (right) for research

In conjunction with this conference we also placed an advertisement in the Membership Directory (Figure 4) and website (Figure 3) of the American Society of Plant Biologists. Other future marketing efforts that will continue outside of this contract include support of the BioIndustry Conference in Chicago in April, and BIO 2008 in June. We have also submitted a proposal to the USDA for value-added planning for tobacco-based Spider Silk.

Figure 3. PLANET's postage banner showing its new Sunbow logo

Task 3

Task 3 of our project was to produce specifications data and case studies of test bed rooms that can be used to establish our credibility and advantages with our customer base. Early in the project the first growth trial of tobacco in the test bed facilities at Orbital Technologies Corporation was planted, and four months later the second tobacco test trial started. Tobacco was chosen as the first test crop because it is commonly used in genetic transformations for protein growth in plants, and is a common research tool. The information was then used to define our baseline system specifications, and is detailed in the results portion of this report.

A third growth test was also completed using lettuce, which is another common plant used for plant-made pharmaceutical production. This test was also focused on a new product development design for supplemental greenhouse lighting. Lettuce was considered an important secondary crop since PLANET discovered (during their market research) a group at the University of Central Florida has embedded insulin in lettuce as a potential delivery system for diabetics. This group was contacted during the project, along with another start-up company, ALTOR, which also uses lettuce as a delivery system for cancer treating antibodies. Lettuce is also used as a potential delivery system for a number of vaccines in study.

Overall, our testing phase was successful, and we feel comfortable that we now have an appropriate amount of data to present to potential customers. In the last months of the contract we were also able to support, with other investment, the development of a very large-scale controlled environment facility at ORBITEC's Middleton location (Figure 14). At the conclusion of this project timeline the room is being outfitted with controls and lighting and will be able to begin testing later this year.

Figure 4. Full-page ad in the Plant Biology Membership Guide

3) What were you able to accomplish?

- **What are the results from this project?**
- **Include any analysis of data collected or materials developed through project work.**

The grant from the DATCP Add program was a significant help in validating our target customer base, beginning discussions with future partners, and identifying the gaps in our business plan that were holding potential customers back from investing. Most importantly, we were also able to discover the biggest technology, cost and security hurdles we need to overcome in customer proposals.

We also identified the need internally for continued focused personnel time, and identified a part-time biotechnology expert and business development resource to focus on customer sales. This person was to have concentrated on

support of plant growth trials and identification of leads, pursuing potential customers and providing market research support. The hiring of this resource would have been invaluable to the team, but unfortunately due to intellectual property (IP) limitations, we could not come to an employment agreement during the terms of the DATCP project.

IP continues to be a major hurdle in business development as well, with several major potential customers hesitant on using a third party facility like the MBI due to competitive concerns. This has driven us to focus customer development for the test bed rooms locally, and to move to system sales on a national basis. We also identified better cost targets for our systems and products, and have identified many ways in which we need to cut costs or offer different payment options in order to compete with inferior, yet much cheaper, alternatives.

Growth Trial Data and Results

In addition to the results of our market research, another significant accomplishment was the collection of technical data on our full systems and products. Throughout the project we completed a number of trial tests on our full rooms and new product developments that will be helpful in demonstrating our capabilities in a way acceptable to our scientific customer base. For example, the earliest tests in the project resulted in data on the control system functionality, shown below.

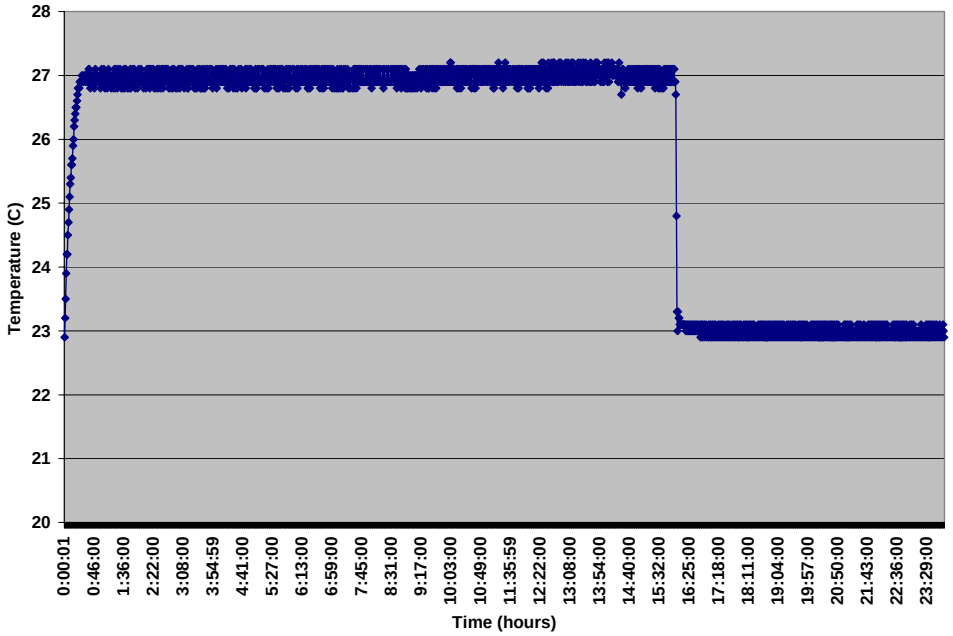


Figure 5. Diurnal Temperature Control

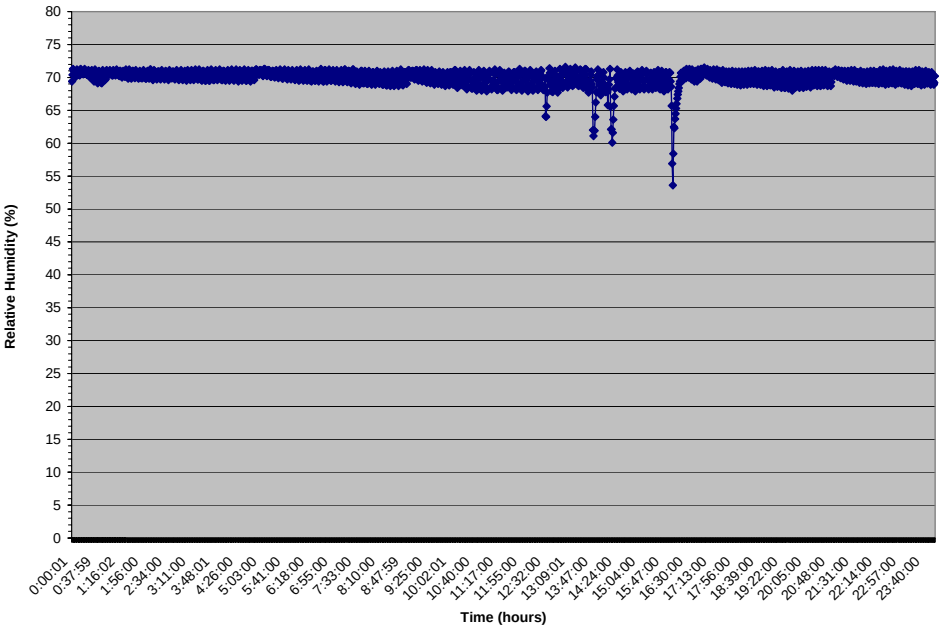


Figure 6. Humidity Control

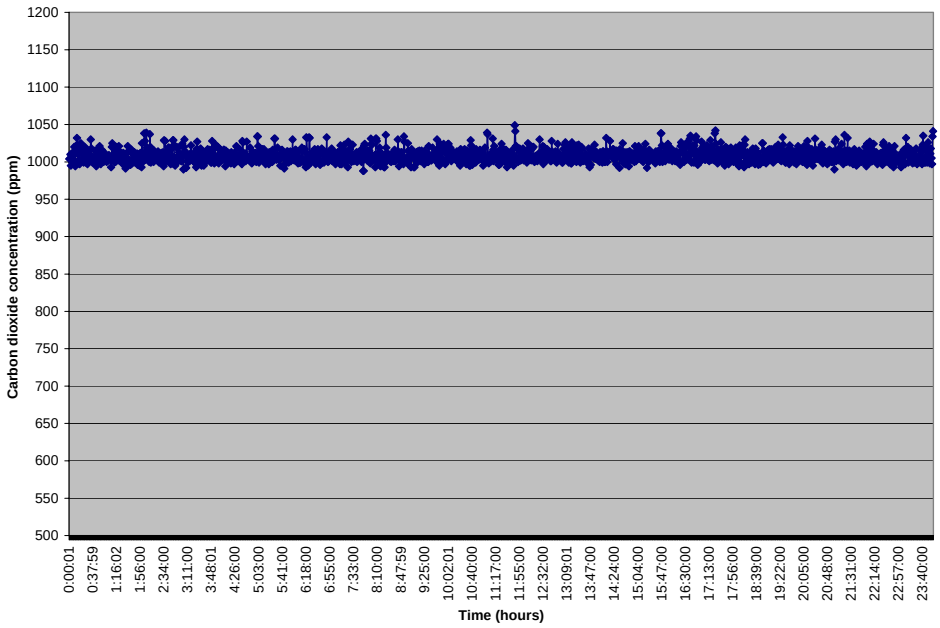


Figure 7. Carbon Dioxide Control

Figure 8 and Figure 9 show more visual examples of the test bed rooms during the second trial testing. During these tests completed near the end of the project, light uniformity was studied. The first test was done with all LEDs in each array at maximum power (Figure 10), resulting in poor light quality at the edge of the rooms. Several other lighting parameters were then tested, until a zonal setting could be found that gave uniform lighting (Figure 11).

Figure 8. Tobacco test trial, early growth stage.

Figure 9. Tobacco test trial, late growth stage.

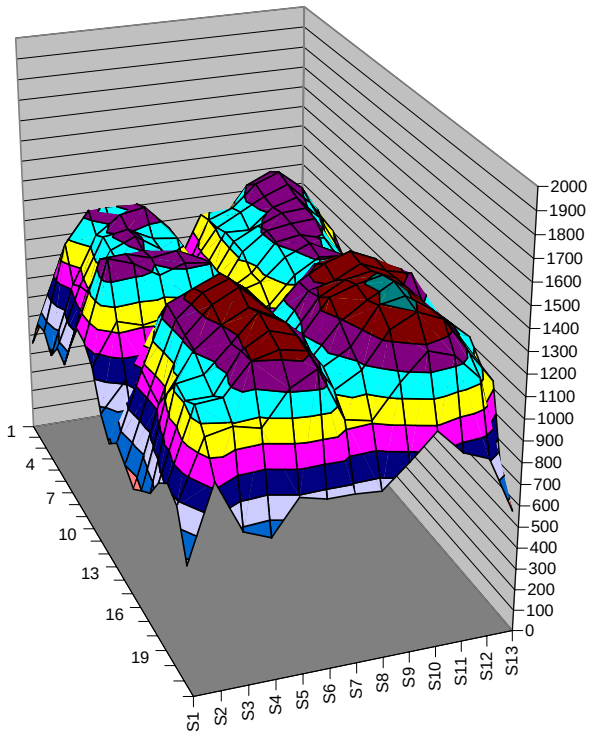
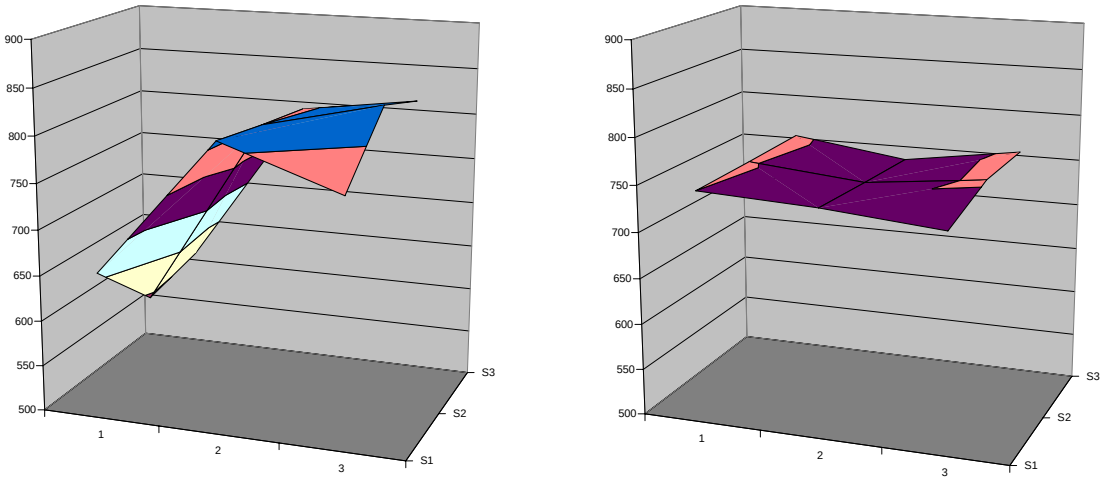


Figure 10. Light uniformity plot at maximum power.



All six zones set at “50” on control system

Zones set at “70,70,45,45,55,55” on control system

Figure 11. Subsequent lighting tests at reduced light levels (left) and reaching uniformity (right).

After lighting tests were complete, data was then collected on the leaf temperature under the LEDs. One of the great advantages of LED lighting is their reduced heat output compared to traditional light sources. Our ability to place the lights closer to the leaves translates to a very significant parameter for plant productivity, since the closer the leaves are to the light source the greater the amount of light energy they will absorb. Tests were conducted in the test bed rooms with a room temperature of 28° C and LED temperatures set to 34° C. Table 1 below shows the results indicating only a marginal increase in leaf temperature under LED arrays.

Table 1. Leaf Temperature Data

	Plants under powered LED array		Plants in same room under unpowered LED array	
Distance between plants and LED array	**Light Level (µmol m-2s-1)**	**Leaf Temperature (ºC)**	**Light Level (µmol m-2s-1)***	**Leaf Temperature (ºC)**
1 cm	**1680**	**29.4**	**12**	**26.8**
10 cm	**1450**	**28.7**	**40**	**27.2**
20 cm	**1204**	**27.8**	**45**	**26.9**
30 cm	**1061**	**28.4**	**40**	**27.4**
*** Spill over from powered array**				

The unique capabilities of LEDs can also significantly reduce power use over existing lamp types through the ability to operate in close proximity to plant tissue, the ability to optimize the light spectrum for productivity, and advanced control capabilities that allow optimization of lighting patterns. As an example, we prepared a comparison test between another 9 m^2 controlled environment room with 60 400 W HID lamps and our 9 m^2 controlled environment room with four 1.4 m^2 LED arrays. Both rooms were designed to maintain 1000 µmol m^{-2} s^{-1} of PAR at the plant canopy as the plants developed. Taking into account lamp ballasts and drivers, preliminary calculations indicate that the LED array provides ***three times more light output*** for the same watt of input power on an equivalent area basis (Table 2). This potential energy savings has become the primary selling point for PLANET's LED lighting systems, and a basis for a new sales revenue model as previously discussed.

Table 2. Energy savings for walk-in chambers providing 1000 µmol m-2 s-1 PAR at canopy surface

Case Study	**Lamp Type**	**"In situ" efficiency**
ORBITEC plant production room	Red/Blue LEDs	1.231umol/m2sec per W/m2
High light growth chamber	HPS/MH mix	0.285umol/m2sec per W/m2
Kennedy Space Center Biomass Production Chamber	HPS	0.417umol/m2sec per W/m2

The culmination of these tests was a 10-page specification document on the complete test room facility that can be sent to customers as a thorough capabilities overview. This document as available by request.

In addition to the tobacco trials in the test bed rooms used to collect system and product data, PLANET and ORBITEC also conducted trials of a new LED lighting configuration. Figure 12 shows the first of the lettuce test trials using bar-type supplemental LED lighting in red wavelengths only. This system using a liquid hydroponics technique in which leafy crops planted in bars with their roots suspended in a liquid nutrient solution. This particular LED system can be used as a stand alone system for crops that do not require blue light (e.g. lettuce), or it can be used to supplement solar lighting in a greenhouse setting. This is used during cloudy weather or during the seasons when daylength is short.

Another test conducted using lettuce was for an ebb/flow nutrient delivery system. The idea is to grow the plants in a particulate matrix using an ebb/flow nutrient and water delivery system, and then fluidizing the particulates when ready for harvest so that plants can be easily removed without cutting. This was the first test (Figure 13). The lettuce was planted through a plastic sheet. We flooded the bed and the lettuce lifted out. We need to improve the aeration system however. Also, we want to try planting the lettuce in a Styrofoam sheet which might float up on its own if the bed is flooded at harvest. Particulate based systems seem to be less susceptible to disease spread than liquid hydroponics, which is why we are looking at this.

Figure 12. Lettuce growth trials under prototype supplemental greenhouse LED lighting

Figure 13. Lettuce after growth trial in ebb/flow system.

Figure 14 shows the construction of the controlled environment facility at PLANET's Greenview location in Middleton where additional tests will be conducted in the future.

Figure 14. Large-scale controlled environment facility during construction in January 2008.

4) What conclusions can you make based on project work the analysis of collected data?

Our work on the MBI facility implementation during the DATCP grant period verified a number of technical advantages we suspected we held in the marketplace, while it also identified major competitive pressures we must address. Positively:

- We are still in the early stages of plant-made product growth and development, and a clear technology leader has not yet come forward.
- PLANET and ORBITEC's technologies currently offer the highest levels of light and control available to the high-value crop and research markets.
- There is excellent potential for working together with the University of Wisconsin, which could be a major pipeline for new business.
- Production of a high-value crop should be a primary focus for the company to demonstrate the capabilities and generate revenue.
- There are significant operating cost savings for our systems vs. traditional controlled environments.
- There are significantly higher levels of controls in our systems vs. traditional controlled environments.
- Preliminary growth tests show excellent production, but comparison studies are still needed on specific crops from potential customers.

Challenges to continue to work with:

- Our system and component costs at the prototype-stage manufacturing volume are a great deal higher than what the market is willing to pay.
- Protection of intellectual property is the most significant issue for facility rental, with location (non-local) secondary and related to IP protection concerns. In many cases this is a "deal breaker" for MBI facility use, while it enhances product sales.
- Current tobacco test trials will work as case studies and provide good energy efficiency data, but they will not provide comparable production rates (too species specific).

- Must have dedicated full-time business development resources to pursue capital investment and customer generation. This will require a not insignificant budget.
- Competing products are just beginning to emerge in the marketplace, especially for lighting. We must not hesitate or we will lose advantages.

5) What do you plan to do in the future as a result of this project?

PLANET and ORBITEC's work on the MBI and controlled environment products and services are still at the beginning stages of implementation. We have invested significant time and resources over the past three years to develop the technologies and market-based information we now need to successfully bring this venture to market.

We are currently working on an outside investment strategy and actively pursuing several interested firms that specialize in bio-ventures. We continue to apply for federal grants to conduct new research into technologies and applications for the facility, and will use investment capital to match these funds. (Our latest proposal is to the USDA for a Value-Added Planning Grant for spider silk embedded in tobacco.) Investment dollars will also be used for full-time business development support necessary to launching the MBI and increasing sales and marketing efforts for individual products.

Another avenue we are pursuing is the direct production of our own plant-made product. We have currently negotiated the rights to plant-made spider silk protein from a university partner on a current grant with the U.S. Army. We are looking for other sources of funding to support a pilot plant to produce industrial scales of spider silk, which is 1/3 the weight of Kevlar but half the weight. (Commercial products from spider silk fiber and fabrics include personnel body armor for the military and police, parachute cable, seat belts and other ropes and fibers.) Production of this plant-based protein would serve as an excellent demonstration of the MBI's capabilities while generating revenue immediately.

6) What information or additional resources are needed to commercially develop this enterprise?

With the completion of the test bed facilities over the course of this project, PLANET now has physical resources to conduct customer trials and demonstrations. At this point our number one need is for additional capital for business development resources focused on customer generation and investment to build a larger scale facility to support production of Phytosilk™ as a first product launch. We are also investigating partnerships with overseas manufacturers to reduce the cost of LED lighting systems.

7) How should the agricultural industry use the results from your grant project?

As discussed earlier, the use of controlled environments (CE) for agricultural manufacturing is a new method of traditional farming. The goal is focused production of proteins, medicines and other compounds that use plants as the growth media, rather than on the crop itself. CE manufacturing optimizes the growth parameters and cycles to produce the highest quality product while at the same time protecting traditional agriculture from the industrial and pharmaceutical crops used. Development and production in closed controlled environment facilities prevents the release of genetically modified materials into the environment, prevents cross contamination with food crops, and protects high value transgenic crops from contamination by wild plants or field crops at the same time it allows new high-value crop products to be introduced.

This means that no environmental harm results from this method, and it can also reduce the carbon footprint needed for production. The basic nature of the controlled environment is "green," integrating: (1) biosecure environments for growth, (2) energy saving lighting and control systems, (3) water recycling and reuse, and (4) planning for full use of entire biomass products (including partnering with ethanol producers and/or production of methane).

The use of CE also means that agricultural production can also be independent of climate and location. This can lead to year-round high-value crop production in rural or urban areas, creating a new revenue stream for areas of the state hit hard by reductions in traditional manufacturing. Year-round optimized growth is also ideally suited to new product development, where CE can be used as a tool to hasten the development of new varieties or products that aid traditional agriculture. The benefit of using plants for agricultural manufacturing is that CEA facilities can be placed in any rural or urban areas where jobs are needed, employees are available, and other resources are economical.