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Developing and Commercializing Sustainable New Wood Products

A Process for Identifying Viable Products



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Abstract

A process was designed to evaluate the sustainability and potential marketability of USDA Forest Service patented technologies. The process was designed and tested jointly by the University of North Carolina, the University of Michigan, Partners for Strategic Change, and the USDA Forest Service. Two technologies were evaluated: a fiber-based product and a wood fiber/fiberglass composite technology. The results indicate several different ways in which the technologies might be exploited to produce new commercial products for both domestic and international markets, through licensing of the patents and other agency/industry partnerships. This report represents the initial effort by the Forest Service to work in partnership with business schools to evaluate the commercial potential of patented agency technologies and locate potential licensees and cooperators interested in utilizing the technologies. The Forest Service will seek additional cooperative ventures with university business schools to develop business plans for other patented, but as yet unlicensed, technologies as the next step in the process of commercializing these technologies.

Keywords: fiber-based products, wood fiber/fiberglass composite

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SI conversion factors

English unit	Conversion factor	SI unit
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
square foot (ft^2)	0.093	square meter (m^2)
cubic foot (ft^3)	0.028	cubic meter (m^3)
pound (lb), mass	0.454	kilogram (kg)

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Developing and Commercializing Sustainable New Wood Products

A Process for Identifying Viable Products

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Introduction

This report documents the process and results of a Masters of Business Administration (MBA) course taught at the University of Michigan, School of Business, and the University of North Carolina, Kenan Flagler School of Business. The course was taught with the support and substantial involvement of the USDA Forest Service, in particular the Forest Products Laboratory (FPL). This project benefited from the commitment and involvement of Janet Stockhausen, Patent Advisor for the Forest Service, and Richard Guldin, Staff Director for Science Policy, Planning, Inventory, and Information for the Forest Service in Washington, D.C. Their support is greatly appreciated.

This MBA course was part of an innovative project undertaken in collaboration with the Forest Service Patent and Licensing Program, which is responsible for maintaining the patents and licenses of inventions developed at the FPL. The project was initiated in late 2001, and the MBA course was conducted in the winter term of 2002. The course was presented in collaboration with the Corporate Environmental Management Program (CEMP) at the University of Michigan and the Center for Sustainable Enterprise (CES) at the University of North Carolina. Gordon A. Enk taught the course at both institutions and is deeply indebted for the assistance of Cyndy Cleveland and Kellie McElhaney at the CEMP and Monica Tousenard at the CES.

The FPL has a long tradition of developing new products and processes to improve the utilization of wood and wood products. It was established in 1910 and currently involves more than 250 researchers and scientists. The FPL focuses on research and development in pulp and paper products, housing, and the structural uses of wood. It also conducts substantial research on the use of recycled fiber in the manufacture of paper and wood-like products. In many instances, the inventions and innovations discovered by the FPL staff are patented.

The Forest Service Patent and Licensing Program is responsible for granting licenses for the commercialization of new products and processes to public institutions and private corporations. In recent years, the program has explored the mechanisms that result in the successful commercialization of products licensed by the Forest Service. This project was related to this effort to increase the understanding of successful commercialization and focused on two products, Spaceboard and Fiberglass-Reinforced Wood Products.

These two products served as the key "case studies" for a course taught in the MBA program at the University of Michigan School of Business (UM) and the Kenan Flagler School of Business of the University of North Carolina (UNC). The course was taught simultaneously at both schools during the winter term (January and February) of 2002.

Course Design, Students, and Key Participants

Seven MBA students participated in the course at the UM and ten participated at UNC. The UM group included a substantial number of "executive education" students who were completing their graduate degrees while working in full-time professional positions; several had responsibilities dealing directly with new product development in their companies. All the UNC students were full-time, and six were citizens of foreign countries. This provided a uniquely international flavor to the class. The course included both individual and team assignments, which were identical in both courses.

The course description and syllabus are presented in Appendix I. The course design was based upon a proprietary model for New Market Identification and New Product Development developed by Partners for Strategic Change in Seattle, Washington. This approach incorporates the learning of more than 30 years of work on the effective development, technology transfer, and commercialization of new products.

The course included substantial involvement of key representatives from the Forest Service and FPL. Janet Stockhausen made presentations and participated in several class sessions at both schools. This included a review of U.S. patent law and practice, an overview of licensing practices, a review of the patents for reinforced wood products (RWP) and Spaceboard, and an overview of the mission of FPL (see Appendix II for list of RWP and Spaceboard patents). Robert Ross and John Hunt, resident scientists at FPL, provided students with an understanding of the researchers' perspective and their approach to new product development. Finally, Richard Guldin provided an overview of the mission of the Forest Service and the role of the FPL in that mission. Stockhausen and Guldin participated in the review of the students' findings and recommendations on Spaceboard and RWP.

This course was designed to be focused, practical, applied, and based on a case study approach. The course design included several key components:

- A review of selected literature focused on the practical aspects of successful development and commercialization of new products
- A practical understanding of the approach to new product development in the forest products industry
- A review of the concept of "sustainability" and a working model of how to evaluate the sustainability of new products
- The opportunity for the students to directly interact with professionals involved in the scientific, legal, and organizational aspects of new product development and commercialization
- The opportunity for the students to design a preferred model for effective new product development and then apply that model to a case study
- The opportunity for the students to evaluate the commercialization potential of two patented products

The results of the course are contained in the written assessments developed by the three student teams. The students described a "model process" for new product development and their preliminary assessment of the commercial potential of Spaceboard and RWP. Each team developed a Business Plan that included their assessment of the commercial potential of Spaceboard and RWP and their approach to commercialization.

Course Benefits

The editors will allow the students' "products" (final papers) to stand on their own. The students were direct and straightforward in their assessment of the commercial potential of Spaceboard and RWP. This section summarizes the editors' perspective on the "findings" or "learning" from this course.

In recent years it has become popular to talk about the "take aways" when analyzing a lecture, article, or case study in a Business School setting. The take-aways from teaching this course included the following.

- These MBA students were uniquely interested in the *theory and practice* of new product development and commercialization. They were particularly interested in and drawn to the team-based or "*scrum*" approach to new product development that simultaneously involves team members from the technical/scientific, marketing, and manufacturing parts of a company. They could see the folly and inefficiencies of a linear or "relay race" approach to new product development.
- These MBA students were excited by the notion that it was meaningful and appropriate to evaluate the potential of new products through the lens of the *triple bottom line*, that is, with equal consideration to the criteria of environmental quality, social equity, and economic profit. The concept of the triple bottom line as utilized in this course was based upon the contributions and writings of John Elkington.
- Many of the MBA students expressed excitement about evaluating the potential of new products from the perspective of the products' total *sustainability* as measured by the triple bottom line. The students had little or no problem identifying with the notion that, unless a product meets the criteria of the triple bottom line, it will not be sustainable, and if a company does not make products that are sustainable, then products are very likely not sustainable. The concept of "sustainable design" of products as utilized in this course was based upon the contributions and writings of William McDonough and Michael Braungart.
- Many of these students, especially the students from foreign countries, felt liberated by the notion that they could and should evaluate the true commercial potential of a company's products based upon more than just the products' impact on the financial bottom line.
- Finally, it was challenging and exciting to teach an MBA course to students who were interested in the topic and excited about taking a balanced "total system" approach to analyzing the potential of new products.

University of Michigan Team

Business Plan for the Commercialization of Spaceboard and Reinforced Wood Products

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Executive Summary

Sustainable Product Solutions (SPS), of Detroit, Michigan, is a company committed to providing consumers with ecologically sound products and services to enhance their lives. SPS analyzes new business concepts using the triple bottom line. The triple bottom line takes into consideration the financial, environmental, and social effects of a product or service.

SPS is currently pursuing venture capital funding for the commercialization of Spaceboard, a patented three-dimensional pulp-molding technology developed by the United States Department of Agriculture, Forest Service, Forest Products Laboratory. SPS is looking to market non-packaging applications of Spaceboard. Specifically, SPS is targeting the Office Furniture manufacturers and the Architecture & Design (A&D) community for use of Spaceboard in partitions.

SPS will make Spaceboard out of recycled paper collected from Detroit. The use of this renewable resource lessens the impact of Spaceboard on the environment. Moreover, the dry process for manufacturing Spaceboard is not energy intensive, furthering its environmental benefits. Furthermore, SPS plans to build the Spaceboard manufacturing facility in inner city Detroit, thereby bringing much needed jobs and tax revenue to the city.

Given the sustained growth in the Office Furniture industry and the interest in the A&D community for environmentally friendly products, SPS believes that there exists a large opportunity for the commercialization of Spaceboard. Spaceboard provides great advantages over fiberglass products by reducing the health hazards involved in manufacturing. The environmentally safe and sustainable properties of Spaceboard give it an advantage over non-traditional specialty synthetic composite fiber products. While the costs of Spaceboard are currently somewhat higher than that of the current products used in office partitioning, SPS will focus on developing a market with allergy clinics and other environments where health is a serious concern. Creation of partnerships with innovative magazines and trade associations in the A&D community will produce the volume demand and necessary pull market to make Spaceboard profitable. In the long term, SPS hopes to pursue additional applications and the bottom of the pyramid applications for Spaceboard, using renewable resources in communities across the world.

In addition to Spaceboard, SPS had considered the commercialization of Reinforced Wood Products (RWP). Due to our environmental, social, and economic analysis of the sustainability of RWP, we have decided not to proceed with the commercialization of RWP. Rather, SPS intends to focus all energy on the successful commercialization of Spaceboard.

Vision

Sustainable Product Solutions (SPS), of Detroit, Michigan, is a company committed to providing consumers with ecologically sound products and services to enhance their lives. SPS analyzes new business concepts using the triple bottom line. The triple bottom line takes into consideration the financial, environmental, and social effects of a product or service.

Financial Bottom Line

SPS will only pursue products that clearly demonstrate long-term profitability in market analysis. This will be achieved by developing new environmentally friendly products for both the ecologically conscious community and the average consumer. SPS's products will focus on efficiency and quality, giving them an edge over existing products. SPS has developed a protected market position by licensing a family of patents for a product called Spaceboard that is produced using a unique manufacturing process. After SPS establishes a domestic market, it will explore additional domestic applications such as those listed in Appendix A and at the bottom of the pyramid opportunities. Bottom of the pyramid products would be inexpensive, quality products for the benefit of the two-thirds of the world's population who earn less than $1,500 per year. Although returns from individual sales in this market will be small, the market is very large. This would allow SPS to earn abundant financial benefit while providing a needed product for the masses. SPS believes its overall success is rooted in superior economic performance and sustainable growth in both domestic and international markets.

Environmental Bottom Line

The environmental bottom line is focused on both the product and the manufacturing process. Products should be made of recyclable or renewable resources and the product itself should be easily recyclable. SPS strives to produce products that can be made from wastestream materials such that new products can be created at lower costs and can reduce landfill materials. SPS will also leverage Design for the Environment processes by evaluating natural resource and energy use throughout the product lifecycle.

SPS is also concerned with how its manufacturing will affect residents in the areas where it gathers raw materials and operates its factories. SPS intends to manufacture in a way that minimizes hazards to human health. SPS will require its manufacturing sites to limit effluents and noise. Manufacturing facilities will be built to blend in with their environments in an aesthetically pleasing way. Ultimately, the environmental bottom line of SPS is to enhance and protect natural environments and habitats while preserving the rights of current and future generations.

Social Bottom Line

Social impact is among the very first considerations SPS will make. Before determining where to locate a factory, SPS will look at unemployment rates, living conditions, and educational opportunities of a region. SPS will select areas to manufacture based on where it can make the greatest contribution to society. SPS can alleviate unemployment rates by hiring and training unemployed workers. It can improve living conditions by paying its employees a fair wage and sharing the profits. Finally, SPS can improve educational opportunities in the area and for the area's residents by donating a portion of its profits to support education. This charitable contribution could be donated directly to the public schools in the area, used for scholarships for the children of its employees, and used to fund educational grants for local public schools and colleges.

SPS would encourage its employees to become active in their communities. Their long-term goal is to provide each of its employees paid time off to perform community service and to fund the projects in which its employees participate, such as cleaning up local parks and building new recreation areas for children. SPS believes in community involvement because its corporate success is intrinsically tied to the success of its employees. Providing opportunities for all employees to continually strive for excellence while being contributing members of their communities is key to this overall success.

Together, the three branches of the triple bottom line form a sustainable company. The triple bottom line method of new product and new business development will allow SPS to be profitable while working in an ecologically conscious manner and contributing to the betterment of society.

Spaceboard is one product that fulfills the corporate objectives of SPS. Spaceboard is manufactured using a patented three-dimensional pulp-molding technology that has been licensed along with its non-packaging applications (U.S. Patents 4702870, 4753713, 5314654, 5198236, 5277854, and 6190151) from the United States Department of Agriculture, Forest Service, Forest Products Laboratory. SPS is initially looking to market Spaceboard to Office Furniture manufacturers and the A&D community for use in partitions.

Market Opportunities for Spaceboard in Office Furniture Industry

Industry Description and Outlook

The target Office Furniture industry is traditionally a slow growth, but stable, industry concentrated in western Michigan. The industry is environmentally conscious and is always seeking nontraditional materials to reduce its environmental impact and improve performance. The industry is

Table 1—Value of U.S. Office Furniture shipments, 1990–2000

Year	Value of Office Furniture			
	Current dollars		Constant dollars	
	Value ($\times 10^6$$)	Change (%)	Value ($\times 10^6$$)	Change (%)
2000	13,285	8.50	7,320	7.10
1999	12,240	–0.90	6,832	–1.10
1998	12,350	7.80	6,910	8.20
1997	11,460	14.1	6,384	13.40
1996	10,040	6.40	5,631	3.50
1995	9,435	6.60	5,438	3.00
1994	8,850	8.50	5,280	4.20
1993	8,160	5.80	5,065	3.90
1992	7,710	6.70	4,876	6.90
1991	7,228	–8.10	4,560	–10.40
1990	7,863	0.40	5,087	–2.80

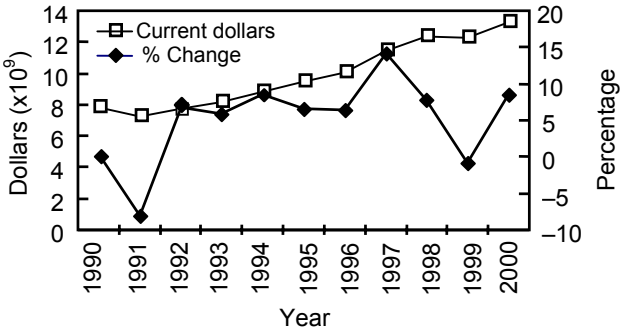

Figure 1—Value of U.S. Office Furniture shipments, 1990–2000.

continually looking for ways to add value to their products through the use of technology and environmentally safe products.

The U.S. Office Furniture market is large and has been growing (Table 1, Fig. 1). Furniture industry growth, however, is projected to decrease over the next few years reflecting the current slowdown within the U.S. economy. Downsizing within many Fortune 500 companies has reduced demand for new Office Furniture. Although this reduction in demand is somewhat mitigated by the growth in the market for small and medium-sized companies, overall these smaller companies purchase have reduced per capita quantities of Office Furniture. In addition, noticeable shifts are occurring in Office Furniture preferences, manifesting in the increased popularity of refurbished or remanufactured furniture and ready-to-assemble (RTA) designs. Together these factors are creating a downward pressure on the new U.S. furniture market (Table 2). Despite this slowed growth in the Office

Table 2—Forecasts for U.S. Office Furniture market, 2001–2002

Year	Volume ($\times 10^9$)	Change (%)
2001	$ 10.914	–17.8
2002	$ 9.952	–8.8

Furniture industry, the potential market is still large and holds great possibilities for products that provide differentiation in the way that Spaceboard does.

Limited differentiation between manufactures has defined the Office Furniture market by price and customer service rather than product attributes. Opportunities for improved profitability exist in generating increased differentiation, cost containment, and operating efficiencies.

Target Markets

Given the competitive environment for Office Furniture, both the Architecture & Design (A&D) community and Office Furniture manufacturers are looking to differentiate their products from the masses. Spaceboard, used as a sustainable alternative material in Office Furniture, specifically partitions, will fill this niche. Spaceboard provides the acoustical and strength properties required for office panels and eliminates the health concerns associated with existing products. Therefore, SPS intends to target the A&D community and the Big Three Office Furniture manufacturers to market new, "green" office partitions made from Spaceboard.

The target market can be segmented into two markets, the A&D community and Office Furniture manufacturers. The A&D community is more environmentally conscious and less cost sensitive than are Office Furniture manufacturers. The A&D community also drives the trends and specifications for building materials and Office Furniture, so they can create a pull demand. The Office Furniture manufacturers are cost sensitive, yet environmentally conscious to some extent and cater to the demands of the A&D community. Given this relationship, Spaceboard will appeal to the furniture manufacturing community as a unique and environmentally sensitive product.

Additional follow-up markets exist. To see a list of those SPS has identified, refer to Appendix A.

Competition

The Spaceboard partition core application is intended to replace the separate subcomponents (fiberglass sheet and acoustical board) with a single unit (see App. B). Competitors are considered suppliers of these subcomponents.

Fiberglass sheet is typically supplied directly from the fiberglass manufactures and non-traditional specialty synthetic

composite fiber manufacturers. The U.S. markets for these materials are dominated by a small number of large manufacturers: Owens Corning, Saint–Gobain (CertainTeed), John's Manville, Knauf, and Thermafiber. Overall U.S. insulation industry revenues in 2000 were $6.8 billion (billion as$10^9$) and growing at an annual rate of 3.2% (National Insulation Association 2002). These companies have leveraged the economies of fiberglass production scale into products for a variety of applications in addition to the office partition industry. Several companies within this industry, most notably Owens Corning and Johns Manville, have filed for Chapter 11 bankruptcy protection reflective of asbestos-related liabilities (Owens Corning 2000). Although breakdown of revenues within individual business segments for each company was not conducted, the emphasis on the building and automotive industries within press releases indicates the office partition segment is not a major revenue driver (Owens Corning 1999). No major public company was found deriving a substantial proportion of revenues from the partition panel market. Minimal existing competitor response is anticipated to Spaceboard's entry into the fiberglass sheet partition panel market because of the low proportion of business constituted by the partition panel market and the industry's large vested interest in existing manufacturing.

The acoustic panel market is dominated by the same companies that are active in the fiberglass sheet market, although the market is much more fragmented. In addition to these mineral fiber based product offerings, the acoustical panel market does have a more environmentally sustainable alternative from a company called Tectum. The vast majority of Tectum's product line is focused on the ceiling panel market, but a complete wall panel system containing sustainable materials is available. Limited knowledge is available on this privately held company, and it is not known what value the wall panel market contributes to their total income. This company must be regarded as a potential threat within this market, especially given the similar market positioning. However, the threat appears to be minimal. Despite a 50-year history of producing essentially the same product, the product is 2 to 4 times the cost of mineral-based products (BuildingGreen 1998). It is questionable if Tectum could maintain economic competitiveness with Spaceboard products.

Strengths and Weaknesses

Spaceboard provides great advantages over fiberglass insulation by reducing the health hazards involved in processing the end products, eliminating any risk of end user exposure, and eliminating exposure during recycling operations at the end of the product life cycle. Fiberglass mats utilized with office partitions contain warnings within the Material Safety Data Sheet (MSDS) about the health risks of fiberglass exposure, including most notably a reference as "possibly carcinogenic to humans" (MSDS 2000). An increasing number of end users are becoming aware of the effect of interior environment of their wellbeing and the potential risk of airborne respiratory size fiberglass fibers. This is in turn placing pressure on manufacturers to consider more environmentally benign materials. This potential liability is motivating partition manufacturers to eliminate fiberglass, especially the cutting of, from their production processes.

An additional strength of the Spaceboard Partition Panel application is the replacement of several subcomponents with a single unit with the obvious savings in assembly labor. Additionally the need for subassembly bonding adhesives is eliminated, especially important to the allergen-sensitive target markets.

A weakness of Spaceboard is that it has not undergone feasibility acceptance per tests defined by the Business and Institutional Furniture Manufacturers Association (BIFMA). These standards are intended to provide manufacturers, specifiers, and users with a common basis for evaluating safety, durability, and the structural adequacy of the specified furniture, independent of construction materials (BIFMA 2002). These test standards are generally accepted as the determiners of acceptance for materials used in the business furniture industry. Although Spaceboard is currently untested, given the current accepted use of similar materials (medium density fiberboard, chipboard, and other wood-based materials) there is no reason to believe the standards would preclude use of Spaceboard.

Cost is the most significant disadvantage of Spaceboard. Fiberglass insulation and acoustic panel manufacturers benefit from large-scale processes while the state of the art process for Spaceboard is an inherently inefficient process still in its infancy. A comparative analysis of partition panel manufacturer cost expectations and Spaceboard indicates approximately a $\$3/ft^2$ versus $\$1/ft^2$ cost disadvantage for Spaceboard (Janet Stockhausen, Forest Products Laboratory, personal communication) (Table 3). It is estimated that the majority of the industry will accept upwards of a 15% increase in partition core costs in exchange for elimination of the fiberglass liability. However, current Spaceboard production processes and scale does not support economic feasibility in the partition panel core board market. At minimum, a scaling of the existing wet-form production process, or more likely an implementation of new production process based upon a dry form technology, is required to meet the cost targets. The strategy outlined in the following section is

Table 3—Comparative cost analysis of Spaceboard and partition core

	Product cost ($)	Area (ft^2)	Cost/ft^2
Spaceboard	90.00	32	2.81
Partition core[a]	14.96	15	1.00

[a]Current competitive cost.

anticipated to enable development of capabilities to eventually participate in the lucrative Big Three furniture manufacturers market.

Competitive Strategy

Anticipating that early production processes will be insufficiently optimized to compete directly with mass market competitors, a three-stage strategy will be undertaken to eventually develop required efficiencies and economies of scale:

1. Spaceboard will be initially positioned as an alternative to partition panel core boards that contain fiberglass and adhesive, for individuals hypersensitive (allergic) to traditional particulate and gas emitting units. Allergy clinics or other environments frequented by individuals with a compromised immune system will be targeted in this stage. The severe consequences of noncompliance of these facilities to their unique requirements are expected to drive a value proposition sufficient to support current production process efficiency ($2 to $3/ft^2).
2. Cashflows from the initial secured market will be used to finance a second generation of production process that supports expanded market presence through emphasis upon general environmental friendliness and sustainability. Through partnerships with innovative magazines and trade associations in the A&D community, product features such as recycled fiber content and favorable energy intensity will be emphasized to the public, in addition to the already established improved air quality. It is anticipated that by the end of the second stage, Spaceboard will be established within the influential A&D community as the required component within office furniture utilized by the environmentally conscious market that supports superior indoor air-quality.
3. Finally, continued development of production efficiencies and leverage through economies of scale will enable production economies sufficient to challenge majority-market competitors for supply to the Big Three furniture manufacturers. Reputations established in the first stages, combined with patented processes, will enable superior margins. Once these cashflows are established, the alternative markets can be addressed (App. A).

Spaceboard Product Description

Spaceboard is manufactured using a patented three-dimensional pulp-molding technology that has been licensed along with its non-packaging applications (U.S. Patents 4702870, 4753713, 5314654, 5198236, 5277854, and 6190151) from the U.S. Department of Agriculture, Forest Service. Spaceboard provides the acoustical and strength properties required for office panels, the first application pursued by SPS.

Spaceboard Operations

Facility Location

As part of its vision for social responsibility, SPS will locate its facility in a low-income community. Given the need for a large quantity of recycled material and the need to be close to Big Three furniture manufacturers, SPS has chosen to locate its facility in Detroit, Michigan. This location will provide jobs for local residents as well as much-needed tax revenue for the city. SPS also believes that the city and state government will have an incentive to aid SPS in establishing its business in the city, because it will offer not only employment benefits, but also environmental benefits.

Michigan currently has a 16% recycling rate, which is behind the average of 26% for Great Lake States, as reported by BioCycle in their 12th annual nationwide survey, which examined disposal, incineration, recycling, composting, and wood recovery activities (Michigan Recycling Coalition 2002). Michigan's recycling rate falls behind states in all six of the other national regions except the Mid Atlantic, which has a 15% average. SPS would help Detroit increase its recycling rate by purchasing recycled paper thereby encouraging the paper recycling process, which would benefit the city and the state.

Manufacturing Facility

The SPS manufacturing facility will be built in an aesthetically pleasing way. It will use some solar power (amount yet to be determined), low energy lighting, and low energy heating and cooling systems. It will also use best available technology to reduce effluents and waste. Ultimately, the environmental bottom line of SPS is to enhance and protect natural environments and habitats while preserving the rights of current and future generations.

Raw Materials

Spaceboard will be made out of recycled materials collected from Detroit and the surrounding suburbs, thereby ensuring a sustainable and renewable resource stream. The wastestream that would contribute to the manufacturing of Spaceboard would decrease paper incineration and increase wood recovery activities. Recycled paper products are available in the Detroit Metro area and generally cost less than the national average (Recycling Manager 2002). Use of recycled paper prevents forests from being wastefully cut, uses less energy than does the logging of standing forests, keeps waste out of landfills, and is less polluting than the harvest of virgin trees (Lind 2002). SPS will also make every effort possible to ensure that the products will be recyclable, working with both its suppliers and buyers to

create environmentally friendly fire retardants that will facilitate recycling of Spaceboard at the end of its lifecycle.

Research & Development

Research and development is still required to ensure the product meets standards and specifications required by BIFMA. Since our strategy is focusing on a niche application, the time and resources required for research will be lower than if targeting multiple applications.

Employment

SPS wants its employees to feel a sense of ownership and community. Therefore, SPS will institute profit sharing. In addition, SPS will provide paid time off to employees to pursue community service in inner city Detroit. SPS will also donate a percentage of its profits to support education. This charitable contribution could be donated directly to the public schools in the area, used for scholarships for the children of its employees, or to fund educational grants for the local public schools and colleges. SPS will form a board of employees to distribute the funds. SPS believes in community involvement because its corporate success is intrinsically tied to the success of its employees. Providing opportunities for all employees to continually strive for excellence and contribute to their communities is key to SPS's philosophy.

Spaceboard Opportunities and Risks to Triple Bottom Line

Environmental Considerations

As discussed in detail throughout this report, Spaceboard has significant environmental opportunities. The most important of those include the following:

- Spaceboard uses recyclable material that is both a sustainable resource and contributes to waste reduction.
- SPS will focus on using a low energy "dry" method of manufacturing.
- SPS will work with its suppliers and buyers to develop fire retardants that maximize recyclability at the end of Spaceboard's life.

Economic Considerations

A significant amount of research and development has already been put into Spaceboard. It is already patented, which will help protect the manufacturing process as the business is launched. Also, Spaceboard has the potential to be a disruptive technology, especially to that portion of the world's population that is hypersensitive to chemicals and particulates put into the air by existing Office Furniture products. There are no competitors playing in this niche, which will help SPS become the leader in this industry. Other applications for Spaceboard apply to the bottom of the pyramid, and this product has potential in international markets (App. A). The biggest concern is the fact that the current processing creates a product that is more expensive than what the total market might be willing to bear. However, the initial target market segments that the Office Furniture manufacturers can capitalize upon, allergy clinics and the like, are likely to be willing to pay more for a product with minimal health concerns. In addition to this segment there are many other applications for Spaceboard, which helps make this a sustainable product.

Social Considerations

There are many social benefits that arise from Spaceboard. One of the most important is based on the location of the plants. Jobs will be provided in low-income areas that will include a fair wage and profit sharing that will provide an incentive for employees to stay with the company. This will also provide tax revenue for these low-income areas to help build up their communities. SPS will be active in donating and supporting local communities with philanthropic efforts.

Analysis of Reinforced Wood Products

At first glace, there appeared to be a need and market for reinforced wood products (RWP), especially in the areas of home improvement and security. However, after further analysis, the product does not appear to be sustainable on the environmental, social, and economic fronts. Thus, SPS will not be pursuing it as a potential product.

Environmental Considerations

Though there are inherent benefits to RWP, such as the use of new growth wood, the main ingredient in these products is fiberglass. Fiberglass is considered by many to be toxic and dangerous to humans and it is not biodegradable. While the finished product will not have heath risks, the process to make the product will expose workers to chemicals and fiberglass particles. Also, using fiberglass will make the product nonrecyclable. Wood treated with reinforced wood products will also become nonrecyclable. While the treated part of the wood could be cut out and the remainder recycled, the reality is that few people are willing to take the time and effort needed to do such conservation. In addition, the chemical industry is energy intensive.

Economic Considerations

RWP is already patented, but there is limited time left. Though the cost of the fibers and raw materials is low, RWP is a nondisruptive technology; it is more of a product enhancement. RWP would enter a crowded market; there are

many other products on the market that consumers will look to first when thinking of both home improvement and security. For home improvement, the application is defined as strengthening for wood, primarily for reinforcing cutouts. Consumers already use products such as metal plates and plastics when making cuts in wood. Builders will be extremely cautious about using RWP to lessen wood usage in trusses, because there are no historical data to support the safety of this practice. In addition, the company producing such a product will face an up-hill battle in convincing building inspectors that this process is safe and in getting building codes changed to support use of the product. To further develop this product, multiple alternative markets would need to be found, but even with additional markets, sustainability in a crowded market seems limited.

Social Considerations

While RWP may provide increased security when used to reinforce doors and windows, it will not be perceived as the best way to secure one's home. Steel doors and bars over windows are better crime deterrents. Moreover, although production of RWP would provide some employment, the economic analysis indicates that the employment would be unsustainable over the long term because the product is unsustainable.

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Appendix A—Additional Potential Market Segments and Uses

Automotive applications (base material for components)

- Headliner
- Rear shelf panel
- Spare tire cover, trunk floor
- Door trim panel
- Instrument panel
- Energy-absorbing material for areas with head impact concerns

Aircraft applications

- Tray tables
- Storage container construction
- Interior walls
- Food and drink carts

Other applications

- Manufactured homes
- Disposable cafeteria trays (substitute for Styrofoam trays)
- Temporary housing in military/refugee camps
- Replacement for plywood (especially where weight is a concern)
- Drywall
- Toys (e.g., walls for build-your-own "quick connect" playhouse)
- Pallets
- Replacement for hardboard
- Construction of housing and schools in developing nations
- Signs

Appendix B—Current Partition Core Sub-Assembly Descriptions and Specifications

Partition Core Sub-Assemblies

Description	Specifications
Molded surface assembly	
Molded surface fabric composite	Polyester backed fabric
Acoustic core	
Synthetic textile pad	0.310 in. thick, 50 g/ft^2
Chipboard	0.60 in. thick 0.2 lb/ft^2
Panel door	
Door inner structure	Wood/fiberboard/hardboard
Sight/sound barriers	PVC
Fiberglass	7 lb/ft^3
Marker board assemble	
Markerboard surface	High pressure laminate
Markerboard and tackboard core	Industrial insulation board, 15 lb/ft^3
Adhesive	PVA glue 1002–5000 and air products

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Spaceboard: The Future is Here

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Executive Summary

The purpose of this business plan is to provide the Forest Products Laboratory with a business model of how to explore the commercialization potential of Spaceboard. This plan is written from the perspective of consultants advising Forest Products Laboratory. Spaceboard is a product capable of transforming several industries, including pulp and paper, wood, agricultural, construction, furniture, and lumber. Spaceboard can be constructed using virgin or recycled fiber to produce various three-dimensional structures. Spaceboard can be used as a substitute for the tons of wood harvested each year for structures. Financially, given the ample availability of raw materials and moderate capital investment required to develop a processing plant, Spaceboard presents a viable investment.

Given the usage of fiber, Spaceboard can be customized to the end user's performance criteria for maximum strength or effectiveness. Spaceboard production is energy intensive but environmentally friendly if the product is not mixed with any synthetic compounds. The end result is a multipurpose product that has the potential to be a disruptive technology. Given the competitive nature of Spaceboard's ecosystem, the Forest Products Laboratory offers a licensee the following opportunities to increase shareholder value and gain market share:

1. Be first to mass market Spaceboard with potential multiple generation designs
2. Be first to achieve full volume production with the design
3. Be competitive in industry race between falling market prices driven by fragmentation and falling costs driven by volume
4. Deter new entrants and competitors through a family of patents

Spaceboard can be used in the construction, furniture, packaging, audio electronics, and agriculture industries. Such flexibility is due to the variety of agricultural, wood, and industrial fibers that can be used to produce Spaceboard. Identified applications include pallets, packaging goods, audio speakers, material for musical halls and production studios, furniture panels, floors, decks, walls, roofs, marine structures, and plant beds.

In the interest of time we narrowed the focus of our business plan to a single application of Spaceboard—pallets. We did not address potential applications in the agricultural and marine industries, for example. However, in the Industry Market Research and Analysis section of the business plan we explored the construction, furniture, and corrugated containers industries as well.

In the United States, most landfills are no longer accepting wooden pallets for disposal and yet millions of pallets are

introduced yearly. Spaceboard presents a unique opportunity for a company to creatively destruct the pallet industry with innovative products. Pallets produced with Spaceboard offer the following characteristics: as strong as wood, lightweight, customizable, nonhazardous, recyclable, and produced from recycled fiber.

Fiberglass-reinforced wood products (RWP) represent an extension of an existing product and are not as environmentally friendly as Spaceboard. Spaceboard has more commercialization potential and opportunities than do RWP because Spaceboard could be considered a disruptive technology.

Construction, Furniture, Packaging, and Pallet Industries

History of Spaceboard

Spaceboard was developed and originally patented in 1987 by the USDA Forest Service, to be used in the field of structural wood components. The product and process were upgraded several times, and the last patent was issued in 1994. The original patent will expire in 2004; until then, the Forest Service pays fees to maintain the patent. The Forest Service can license companies to make applications of Spaceboard, charging fees (execution, maintenance, and royalties) for each application, negotiable case by case.

Product Characteristics

Although Spaceboard was originally produced with wood fibers (new or recycled, from hardwood or softwood), it can actually be produced with any fiber. This flexibility is very important, especially in reducing the effects of pulp market prices in the raw material costs, because the main raw material can be easily changed.

The production process is also very flexible and can be customized to meet product specifications. The process can be wet or dry, continuous or batch. Several additives can be used to increase strength, waterproof, or finishing, although a sheet of Spaceboard made of wood fibers without any additives is 100% recyclable. The whole process can be implemented following almost all concepts of sustainability, except if chemicals are used to increase product properties or if drying is needed (high level of power consumption).

The size and shape of each sheet of Spaceboard is customizable, increasing the number of possible applications, including non-flat surfaces. A typical sheet of Spaceboard has one flat side and a honeycomb structure on the backside. The honeycomb increases the strength in the direction normal to the sheet, without adding much weight compared to that of solid wood. This strength level can be adjusted based on the fiber used, the production process, and the width and height of the honeycomb walls.

The honeycomb structure has other important features, including thermal and acoustical characteristics. The air-filled spaces inside the honeycomb can provide thermal isolation. The honeycomb also weakly reflects audio waves and can be used to mitigate noise.

Additional information on Spaceboard is given in Appendix A.

Potential Applications

The customization capability of Spaceboard added to its physical properties allow it to be used in a wide range of applications, both as a substitute and as a complementary product, and production could be targeted toward niche or mass markets. Applications could be categorized in three broad categories: Construction, Furniture, and Packaging/Pallets.

Spaceboard can be used in the Construction market mainly as a substitute product for walls, doors, floors, ducts, or stairs. The high strength/weight ratio is the key success factor in approaching this market. Spaceboard could substitute for plywood, hardwood, or concrete, because it is more sustainable and less expensive than these materials. Its ease of handling, customization capability, and light weight makes it possible to construct a house in a short time without requiring special machinery, tools, or skills. In this application, Spaceboard would serve as a complementary product and could be used as a temporary solution for housing needs in poor communities, in places devastated by natural forces (hurricanes, earthquakes), or for military use. It also can be used in niche markets like aeronautic and naval applications, where the heaviness of the entire structure is critical.

In the Furniture market, Spaceboard could serve as a substitute for products made of steel and wood, like tables, shelves, and boards. Its light weight makes it very useful for portable or single-use furniture. The ability to shape Spaceboard into many forms and multiple finishing possibilities makes this product very attractive for modern furniture design.

In the Packaging/Pallets market, Spaceboard presents a high-value added solution because of its strength/weight properties. The physical characteristics and recyclability of Spaceboard enable it to be substituted for typical packaging/pallet materials, such as wood, paper (corrugated cardboard), plastic, and steel. Compared with wood, Spaceboard has a better strength/weight ratio and can be made in any shape, reducing assembly workload and the need for nails. Compared with paper, Spaceboard is more resistant to weather conditions (waterproof) and supports heavier weight. Compared with plastic and steel, Spaceboard is more easily recyclable and environmentally safe; for military use, it retains less radioactivity than does steel.

Market Assessment of Applications

Construction market

- Market size: US$30.6 billion/year in 2000 (*National Home Center News*)
- Predicted annual growth: 1% (U.S. Census Bureau and Deutsche Bank estimates)
- End users: Construction companies, tradesmen, and "do-it-yourself" people
- Substitute product: For hardwood flooring, wall panels, roof panels, marine and aeronautic structures
- Distribution channels: Direct sale to construction companies, retailers, wholesalers
- Customer characteristics: Price sensitive, commodity driven
- Market characteristics: Fragmented, high entry barrier, competitive
- Geographical clustering of competitors: Spread across the United States

Furniture market

- Market size: US$5 billion/year in 2000 (Furniture Research Institute)
- Predicted annual growth: 3% (Furniture Research Institute)
- End users: Furniture manufacturers, tradesmen, and "do-it-yourself" people; major U.S. markets for household furniture are the metropolitan areas of New York, Chicago, Los Angeles, and Washington, D.C. (Furniture Research Institute)
- Substitute product: For low and mid-range furniture
- Distribution channels: Sole dealers, independent dealers, superstores, mass merchandisers, office discount, wholesalers, public purchasers, direct sales; distribution system is quite a complex aspect of the U.S. office furniture industry, as the growing trend towards cheaper and simpler products has determined growth in the number of distribution channels existing within the sector (Furniture Research Institute).
- Customer characteristics: About 60% of office furniture demand is accounted for by big purchasers; this share is not expected to grow in the next 2 years, while significant increases are expected for SoHo and home office products; price sensitive (Furniture Research Institute)
- Market characteristics: Concentrated, high entry barrier, competitive
- Geographical clustering of competitors: High degree of concentration (six companies account for 50% of the market), mainly in North Carolina and South Carolina

Packaging/Pallets market

- Market size: US$4 billion/year in 2000 (Industrial Resources, Inc.)
- Predicted annual growth: 1% (Industrial Resources, Inc.)
- End users: According to the *National Wooden Pallet and Container Association*, no one economic indicator can predict the demand for pallets because of the diverse end-use sectors and national variations of seasonal and cyclical trends. However, the grocery and food industry does account for roughly a quarter of all pallets used.
- Substitute product: For wood, plastic and steel pallets (96% of pallets purchased in the United States come from trees); boxes, tubes, cushions
- Distribution channels: Direct sale
- Customer characteristics: price sensitive, commodity-driven; high demand for customizable products (There are more than 400 different sizes of pallets used in the U.S. alone.)
- Market characteristics: Fragmented, highly competitive; recycling considered to be the fastest growing and most profitable segment of pallets
- Geographical clustering of competitors: Spread across the United States

Market Analysis

Industry Analysis

The USDA Forest Service estimates there are 1.9 billion wooden pallets in the United States. Of these, one billion pallets are in use, 175 million pallets have been repaired or recycled, 225 million have been completely discarded in landfills, and 100 million have been abandoned or lost. An estimated 2,800 U.S. establishments are currently manufacturing wooden pallets, with total annual sales of $3 billion in the United States and $400 million in Canada (Industrial Resources, Inc.).

Market Demand

Approximately 420 million new wooden and plastic pallets are purchased each year (USDA Forest Service). The end-user consumer comes from a variety of industry sectors, which are largely comprised of distributors and retailers of consumer products and building materials and the U.S. military. Any entity interested in shipping bulk or heavy

goods is a potential consumer of pallets. Issues faced by these consumers with regard to pallets are centered on the financial drain of having to repeatedly replace or repair broken pallets and the environmental impact of discarded pallets. Industry surveys show that 50% of pallet users expect to purchase more pallets in the next 5 years (Industrial Resources, Inc.).

Pallets are a necessary component when transporting goods. It is clear that the wooden pallets industry is growing, with trends indicating a two-fold need for recyclability. The cause for these trend is the volatile cost of lumber the increased focus of society on environmental concerns. First, consumers are looking for more durability. The demand for plastic pallets has been on the rise; usage increased from 3 to 4 million units in 1995 to 10 to 13 million in 2000. That number was expected to increase to 20 million by the end of 2001. Multiple-use pallets have reached 30% of the market share, compared to just 5% in 1985 (Industrial Resources, Inc.). Some companies specialize in repairing damaged wooden pallets. It is evident that consumers are interested in extending the life cycle of the pallet for economic reasons. Therefore, consumers would welcome the cost savings that would be afforded by a stronger pallet. Second, as evidenced by the 325 million discarded pallets in the United States, there is a problem with disposal of damaged wooden pallets. This is considered a serious problem at shipping ports, where an abundance of damaged wooden pallets have piled up. Most pallets are used once and then discarded. Given this waste, there are boundless environmental benefits to having reusable pallets and pallets made from recycled material since 96% of pallets purchased in the United States are made of wood. In response to environmental concerns, the recycling sector is growing at a rapid pace. In the past 3 years, wooden pallets that had been used or damaged were recycled 30% more often than in previous years (Industrial Resources, Inc.).

Customer Analysis

As mentioned previously, the end-user consumer comes from a variety of industry sectors, which is largely comprised of distributors and retailers of consumer products and building materials and the U.S. military. Any entity engaged in the transport or storage of bulk, heavy goods, or equipment is a potential consumer of pallets. Ownership of pallets changes frequently as pallets are often not returned to the entity originating the shipment.

Competitor Analysis

Michigan and Pennsylvania have the highest concentration of pallet manufacturers in the United States. The majority of manufacturers are located near heavy manufacturing areas (Industrial Resources, Inc.). However, one competitor—IFCO Systems North America—is located in Houston, Texas, and is one of the largest pallet recycling companies in the United States. This company was able to generate $229 million in revenues from pallet services in fiscal year 2000, providing a complete range of services for pallet management, from sales, supply, and storage through back dock management, reconditioning, and disposal. Through this well-rounded value-added approach to serving its customers, IFCO was able to generate a 12% operating margin on this business alone in fiscal year 2000.

Other major players include Potomac Supply Corporation and Pallet Management Systems Inc., which generated $89 million and $72 million in revenues in fiscal year 2000, respectively. These companies also specialize in providing a well-rounded value-added approach to serving their pallet customers. On top of offering variety in customization options, these companies offer distribution and logistical services targeted towards solving such industry-wide issues as disposal and return transport. Presumably, this "whole product" offering enables such companies to be industry leaders. (See Strategic Market Assessment for explanation of concept.)

As a result of the growing concern for recyclability, pallet manufacturers will increasingly specialize in extending the life of the wooden pallet or introducing substitute materials. For that reason alone, the competitive landscape for the pallet manufacturing industry may exhibit significant change in the next 5 years. This may lead to an increase in mergers and acquisitions, as companies try to build capacity to meet the new demand for recyclability, which will require increased investments in new technology that many small companies will not be able to afford on a stand-alone basis.

Channel Systems

The general infrastructure that supports the pallet industry demand stems from a variety of sources. A majority of industry players have taken advantage of the Internet by offering services ranging from a wealth of information on their product offerings to exclusive, online pallet information management systems that facilitate pallet inventory management and pallet retrieval. Another center of consumer and pallet manufacturer exchange is the National Wooden Pallet & Container Association (NWPCA), an international trade association representing manufacturers, recyclers, and distributors of pallets, containers, and reels. This organization endorses members (pallet manufacturers) and supports industry needs. A majority of pallet manufacturers are members, so when a customer, for example, visits the NWPCA website they are provided a wealth of information on pallet design possibilities and suppliers. Other methods for industry participants to reach consumers are through local broker networks that are embedded in manufacturing communities. Larger customers may organize their own pallet manufacturing or distribution centers.

Strategic Marketing Plan

Strategic Market Assessment

Given the necessity for transport of bulk goods, pallet manufacturing will continue to be a high volume, commodity business. The industry is highly fragmented, where pallet manufacturers locate themselves closest to consumers. Location has been a critical competitive advantage for pallet manufacturers because of low cost and the reorder demands of small-scale consumers. However, for large-scale consumers, location is not as much a necessity. Rather, large-scale consumers demand a distribution infrastructure that supports this scale. In this case, a pallet manufacturer's membership to the NWPCA may facilitate a large-scale consumer's search for affiliated pallet manufacturers or large-scale pallet manufacturers like IFCO Systems.

To drive sales in this market, many pallet manufacturers have developed a "whole product" offering geared towards attracting consumers from competitors and to addressing market needs such as two-fold recyclability. The whole product concept describes a range of supplemental services (i.e., reverse distribution and logistics services) designed to satisfy needs associated with the use of a particular product, coupled with customization of the product to suit the needs of the consumer (i.e., custom labeling or pallet design). (Note: Geoffrey Moore describes this concept in detail in *Crossing the Chasm*.) This approach enables barriers to entry to be created by competing pallet manufacturers, as manufacturers who offer less services get blocked from acquiring new customers and lose opportunities to serve large-scale consumers. The whole product offering by today's pallet manufacturers targets a reduction in replacement and repair costs and environmental concerns. For some companies, offering repair services and reverse distribution and logistics services accomplishes this. Facilitated by high technology and the creation of management information systems, pallet service offerings have grown. However, environmental concerns have not been completely addressed by this industry. Many steps have been taken to increase pallet life cycle, as evidenced by the growing popularity of plastic pallets and treated wood; one chemical used to treat wood is extended polystyrene (EPS). However, wooden pallets remain a customer preference, signifying the need to find better solutions to curtail the negative environmental impact of wasted wood and non-recycled wood.

Product Analysis

Using Spaceboard to create a pallet satisfies what the industry is looking to offer its consumers in terms of durability, life cycle costs, and environmental responsibility. However, a more tangible differentiating element to Spaceboard, aside from the competitive advantage afforded by the patent, would be the added benefits to the pallet manufacturer and consumer. The pallet manufacturer benefits in terms of streamlined production that creates potential for reduced labor and increased safety for its employees, while the consumer benefits from the light weight and versatility of the product.

Structurally, Spaceboard will create a pallet that is in fact stronger, easier to produce, and versatile than wooden pallets. This product has a higher strength to weight ratio compared with that of wooden materials, while weighing much less. To increase the strength or durability further, synthetic fibers can also be incorporated into the Spaceboard manufacturing process. Additionally, the product is uniformly strong, given its three-dimensional characteristics. A pallet manufacturer may find this three-dimensional feature beneficial because it may streamline the manufacturing process, given that this material can be designed and formed to near net shape with fewer processing steps. This also creates an avenue to improve employee safety since no nails are required, reducing splinter injuries. Many of these benefits will be translated into consumer savings. Fewer repairs resulting from structural integrity, lower shipment and recovery costs (lighter weight), and the elimination of volatile material costs (lumber prices) can reduce initial and overall life cycle costs for the consumer. Furthermore, the design versatility that Spaceboard affords creates boundless opportunities for a pallet manufacturer to capitalize on and for consumers to customize the product to their needs.

From an environmental standpoint, Spaceboard provides the solution that the industry is looking for. First of all, Spaceboard reduces the need for virgin fiber and cutting down old-growth forests. Second, depending on customer specifications, the product can be made without resins that contain formaldehyde. Third, it can be made from 100% recycled materials. These factors, coupled with the reusability afforded by the strength characteristics of Spaceboard, provide a well-rounded alternative to address the environmental issues faced by wooden pallet manufacturers.

The structural and environmental benefits of Spaceboard will create a significant competitive advantage for any company licensed to use this technology. To successfully capitalize on this, the company would have to create a whole product offering that satisfies the demands of the product's life cycle. This will include building a distribution infrastructure that is cost effective for both small- and large-scale potential consumers and offering a pallet information management system (PIMS) that is accessible to consumers. A PIMS will enable consumers to get a greater return on their pallet investment and, as a result, consumers will reward the company that does this best with renewed business. Therefore, there is potential to build a brand name, where consistent quality and service will be trusted most to yield cost savings. In a commodity driven market, this aspect will be critical when patent protection expires.

Tactical Marketing Strategy

Product

The Spaceboard pallet should be marketed as the premium-quality product that it is. All differentiating benefits must be outlined for consumers to see the value added to their respective business by purchasing Spaceboard pallets. To be a viable substitute product that competes successfully, the Spaceboard pallet must be offered as a whole product.

The Spaceboard pallet must be offered as customizable to satisfy not only industry specifications but also consumer needs. To build on this, custom labeling, painting, and logo branding or stenciling must be offered. Also, packaging accessories (including bubble packs, shrinkwrap, strapping, bags, and tape) must be offered at a discount when consumers choose Spaceboard pallets.

A PIMS is another product dimension that must be offered to Spaceboard pallet consumers. Consumers want to know pallet inventory levels at their facilities, pallet retrieval data, pallet handling specifics, and surplus pallet disposal figures. This consolidated information will provide a greater return on pallet investment for consumers by lowering management costs, reducing handling costs, and minimizing lost pallets. Building on this competency, a Spaceboard pallet manufacturer (the company) must also offer reverse distribution and reverse logistics services. This way, the benefits to using Spaceboard pallets will extend beyond what industry competitors are successfully offering. The Spaceboard pallet consumer must know that the company's service offerings are consistent, with quality unmatched anywhere.

Price

Given that this product is substituting a commodity product, there is little room for major mark-ups to communicate the premium-quality message. Spaceboard pallets will be offered at a slightly higher (approximately 7%) price. Product benefits must be strongly communicated to justify the higher cost, and a cost savings analysis for the estimated useful life will be a critical tool. In addition, the company must become a member of NWPCA, as this will endorse the product's worth.

Promotion

The design versatility and light weight of Spaceboard pallet must be exploited. A few consumers should be offered a free customized trial sample period. Customers to receive a free trial should be selected based on the potential for the largest sales volume. Results of customer trials should be advertised at trade shows and in NWPCA publications. At this level, opportunities to build the brand name will emerge as the company's whole product delivery is proven. Discounts can be offered on first orders.

Location

Distribution channels must mimic that of competitors, while gaps in industry distribution are thoroughly explored. While the lightweight aspect of Spaceboard may alleviate distance barriers created by high shipment costs, it may be necessary to open a small distribution center in a highly concentrated consumer location.

Design and Development

Cost Analysis

The present study is a first approach to define the feasibility of the project and was developed as simply as possible to facilitate the sensibility analysis. Considering the quality of the information gathered, we recommend a later enhancement to improve the accuracy of the analysis.

The first assumption is about the pallet geometry, settled with the standard width and length (48 by 40 by 6 in.). Two densities are employed in the weight estimate: dried pulp density (750 kg/m^3) and Real Space Occupied (15%), which take into account the empty space inside Spaceboard, depending on the width and arrangement of the honeycomb.

Administration is usually considered as a fixed cost, but here it will be treated as 4% of the sales. The capacity of the plant is 45 pallets per hour working at full load, but the early months will operate under capacity, not only by the curve of market penetration but also by the learning curve, which is considered in efficiency to calculate every quarter in the cash flow analysis (see Appendix B). At 45 pallets/hour, two 8-h shifts, and 25 days/month, 216,000 pallets will be produced per year, signifying almost 0.05% of market share for each plant.

Variable Cost

Fiber—Fiber could be a mix of virgin and recycled, since the virgin fiber improves resistance and recycled fiber reduces the cost. Both types of fiber tend to have significant variations in price, but it is assumed a fixed price of $90/ton for recycled and $400/ton for virgin. An optimal blend is settled with 90% recycled and 10% virgin. The price is estimated at $121/ton and fixed for the next 10 years.

Thermal Energy—The most efficient system comes from a co-generating process, where the steam employed to dry the pulp is the residual energy in a higher energy system (i.e., electric generator). Therefore, it would be very convenient to place the Spaceboard facilities near a large factory like a pulp mill or a thermoelectric plant to take advantage of low energy, which is sometimes wasted by such facilities.

Steam yield, in terms of heat consumed to dry a ton of pulp, depends of many factors that are out of the scope of this study but could be summarized in pressure, temperature (saturated steam is more efficient), heat transfer efficiency,

ventilation and general efficiency of the system (including heat and condensation recovery). The most common system to generate steam is the boiler, which is usually fed by hydrocarbons, whose price is linked to the variations of the international oil price. As such, an assumption of 3,000 steam lb, at $\$9/10^3$ lb @ 80 psig, yields the cost of drying at $27/ton.

The easiest and most expensive way to generate steam in this case is to erect a new boiler fed by oil or gas. However, another source of energy could be analyzed, such as biomass, sawmill, bark, and other industrial waste with low thermal efficiency at a lower price.

Taking into account other facilities required by the whole manufacturing process and the investments required, the best option would be to build the Spaceboard plant inside an underutilized paper mill (which is not too difficult to find). This way, it is possible to start with low investment risk when employing the cleaning, refining, and feeding systems available in the wet end.

Electric Energy—Electric energy will be required to power machinery, pumps, refiners, and vacuum systems for the formation, pressing, and drying of Spaceboard. An index of 660 kW·h/ton was chosen to determine how much electric energy is required; the price of 4.62 cents for each kilowatt hour (kW·h) is the average in the United States over the past 10 years for the industry. Although there are big differences among states, the price for every state has been more or less stable.

Fixed Cost

Amortization—It is considered that an original investment of $2 million would be enough to build the plant next to an existing recycled paper mill to produce the amount of pallets stated in the previous text. The debt has 10 years to be paid and is assumed at an interest rate of 3.5%.

Labor—The level of machinery at the plant will determine how many employees are required. For the assumed investment just mentioned, three workers would need to be hired to operate the plant, at $20/h each. The total labor cost would be $480/shift. The wage of $20/h is estimated by averaging holidays, insurance, benefits, etc. It is assumed the plant will be closed on Sundays.

Manufacturing and Operations Plan

Raw Materials

Spaceboard has the potential to make use of the aggravation caused by wood in the packaging and shipping industry. Spaceboard was invented as an alternative application for short fiber/hardwood that was dumped into the landfills. As short fibers were not reusable in the papermaking process, the scientists decided that compression molding process could make some useful product.

1. This technology could significantly enhance the basic Chapman Process of hardboard production to create a product exhibiting strength characteristics comparable to that of wood.
2. The blend can consist of 90% recycled and 10% virgin fiber.
3. In a molded forming process, a panel (4 by 8 ft) of Spaceboard can be produced efficiently in up to 1-in. thickness; it can then be fabricated to make shipping pallets.

Geographical Location

Given the necessity of recycled wood and high consumption of energy, it would be advisable to locate the facility in close proximity to an area where recycled wood and energy are easily accessible. There are two options for locating the plant:

1. Near a large factory like a pulp mill or a thermoelectric plant in to take advantage of low energy
2. Inside an underemployed paper mill, given the fact that it is possible to minimize the risk by employing the cleaning, refining, and feeding systems available in the wet end.

Manufacturing Process

Putting aside all other techniques used to make composites, using a silicon and stainless mold is the critical operative in setting Spaceboard technology. Many forms of recycled and post-industrial waste fiber can be used as the raw material.

1. A simple, proven, and inexpensive production line can be established to generate several hundred panels of Spaceboard per day.
2. The concept uses pulped furnish from old corrugated board or other recycled paper destined for the landfills.
3. By distributing a layer of furnish (slurry of raw material fiber) over the proprietary mold, the system extracts the water out of the sheet of Spaceboard to form a 4- by 8-ft molded hardboard sheet.
4. The sheet then goes through a “cold” press to remove water. The final stage requires a steam-heated, multi-opening press to physically form the furnish in the shape of the mold and then heat it to “bone dry” while pressing at 150 lb/in^2 for shape, strength, and hardness.
5. Once the sheet is made, fabricators will cut the 4- by 8-ft sheets into appropriate segments and then glue them into the final product form.
6. Stacks of the final product will be shrink-wrapped and shipped to the customer for immediate use.

7. A unique 3D fiberboard of structural molded fiber (SMF) needs to be applied.

Spaceboard manufacturing considerably reduces the amount of energy required to produce an "equivalent product" if there had been a requirement to make the product from wood. The final consideration for manufacturing is the significant reduction in use of wood that occurs when displacing wooden throw-away products with recycled paper in the form of Spaceboard.

Management Team

Not applicable to this business plan.

Critical Risks, Problems, and Assumptions

Industry Risks

In our research, the only potential direct competitor is Sonoco. Sonoco has a license from the Forest Products Laboratory (FPL) for packaging application using Spaceboard. Headquartered in Hartsville, South Carolina, Sonoco is a global manufacturer of industrial and consumer packaging products and provider of packaging services. The company views itself as a leader in the packaging goods industry. Given the exclusive licensing arrangement to which FPL subscribes, we do not view Sonoco as a direct competitor. However, nothing prevents Sonoco from pursuing other licensing agreements from FPL since the company already manufactures and sells pallets. The company could be a formidable competitor given its financial standing and global operational reach. Its mission statement and most recent annual report suggest that the company will continue to focus on growth through acquisition and double-digit growth.

Other primary competitors are the wood and plastic pallet industries. We see no reason why a licensee of Spaceboard cannot compete in this environment. With the existing competition, entrenched industry ties, and positioning, we would not be able to price compete with them in the market. Rather, we will compete on the superior attributes and potential value of Spaceboard.

Company Risks

The company will have to contend with the issues of expiration of Spaceboard's family of patents, new market entrants such as plastics, and patent infringements from competitors. To protect against any intellectual infringements, the company may need to take legal action against companies that unfairly use the licensed patent for Spaceboard.

Personnel Risks

In terms of acquiring and producing Spaceboard, the two biggest personnel risks in our view are underestimating the cost of engineers, designers, and technical workers. The company needs to compensate these employees fairly, and depending on the regional location of facility, the competition for hiring them will be fierce. The company can respond to employee financial needs by operating a sustainable enterprise. Financially, compensation packages should includes stock options, 401(K) plans, and profit sharing. Socially, the employees should be offered an ergonomic, safe, and nontoxic work environment. The company should be responsive to the needs of the community and not waste resources by discharging pollutants into the environment and water supply.

From an expansion perspective, as the company grows quickly they may struggle to find quality workers on the market who can learn the business quickly unless the company already has overcapacity. Another issue is addition of new customers who require customized products. This will further challenge employees and expansion efforts.

Market Appeal

The company's biggest challenge is to effectively communicate the value of its product—specifically, how Spaceboard adds value to not only the customer but also the "triple bottom line." Another obstacle is to sustain the staying power of Spaceboard in the market.

Timing Risks

As with any product, Spaceboard could probably end up as a niche product because the mass market is not ready for such a technology. However, due to government regulations, for example, the pallet or another industry such as construction may be forced to look for new sources of raw material in their production process, thereby giving Spaceboard mass market appeal.

Financing Risks

Financing risks are not applicable to our business plan. However, the financial risk for the company will depend on credit terms and contracts with customers, as well as on how effectively account receivables are handled and whether favorable payment conditions can be obtained from creditors.

The Financial Plan

The size and location of the production plant or plants along with the product line mix will influence the financial plan. If Spaceboard is licensed to an existing company, such as International Paper, with already existing capacity and re-

sources, then some items discussed in this section on the Financial Plan will be irrelevant. In this case, the company will be concerned with acquiring equipment and working capital. However, if we were advising a start-up company interested in producing Spaceboard, we would suggest securing funding through a combination of angel investors, family, and friends. The following typical arrangement could be devised. Management would contribute cash equal to a determined amount per founder. Equity shares equal to 25% of authorized shares would be issued to investors in exchange for cash. Managers would own a combined percentage of the company equity. The company could be formed as a corporation, with authorization to issue shares of par value stock. To attract employees, the remaining shares in the company could be reserved for employee recruitment, retention, management bonuses, and future investors.

Long-term debt financing would be secured for capital equipment purchases used by the company. Under current market conditions, the loan should bear an interest rate less than 11% and be collateralized by the capital equipment. Rental equipment such as office furniture could be financed through a revolving loan agreement. The value of the loan would equal the original purchase price of the equipment and the revolving debt secured by the rental equipment. Working capital would be financed through a line of credit not to exceed a predetermined amount.

The company is free to determine its cost structure. A sample fee structure for Spaceboard may be that it is sold to clients on a contract basis or at market rates. All customized requests will be on contract basis. The majority of contracts will be for a fixed number of sheets at a specified price to be delivered during the contract life. At signing, the equivalent of one-third of cost will be due as a prepaid deposit. It is expected that the average collection time will be 45 days. Overall, there is expected risk, however little, of uncollected sales.

Conclusion

After examining the commercialization potential and plans for Spaceboard in the pallet industry, we have determined that the product has enormous applications and promise. Based on the business model for pallets, we believe that positive cash flows will not be difficult to achieve, and that profitability is likely if a company has an exclusive license or family of patents. Nevertheless, patent infringements are expensive to litigate, and it would be advisable for the company to also have a unique production competence that is difficult for competitors to replicate. These measures will help mitigate the low barriers to entry for any company producing Spaceboard after the patent has expired and the products enters a crowded and price-competitive industry.

We do not believe that the pallet business will generate the substantial profits that a large-scale investor would expect. We attribute this to two significant factors. First, a commodity market is based on intense competition. Second, there is a limit to the amount that cost can be driven down either through production processes and inputs. It is very likely the licensing company can extract favorable deals from the recycled fiber or energy industries. One can assume that FPL engineers and technicians will need to work with the licensee company to produce Spaceboard using a continuous process. If we could reduce the energy cost, we can provide higher profits enough to attract large-scale investors. We believe that given a 5-year plan and low cost employees, we could provide a return.

Our conclusion is that Spaceboard has all the unique properties and attributes to be a disruptive technology. Although 2 years remain for the Spaceboard patent, FPL should continue marketing the technology to the furniture, agriculture, music and performance studio, construction, and packaging industries. The marketing strategy for the pallet industry is the strength, light weight, and ease of recycling of Spaceboard products. Also, companies such as Johnson and Johnson can invest in small pallet-making machines and produce Spaceboard in-house. In construction, governments and relief organizations could use prefabricated structures designed using Spaceboard. Spaceboard is also a good substitute for plywood in underdeveloped countries where forests have been depleted.

The benefits of Spaceboard are a high margin resulting from low production cost, reduction of pollutants emitted into the atmosphere, and reduced depletion of virgin forest through the use of low quality hardwood. Mixed wastepaper can be used as raw material without preparatory processing to remove large contaminants such as clay, plastics, and staples. The open-cell grid allows Spaceboard to be used in or with a wide variety of structures. Another advantage of this patented technology is that the fibers in Spaceboard can be processed using either dry or wet vacuum techniques and bonding can be accomplished using either heat, pressure, or adhesive agents, or any combination of these. Spaceboard production is versatile and can use either batch or continuous processes. Also, the use of molds that press in one direction lower the cost of production.

Appendix A—Market Research

Responses From Forest Products Laboratory

1. What support (load capacity and structural) does Spaceboard offer in terms of vertical and horizontal strength when compared to wood or plastic? Shock absorbency?

   See the Spaceboard 2 information on the FPL web site for information.

2. Is Spaceboard rot and warp resistant? Can it be made resistant to weather and termites? Flameproof?

   Yes, with chemical treatment, Spaceboard can be made resistant to weather, insect infestation, and fire.

3. What is the typical average production schedule for Spaceboard?

   Average production time depends on board thickness. Typical Spaceboard takes about 30 seconds to dry. A 1-in.-thick board takes 30 to 40 min to dry; 1-in.-thick Spaceboard can be dried by microwave energy in 5 min.

4. How reparable is a Spaceboard pallet in the event of light damage?

   A pallet made from Spaceboard is not as easily repaired as a wooden pallet. To repair a chip that affects the structural integrity of the pallet, more fiber cannot be injected into the pallet. If the inner core is damaged, a wooden piece can be inserted (routed out) and glued in place to obtain the desired resistance.

5. Are there any quality (consistency) issues with current production machine technology?

   No. Just like any production process, if high quality raw materials are used and the process is efficient, the quality of the Spaceboard manufactured will be high.

Appendix B—Cost Analysis

	units	yield / Ton	($ / un)	($ / ton)
Fiber	ton	1	121	121
Electric Energy	Kwh	660	0.046	31
Thermal Energy	steam pounds	3,000	0.0090	27
Variable Costs			per ton	179
			per pallet	3.8

	Pall / hour	hour / day	day / year	1000 pall / year
Production	45	16	300	216

	$ / shift	shift / day	day / year	1000 $ / year
Labour	480	2	300	288

Every shift of **8** hours, **three** workers @ **20** $/hr

	annual rate	Invest (1000$)	years	pmt (1000 $)
Amortization	3.5%	2,000	10	240

Sale price / pallet	8		
Sales ($ 1000 US)	$1,728		
Var.cost	$820		
Labour	$288		
Amortization	$240		
Administration	$69	4%	as percentage of sales
Margin	$311		

Fiber Price	Mix	($ / Ton)
Virgin	10%	400
Recycled	90%	90
Furnish		121

48" x 40" x 6"	inches	meters	dm^ 3	kg
Wide	48.00	1.22		
Length	40.00	1.02		
High	6.00	0.15		
Gross volumen			188.8	
Net volumen	Dens.Space	15%	28.3	
Weight	Dens.Pulp	75%		21

Main parameters to play

- Pallets per hour
- Shifts per day
- Initial investment
- Densities

Quarterly Forecast	1st YEAR				2nd YEAR				3rd YEAR			
Lineal Growth	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Sale price / pallet	**6.5**	**6.5**	**7.0**	**7.0**	**7.5**	**7.5**	**8.0**	**8.0**	**7.5**	**7.5**	**8.0**	**8.0**
(pallets / hour)	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**45**	**45**	**45**	**45**	**45**
Prod. (pallets/quarter)	18,000	24,000	30,000	36,000	42,000	48,000	54,000	54,000	54,000	54,000	54,000	54,000
Sales ($ 1000 US)	**117**	**156**	**210**	**252**	**315**	**360**	**432**	**432**	**405**	**405**	**432**	**432**
Efficiency	**70%**	**75%**	**80%**	**85%**	**90%**	**95%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
Var.cost	98	121	142	161	177	192	205	205	205	205	205	205
Labour	72	72	72	72	72	72	72	72	72	72	72	72
Amortization	60	60	60	60	60	60	60	60	60	60	60	60
Administration	5	6	8	10	13	14	17	17	16	16	17	17
Profits	**(117)**	**(104)**	**(73)**	**(51)**	**(7)**	**22**	**78**	**78**	**52**	**52**	**78**	**78**
Cummulate Profits	**(117)**	**(221)**	**(294)**	**(345)**	**(352)**	**(330)**	**(252)**	**(175)**	**(123)**	**(71)**	**7**	**84**

Quarterly Forecast	1st YEAR				2nd YEAR				3rd YEAR			
Annual Growth	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Sale price / pallet	**8.0**	**8.0**	**8.0**	**8.0**	**8.0**	**8.0**	**8.0**	**8.0**	**8.0**	**8.0**	**8.0**	**8.0**
(pallets / hour)	**15**	**15**	**15**	**15**	**30**	**30**	**30**	**30**	**45**	**45**	**45**	**45**
Prod. (pallets/quarter)	18,000	18,000	18,000	18,000	36,000	36,000	36,000	36,000	54,000	54,000	54,000	54,000
Sales ($ 1000 US)	**144**	**144**	**144**	**144**	**288**	**288**	**288**	**288**	**432**	**432**	**432**	**432**
Efficiency	**80%**	**80%**	**80%**	**80%**	**90%**	**90%**	**90%**	**90%**	**100%**	**100%**	**100%**	**100%**
Var.cost	85	85	85	85	152	152	152	152	205	205	205	205
Labour	72	72	72	72	72	72	72	72	72	72	72	72
Amortization	60	60	60	60	60	60	60	60	60	60	60	60
Administration	6	6	6	6	12	12	12	12	17	17	17	17
Profits	**(79)**	**(79)**	**(79)**	**(79)**	**(7)**	**(7)**	**(7)**	**(7)**	**78**	**78**	**78**	**78**
Cummulate Profits	**(79)**	**(159)**	**(238)**	**(317)**	**(324)**	**(332)**	**(339)**	**(347)**	**(269)**	**(191)**	**(114)**	**(36)**

University of North Carolina Team 2

Reinforced Wood Panel Technology: Product Application Reviews

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Executive Summary

The USDA Forest Service Forest Products Laboratory (FPL) in Madison, Wisconsin, is the nation's leading wood research institute. The focus of FPL research has primarily been on how to derive useful applications from wood products to benefit the housing, furniture, and other wood and paper related markets. In their bid to intensify the development of wood products that have significant commercial potential without sacrificing environmental and sustainability concerns, FPL has decided to engage industry experts and business students to help improve the marketability of their products, which were developed using cutting edge technology.

The Kenan Flagler Business School (KFBS) of the University of North Carolina at Chapel Hill is one of the institutions picked to collaborate with FPL as part of this new commercialization drive. The MBA students enrolled in the course have been charged with the task of advising FPL on the following issues:

- Define a model for New Product Development that can be utilized by FPL.
- Analyze the commercial potential of two patented products developed by FPL.
- Compare the commercialization potential of the two products.
- Explore the characteristics of these two products and determine if they are sustainable.
- Make recommendations to FPL on how to move forward with the commercialization process and the integration of New Product Development thinking into their organization.

For the purposes of this project, KFBS students were split into two groups, with our group choosing to focus on reinforced wood panels (RWP). The issue of defining a model for new product development was addressed in a presentation to FPL and USDA Forest Service personnel at KFBS in February 2002, and those materials are provided in a separate document. This paper deals with the final four points on the abovementioned list. Specifically, we look at two applications for RWP that we believe hold commercial promise: reinforced wood doors and engineered lumber reinforcing patches. Section 1 examines the commercialization potential of these two applications. Section 2 assesses the characteristics of these applications through the lens of sustainability. Next, we compare the commercialization potential of RWP products and Spaceboard products in Section 3. Finally, in Section 4 we conclude with some recommendations for FPL on how to better pursue current and future commercialization efforts.

Research contacts for RWP product applications are listed in Appendix A.

Section 1—Applications of Fiberglass-Reinforced Wood Panel Patents

Application 1—Reinforced Wood Safety Doors

Traditional exterior wood doors do not possess as much strength as steel doors to resist heavy impact or extreme weather conditions. Together with weatherstripping, a door frame, and a threshold, doors keep external elements at bay. The support from each of these items, however, still does not address the vulnerable places on a door such as the areas supporting the doorknob and door hinges. The reinforced wood panel (RWP) technology patented by the Forest Service provides a viable solution to this problem.

The primary applications for entry doors include single-family homes, multi-family dwellings, and commercial buildings. On the market today, one can find a tremendous variety of steel, fiberglass, and wood composite exterior doors that are aesthetically pleasing and provide security from extreme weather, fire, and intruders. Each type of door has its own unique set of qualities and addresses a variety of needs. For instance, some steel doors on the market come with a 5- to 10-year warranty to guarantee quality and durability. Fiberglass doors also come with such guarantees; however, they do not provide resistance to fire. Insulated steel continues to dominate unit sales in the entry door market, but greater emphasis is being placed on a broader range of products such as fiberglass and wood composites (National Glass Association 2002).

The door market is highly fragmented with over 325 steel door manufacturers and 250 wood door manufacturers. There is a growing trend toward consolidation in this industry, as evidenced by the increasing number of mergers and acquisitions as well as the expansion of the top 100 door manufacturers (National Glass Association 2002).

Given the wide variety of choices in the traditional entry door market, the team explored alternative markets for doors manufactured with fiberglass-reinforced wood. Three areas of interest arose from the initial investigation of possibilities:

Severe Weather Housing Replacement—Coastal areas plagued by severe weather and natural disasters present significant revenue potential. In North Carolina, for instance, 11,000 homes affected by Hurricane Floyd in 1998 are being rebuilt. The goal is to keep the cost of a home below $35,000 and to provide a stable, weather-resistant dwelling. Fiberglass-reinforced wood entry doors would keep the cost in an acceptable range for this project. Individuals in other disaster-prone areas such as in Florida and New England may also consider this product an affordable alternative to provide safety and peace of mind.

Public Housing—Public housing is generally located in high crime areas and public housing projects are subject to considerable budget constraints. A fiberglass-reinforced door would provide added safety from intruders and improved aesthetic appearance for these units at a reasonable cost compared with the simple steel doors generally used. Today there are over 4 million HUD assisted units in the United States alone. Assuming that HUD would be willing to replace the entry doors on a minimum of 10% of these units over a period of 2 to 3 years, the revenue potential is considerable. Additional research is required to understand the market for new housing projects.

Military Housing—According to a representative from the National Association of Home Builders, the demand for doors that provide added security from intruders will rise for military housing and embassies located in other countries. This demand stems from the recent terrorist attacks on the United States. and heightened awareness of security issues. The size of this market is difficult to assess at this time and needs further review.

Resources Necessary for Commercialization of Reinforced Wood Safety Doors

The successful introduction of most new products usually follows a well thought out and elaborate process. This involves careful examination of the market conditions, manufacturing and distribution challenges, and the resources necessary for the sponsoring company to make a successful commercial launch. A similar framework, as described in the commercialization model, will be followed in outlining resources necessary for the commercialization of RWP.

Market Assessment for Reinforced Wood Safety Doors

Reinforced wood products are being positioned as an alternative to steel doors or a solution to safety concerns regarding the resilience of entry doors in public and military housing. This means an ability to determine the major players within both the steel and wooden door markets. To understand where these players believe value could be added to the existing product is key to having a successful commercialization strategy. Market trends and stage of market life cycle will have to be determined to assess the most appropriate market segment for RWP and the timing of its introduction to that market.

Other customer-related insights from market studies would provide additional important information including but not limited to

- Customer demographics
- Customer buying power
- Customer profitability
- Value chain characteristics

- Price elasticity
- Desired outcomes for integrating new technology

Such assessments require good industry market research using both primary and secondary data from sources that include various focus groups pooled from

- Tradesmen
- Architects and contractors
- Manufacturers and distributors (e.g., Home Depot, Weyerhaeuser, Premdor)
- Building societies and associations (e.g., National Association of Home Builders)
- State and local government officials (e.g., Durham Public Housing Council)

Secondary sources may include census data and industry specific reports. Third party research firms could be contracted to produce this kind of market assessment report, or the internal research unit of the company acquiring the technology could undertake such a task.

Availability of Raw Materials / Inputs

In general, raw materials for RWP are widely available commodities. Careful selection of sourcing partners is necessary to ensure competitive pricing inputs. Wood, epoxy resins, and fiberglass mats are the primary inputs.

- Wood—The availability and cost of wood varies with the type desired.
- Epoxy resins—Epoxy resins are readily available from a number of manufacturers. The cost of the resins varies depending on the properties desired. The cost of epoxy resins can range from $45 to $75 per gallon and may be subject to air hazard charges.
- Fiberglass mats—Fiberglass mats are also readily available from a number of manufacturers. The cost varies according to type of product desired:
  - Corrosion resistant fiberglass mat: $25/yard
  - Chopped strand mat: $9/yard
  - Woven roving: $14/yard

Requirements for Manufacturing, Distribution, and Market Commercialization

Manufacturing and Distribution—A company acquiring the RWP technology could be one that is new to the industry or a firm that is already fully engaged in the wood processing industry, be it furniture, doors, or a related wood applications market. For a company new to the market, entering the market would require setting up a manufacturing plant that is capable of producing RWP in a manner that is not only able to fully leverage the technology but also efficiently manage the process to realize the potential cost advantage that RWP applications could have over steel and its applications in residential housing construction. A new company will also have to develop channels of distribution, which may require either displacing established competitors, which would be expensive and difficult, or creating a wholly new channel in an seemingly matured market.

Companies already in the re-engineered wood business would have to adapt their existing machinery and manufacturing process to accommodate the inclusion of reinforcing fiberglass laminates. To manufacture reinforced wood doors, epoxy resins and fiberglass mats must be applied to the area that surrounds the doorknob and the hinges. A machine would have to be added to the manufacturing process to spray the epoxy adhesive over the required areas. Pre-cut fiberglass mats would then be pressed to the epoxy surface before it hardens. This could mean little financial outlay. Energy and labor requirements seem to be potential areas of significant expenditure that companies adopting RWP technology may have to consider.

Marketing and Education—A firm needs resources not only to obtain the necessary market intelligence as well as manufacturing and distribution competencies, but also to achieve the managerial and technical know-how to test market and distribute the product. These resources may be available both within and outside of the company. Internal competencies should enable the company to effectively map out the competitive landscape to determine the number and density of competitors and substitute products, barriers to entry, and ability to control channels of distribution and assess potential synergies that could be obtained from the marketplace. Internal resources for training, capital equipment, infrastructure, and manufacturing capabilities requirements are all necessities for successfully implementing a launch strategy.

However, a firm may not necessarily have to be burdened with all the technical and marketing requirements needed for a new product launch. Partnering with outside groups whose business focus provides the needed synergies can help leapfrog the process. In the case of RWP, tests for missile penetration, flammability, and durability could be coordinated with research laboratories or trade groups that have the resources and capabilities to conduct these tests. Such an approach could significantly reduce the financial strain and enhance the marketing and adoption of the technology into the market.

Some research institutions and consumer organizations have been identified that could provide support for the commercialization of RWP. We recommend that any partner choosing to commercialize RWP should contact these organizations, which include:

1. Test laboratories of the National Association of Home Builders,
2. Blue Sky Foundation, a non-governmental organization that provides storm-resistant housing,
3. Missile Testing Laboratory of Clemson University, and
4. North Carolina State University.

Application 2—RWP Reinforcing Patches for Engineered Lumber

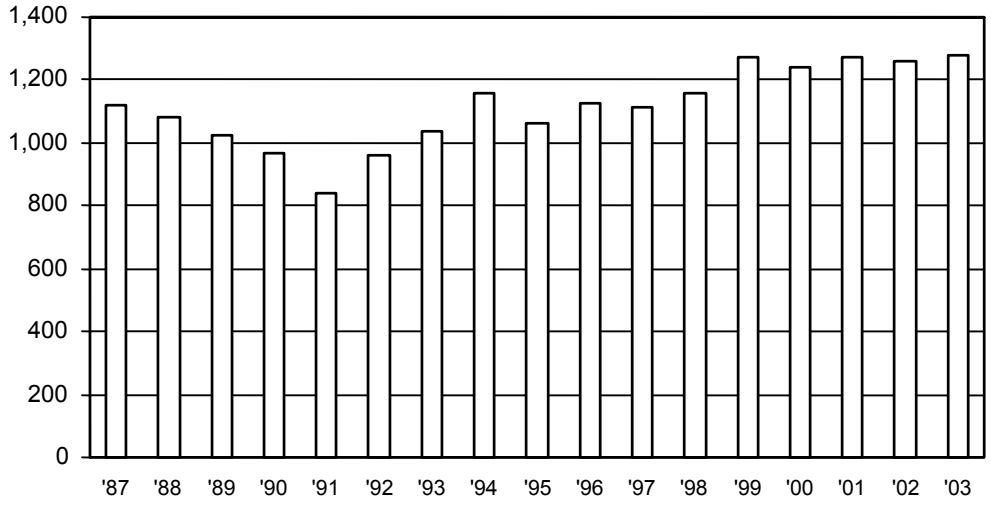
Patent Number 5,720,143, "Localized Notch Reinforcement for Wooden Beams," elucidates a very specific application for the fiberglass reinforcing technology developed by Dr. Robert Ross and others at FPL. According to Dr. Ross, this application has been successfully employed in structures using heavy wooden beams that span significant distances. While this application certainly can add value to projects utilizing these materials and construction techniques, conversations with Jay Fulkerson, an architect based in Chapel Hill, North Carolina, brought to light an alternative application for this technology that our team feels holds great promise.

Mr. Fulkerson, who specializes in residential and light commercial designs, suggested that reinforcing fiberglass patches might prove to be the solution to a problem that he had encountered in several buildings. The problem relates to the placement of mechanical systems (i.e., electrical systems, plumbing, and HVAC) under floors supported by engineered lumber, such as laminated beams and wooden I-joists. While these engineered lumber products are very strong and have largely been a boon to the construction industry, they also have certain limitations. The key limitations in relation to this project are restrictions on the size and placement of holes drilled through these engineered products. It is often the case that architects fail to adequately take into consideration the placement of mechanical systems in their designs. As a result, the tradesmen and contractors charged with installing these systems on site are often faced with a dilemma. The best placement for a given electrical run or drainpipe may not be an option. They are restricted from drilling holes of the necessary size and placement by engineered wood manufacturers who will not guarantee the structural stability and strength of their products if they are altered beyond strict parameters. As a result, the tradesmen and contractors must find alternate routes for the mechanical systems, usually requiring more time and materials, or, in extreme cases, the design of buildings may have to be altered to accommodate the placement of necessary mechanical systems.

This waste of time and materials presents an opportunity for FPL's wood reinforcing technology. By strengthening the wood around openings for mechanical systems, we believe that reinforcing patches could allow for larger holes in engineered lumber with fewer restrictions on placement. The ability to optimize placement of mechanical systems would save time and materials on the job site, creating a significant amount of value for potential consumers.

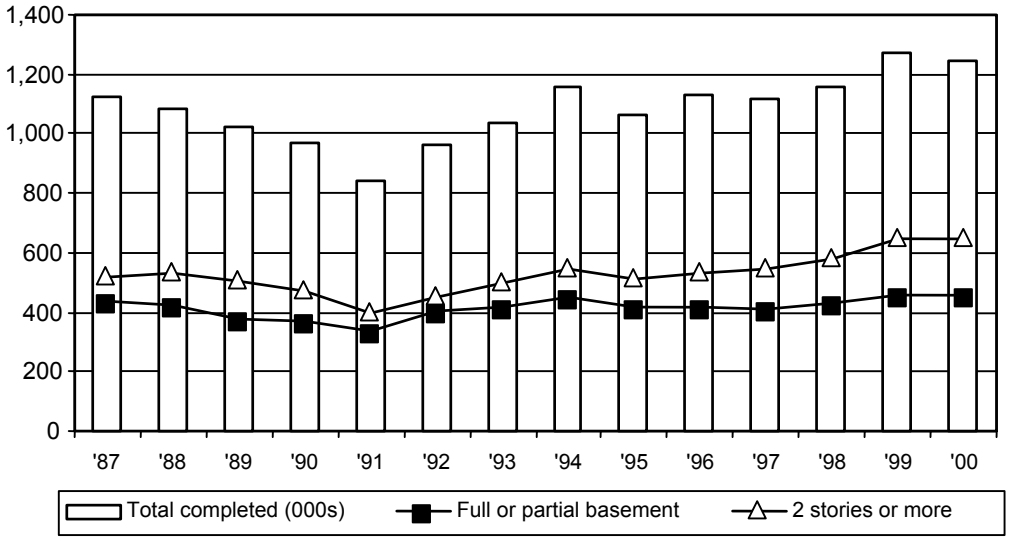
Market Assessment for Reinforcing Patches

While it is difficult to exactly quantify the potential market for a reinforcing patch for engineered lumber, we can begin to scope this potential by examining historical trends and forecasts for new, single-family home construction. Figure 1 shows the number of new, single-family homes completed and projected to be completed from 1987 through 2003 (see Appendix B for raw data). Although the annual number of



Source: US Census Bureau and National Association of Homebuilders

Figure 1—New single family homes ($\times 10^3$).



Source: U.S. Census and National Association of Homebuilders

Figure 2—New homes with basement or >2 stories ($\times 10^3$).

Wood Used in New Residential Construction, 1998 & 1995

What kinds of building materials are used in residential construction? What is the product volume by type of material? The answers to these questions are contained in this new residential market study, available from the Wood Products Council.

The Wood Products Council, a group of wood products associations and related partners, commissioned a study of all wood products used in residential construction in 1998 to follow up a 1995 study. Conducted by the NAHB Research Center, the study also provides details on the use of nonwood structural materials such as steel and concrete. An executive summary provides a comparison between 1998 and 1995 as well as an earlier 1988 study.

The following comprehensive data are provided for both 1995 and 1998:

- Components: Foundations, Floors, Walls, Roofs, Millwork and Outdoor Structures.
- Products: Softwood and hardwood lumber (framing, boards, beams, treated), softwood and hardwood plywood, OSB, glulam, I-joists, LVL, Parallam, and Timberstrand
- Regions: West, South and North - U.S, East and West Canada.

This 157-page report is free to member companies of the sponsoring associations and is available to consultants and other interested parties for $600, Form SPE-1108.

new, single-family homes dipped as low as 800,000 units in 1991, since 1999 the number of new homes constructed has been above 1.2 million annually. Additional data can help to narrow this market. Given the problems that a reinforcing patch for engineered lumber is trying to address, we should limit our potential market to those homes that require mechanical systems to be placed in the spaces as flooring support systems. In other words, this product would have little value in a single-story home with a crawlspace. However, homes built with finished or unfinished basements and/or two or more stories would require mechanical systems to share space with a flooring support system. Figure 2 shows the percentage of homes with these characteristics superimposed on the total number of new homes built from 1987 through 2000 (see Appendix B for raw data).

Using these new numbers, the potential market shrinks somewhat, but judging from the past few years it appears that construction of new homes with these qualifying characteristics will range from 400,000 to 600,000 annually.

While these data can give us a general idea of the potential market size, to more accurately gauge the potential market for reinforcing patches in this application we would want to know more about the sales and consumption patterns for engineered lumber products. This information is available in the form of market studies commissioned by the Wood Products Council. It was not within the scope or the resources of this project to obtain a copy of this marketing report, which is available through the APA–The Engineered Wood Association website at www.apawood.org. The report most relevant to our analysis, "Wood Used in New Residential Construction, 1998 & 1995," is described in the inset.

The pertinent data we would seek from this report are estimates of the amount and purpose of engineered lumber used in new home construction. Based on these estimates we could then determine the amount of engineered wood that is used in flooring systems and could potentially cause the previously discussed problems for mechanical systems installers. As a final piece of analysis, we would conduct interviews with mechanical systems installers (electrical, plumbing, and HVAC) to quantify how often problems with system placement arise and how much time and material are wasted in creating a work-around solution. Once this data was gathered, we could then estimate the potential number of applications for a reinforcing patch per new home and total number of patches used per year given various estimates of market penetration.

In summary, despite the limitations of our market analysis, we believe that there is significant potential for a reinforcing patch for strengthening the wood around openings for mechanical systems. The National Association of Homebuilders estimates that pressure from both the government and private sectors will limit the supply of older, larger trees, thus driving the growth of engineered lumber products. Given that most of these products will go into residential and light commercial structures, it is likely that the problems we've discussed will confront a growing number of contractors. Thus, if the proper testing, certification, and education can be done in support of the reinforcing patch, we believe that a significant market for the product will exist.

Product Development Requirements and Challenges

Four areas must be addressed for application of a reinforcing patch for engineered lumber to succeed in the identified target market. These areas are:

- Testing
- Raw Materials/Manufacturing
- Distribution
- Marketing/Education

It is important to explore each of these areas thoroughly and determine whether any insurmountable barriers to launching the product exist. If there are such barriers, it is much better to find it out at this early stage of product development than after much more time and many more resources have been expended. If no such barriers are found, a thorough knowledge and understanding of these areas will be key to the successful launch of the engineered lumber reinforcing patch.

For the engineered lumber reinforcing patch to gain acceptance in the target market, a significant amount of testing of the product in its intended application will have to be conducted. Specifically, we believe that extensive tests of the reinforcing strength of the product must be conducted to prove our contention that the product can add enough structural stability to engineered lumber to allow for larger holes to be made with fewer restrictions on their placement. While the tests already conducted on reinforced wood products for bolted wood connections clearly demonstrate the strength that can be achieved with a reinforcing product, tests specific to different types of engineered lumber and the placement and size of holes in each of these must take place to gain the approval and acceptance of both engineered lumber manufacturers and building inspectors.

After structural testing, we believe that tests concerning the flammability of an engineered lumber reinforcing patch are necessary to gain market acceptance. If the product does not have flame resistance at least equal to the underlying material, it will be worthless as a reinforcing agent. If in the event of a fire the patch burns away, the structural strength of the engineered lumber is no better than if the patch had not been used and thus would preclude the drilling of larger holes. Creating a combination of fiber and adhesive that has the desired flammability characteristics is key to the success of the product and can only be determined through testing.

Finally, the wear characteristics of the reinforcing patch must also be assessed. Here we are concerned with the performance of the patch over time. Questions such as "Will the patch fail to maintain adhesion?" and "Will the fibers degrade?" must be answered. In addition, the performance of the product under unlikely, but foreseeable, circumstances must be tested. For example, Will the product maintain its reinforcing properties if it gets wet as the result of a leak or flood? Can substances in the underlying wood, such as sap or other adhesives, degrade the reinforcing properties of the patch?

As this discussion illustrates, testing of an engineered lumber reinforcing patch will have to be extensive. However, it is of paramount importance to determine whether or not the patch will perform as we predict and to gain the acceptance of key market players. This being said, it is not necessary for the FPL to conduct this testing on its own. Indeed, there may be organizations with both the capability and incentive to assist the testing of an engineered lumber reinforcing patch. Two organizations that we believe might be willing partners in this endeavor are APA–The Engineered Wood Association and the National Association of Homebuilders. We believe the APA would have a great deal of interest in determining the viability of a reinforcing patch as an adjunct to its members' products. From our perspective, such a product would only increase the versatility and ease of use of engineered lumber, thus providing added value to the consumer. The National Association of Homebuilders is also likely to have interest in the results of such tests. From their perspective, the product could potentially save time and money on job sites. If these potential savings are significant, the Asso-

ciation will have a vested interest in the success of the engineered lumber reinforcing patch.

Availability of Raw Materials/Inputs

The issues of sourcing raw materials and developing manufacturing capacity were not ones that we were able to consider in depth for this project. However, we believe that there are important issues that should be addressed in this area. Given that an engineered lumber reinforcing patch is unlikely to be a material intensive product, we find little reason to believe that the sourcing of raw materials will be a significant hurdle in its commercialization. It might be conceivable that if some exotic fiber and/or adhesive are used, raw material acquisition could pose a problem. However, we consider it much more likely that more common materials such as fiberglass and readily available adhesives will be used in the formulation of the product.

Requirements for Manufacturing, Distribution, and Market Commercialization

Manufacturing—We are looking for the ability to produce engineered lumber reinforcing patches in the quantity that we predict will meet demand at a cost that will allow us to reap a profit. Again, given the relatively basic nature of the product itself, we do not foresee that acquiring adequate manufacturing capacity will pose a significant constraint on developing this product. It would, however, be wise to look to companies that already have expertise in the materials that make up our product and explore the possibility of partnerships with these organizations. Two such companies that we believe have potential in this regard are 3M and Dupont. Both companies have experience and expertise in the areas of synthetic fibers and adhesives. Given this fact, it would be prudent to determine whether either or both of these companies can or do offer a product that is similar to what we propose. If so, unless airtight patent protection for our product can be secured, it may be wiser to cut losses and abandon this market, rather than engage in a lengthy and expensive marketing battle with huge corporations. If not, however, exploring relationships with these firms could produce a manufacturing or raw materials sourcing agreement. Which of these options would be the better choice is an issue that needs further analysis.

Distribution—Once the issues of testing, raw material sourcing, and manufacturing are addressed, the next step in commercialization will be to determine how best to distribute an engineered lumber reinforcing patch to the target market. We see three main choices for distribution of this product: mechanical systems distributors, lumber yards/distributors, and engineered lumber manufacturers. Each of these choices has its advantages and disadvantages, as discussed below.

***Mechanical systems distributors*—**These firms are in the business of supplying contractors and tradesmen with the supplies they need to complete their jobs. Their inventory mainly consists of various types of pipe and pipefittings, electrical wire and fixtures, and complementary tools and supplies. The advantage of distributing through such firms is that they have the closest relationship to the end users of the engineered lumber reinforcing patch, i.e., mechanical system contractors and tradesmen. This relationship can be valuable when we try to market our product and educate the end users about its benefits. However, the disadvantage of working with large mechanical systems distributors is that engineered lumber reinforcing patches would be just one among thousands of products carried by these businesses. Unless they could reap large margins from their sale they will have little incentive to help market the product and educate mechanical systems contractors. As such, we believe that mechanical systems distributors are not the best choice for distribution of this product.

***Lumber yards/distributors*—**These businesses are principally engaged in serving contractors by delivering large loads of construction materials to job sites, including engineered lumber. The advantage of distributing through lumber suppliers would be that they carry a variety of engineered lumber and would be able to sell reinforcing patches for each type. In addition, because they know when an order for engineered lumber will be delivered, they could easily sell reinforcing patches as a complementary product and deliver the two products together. The disadvantages, however, are similar to working with mechanical systems distributors. Unless lumber distributors can earn high margins, they will have little incentive to aggressively market reinforcing patches. In addition, because they do not generally deal with the subcontractors who install mechanical systems, their link to end users is somewhat tenuous. Thus, as with mechanical system distributors, we feel that lumber yards/distributors are not the ideal partners for distributing this product.

***Engineered lumber manufacturers*—**These businesses, essentially the members of the APA–The Engineering Wood Association (see Appendix B for full membership list), are in the business of designing and manufacturing engineered lumber products. They may produce a range of engineered products as well as more traditional dimensional lumber, plywood, and even pulp and paper, or they may specialize in the manufacture of one type of engineered lumber. The advantage of working with these types of organizations is that they have the incentive to market a reinforcing patch as a value-added complement to their products. The ability to create larger holes in their products could give them a substantial competitive advantage over other manufacturers. In addition, this incentive may prompt them to assist with the testing and manufacturing phases of commercialization. The disadvantage of working directly through manufacturers is tied to the creation of competitive advantage for their products. Given that we believe a reinforcing patch will add value to a manufacturers product line, that manufacturer will be loath to share this product with other manufacturers. If

the whole industry has access to the technology, then it will likely become a standard feature and no one manufacturer will be able to extract a price premium for it. Thus, distribution through engineered lumber manufacturers will necessarily be limited to one or two manufacturers. Despite these limitations, we believe that partnering with a manufacturer is the best choice for distribution of a reinforcing patch. Given that such a partnership will be limited to one or two companies, we suggest that partnering with a large manufacturer makes the most sense. In addition to being in a position to reap the greatest reward from the successful launch of a reinforcing patch, manufacturers such as Georgia Pacific, Weyerhaeuser, and Bosie–Cascade have the resources to support commercialization efforts in other ways as well.

Marketing and Education—The last piece of the commercialization problem facing a new product is marketing and education. It should be noted that we discuss this piece last in regards to the engineered lumber reinforcing patch because we believe that the other three parts of this commercialization effort are prerequisites. If the areas of testing, raw materials sourcing, and manufacturing and distribution cannot be solved, then it is better to discontinue efforts to commercialize a product that has little chance of success, even if a great marketing and education plan is implemented. In fact, marketing the reinforcing patch and educating end users about its benefits may be the most difficult part of commercializing this product. The difficulty lies in reaching an extremely fragmented base of end users, namely mechanical systems contractors and tradesmen, who are mainly independent contractors. Since these are the individuals that will reap the rewards of time and material savings, it is imperative that they understand the value of the reinforcing patch. We see two possibilities for partnerships that could overcome this difficult problem. The first is to partner with trade associations that govern the various mechanical systems trades. Partnering with these associations to disseminate information to their constituent members is the most direct path we can discern to educate this fragmented audience. Alternatively, working with building authorities to amend construction codes to allow for reinforcing patches will also inform end-users about the product, albeit in a much less direct fashion. If this tactic is used, it is unlikely that information beyond purely technical specifications will reach end users. While this may create awareness, it will not educate these consumers about the benefits of the product and motivate them to try it. As such, we believe that working in conjunction with trade associations is the best alternative for creating a marketing and education campaign in support of engineered lumber reinforcing patches.

Section 2—Sustainability Assessment

We assessed both the RWP doors and reinforcement fiberglass patches for their potential to be developed in a wholly sustainable fashion. This analysis required us to make mostly qualitative judgments given the early stage of product development and our limited existing knowledge. Once additional tests on attributes such as flammability and wear resistance are conducted and quantified, and after the actual commercialization is underway, a more rigorous assessment will be possible.

As a supplement to our initial assessment we have pulled together various principles from leading literature, principles that if incorporated as part of the new product development and commercialization process should lead to more sustainable RWP products. In fact, if it is FPL's hope to develop its technologies as sustainable technologies, all of its future research directions should integrate these principles of sustainability. We conclude this section with more general recommendations for FPL, recommendations that fall outside the scope of its two RWP products but that may help FPL to become an organization with a sustainable vision and strategy.

Stage 1—Sustainable Product Development and the Triple Bottom Line

Initially we hypothesized that these two RWP products are sustainable, and we then evaluated this hypothesis against key industrial ecology principles and the triple bottom line model. We determined that at the current stage of development, the underlying technologies and resulting products are not sustainable in nature.

Conceptualized by John Elkington, the tenet of the triple bottom line holds that the most profitable businesses will be those that focus on not just bottom line profits, but the social and environmental impacts of a firm or product and their contribution to the bottom line. That is, sustainable companies are those that succeed on all three fronts. Fiksel, McDaniel, and Spitzley (1998) propose a product performance measurement framework that includes the triple bottom line, applying it across each stage of the product life cycle. Adopting this model, we evaluate RWP doors and patches (Fig. 3).

At first glance RWP has appealing attributes. Clearly, the use of renewable wood fibers is more environmentally friendly than is non-renewable steel. The thought that reinforcing patches can eliminate waste from the material intensive construction industry also makes intuitive sense. However, when stacked up against even this high level qualitative review, the challenges of true sustainability become apparent. Assuming product development survives the additional safety and durability testing these technologies require, the economic prospects of RWP applications are good, particularly for engineered wood reinforcement patches. But considerable uncertainty surrounds the environmental and social bottom lines. Substantial planning and absolute dedication to

	Supply	Manufacturing	Distribution	Consumption
Societal				
	• Unknown. Sourcing decisions depend on partnerships. RWP could present business opportunities in rural communities.	• Unknown. As a low tech product, RWP could present manufacturing opportunities in rural or urban communities where there is less skilled labor.	• Negative. Recommended use of manufacturer as distributor has negative social implications – fewer jobs created, must create shared vision with partner.	• Neutral. Use of patches or doors are low impact. Provide added security or safety in low-income housing. Communication of benefits look challenging.
Environmental				
	• Neutral. Exotic and timber fibers are renewable, seen as a design opportunity. Epoxies and fiberglass less enviro friendly. Harvesting energy intensive.	• Neutral. Product promotes resource efficiency. Yet production reliant on capabilities and vision of partner. Considerable retooling may be needed.	• Negative. Recommended use of partner as distributor has negative implications if existing methods energy inefficient.	• Positive. Doors and patches have low usage impact. May minimize building material wastes. Recycling of patches with fiberglass may be problematic.
Economic				
	• Neutral. Inputs are commodities and cheap. Choice of suppliers affects cost. Compare recycled versus virgin fibers. Exotic fibers more costly?	• Positive. Use of existing mfg allows production to scale and leverages existing know-how. RWP low cost to produce but some retooling might be needed.	• Positive. Use of existing manufacturer's distribution gives broad market access. Patches complement engineered wood and can be bundled accordingly.	• Neutral. Entering door market as substitute is strike against. Adoption of patches with engineered wood presents unique positive opportunity.

Figure 3—RWP products should cater equally to the requirements of economic, societal, and environmental profitability. Attributes should be assessed along the entire value chain, broken down here as four separate functions. At the current stage of development, significant gaps in knowledge exist. Future planning with this framework facilitates evaluation of RWP product sustainability. Development of indicators or measures would assist with tracking progress in these functional areas.

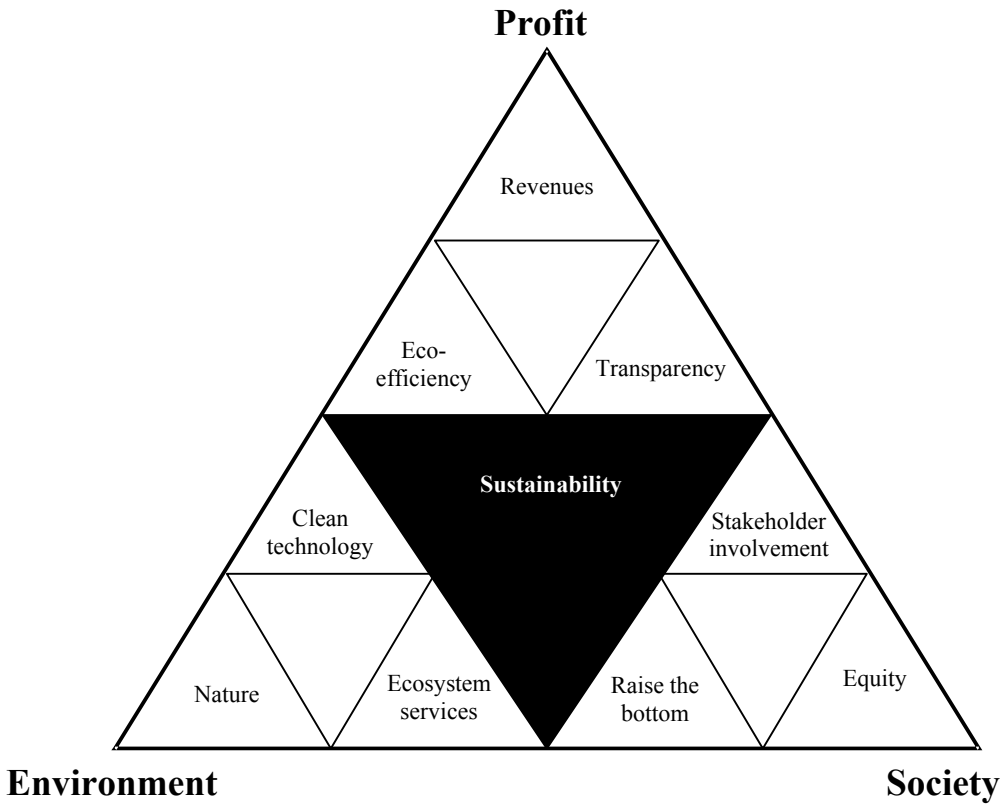


Figure 4—The sustainability triangle, adopted from the works of William McDonough (www.mcdonough.com), presents another method for assessing the relative sustainability of a product or an organization.

a sustainable vision will be required to create sustainable RWP applications.

Taking another view of the triple bottom line, William McDonough proposes a sustainability triangle, which assesses degrees (fractals) of sustainability (Fig. 4). This model exploits the notion of interactions between the social, environmental, and economic. Typically, the most sustainable products preserve ecosystem services while using clean technologies, uplift the disenfranchised, and encourage multiple stakeholder involvement, while generating profits through an organization that maintains a high level of transparency and a trusting culture. Those are at the center of the triangle. Historically, most products have operated at the extremes or "tips" of the triangle, prioritizing shareholder value and doing well by upholding a more basic social and environmental philanthropic credo. Figure 5 is a two-dimensional map that shows where RWP currently exists. Ideally, as the products develop, initiatives will push RWP into the upper right quadrant.

As Figure 5 shows, RWP doors have more perceived value along the environmental and social axis, but entering as a substitute product in a well-developed security door market presents substantial economic challenges. Profitability may only be marginal unless true differentiating attributes can be identified and valued by consumers. However, steel security doors are likely to be only marginally profitable over the long term in this apparently fragmented industry. Environmental quality issues (e.g., resource intensive use) may drive economic value backwards over the long term, but steel recycling may prevent this downward migration.

The RWP patches appear to have greater potential, particularly if development complements engineered wood. A proactive partner that identifies sustainability as a key value driver could build the market for the patches and engineered wood. The home building industry remains resource intensive, and only now are the notions of green buildings starting to take root (reference the works of William McDonough and the U.S. Green Building Council). The FPL could also establish itself as a technological driver of sustainable change in this industry, as discussed in Section 3.

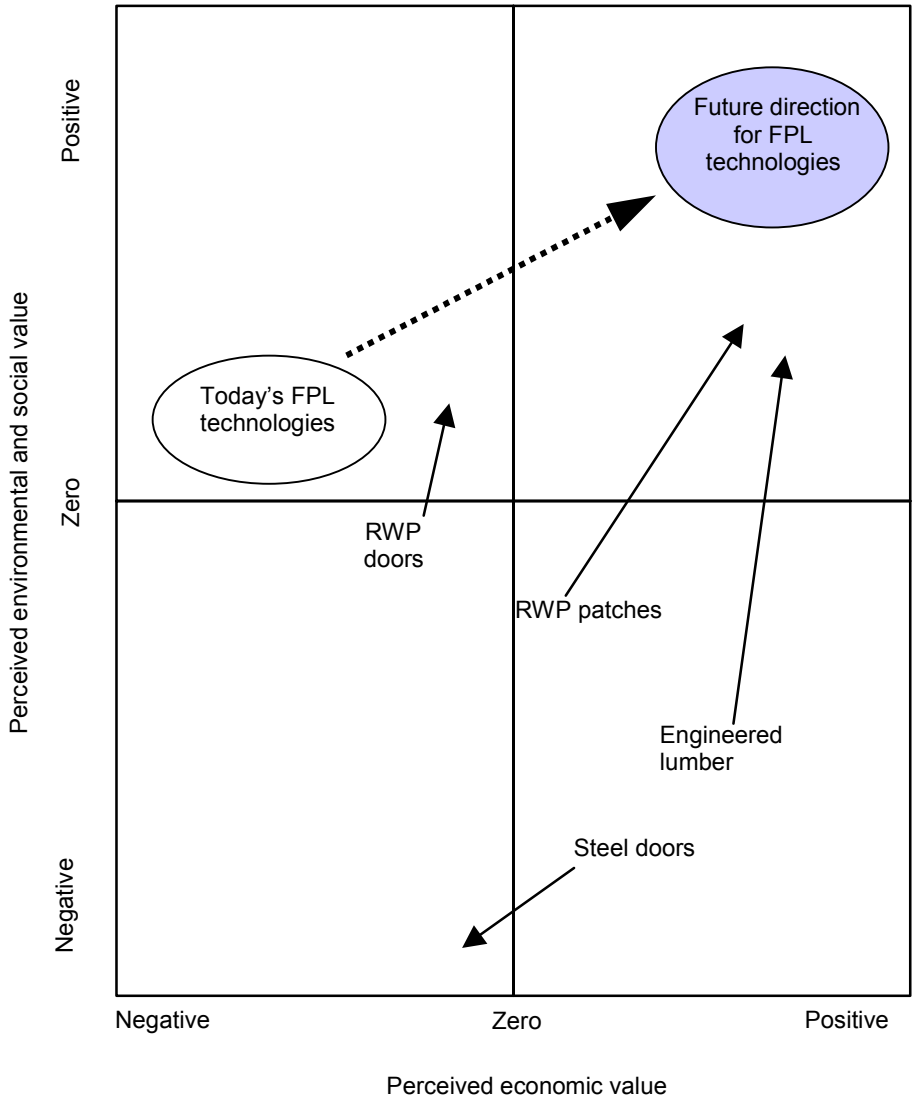


Figure 5—Mapping the current position of RWP applications and future development direction. Note that the FPL as an organization has an opportunity to focus future research on more sustainable uses of forest products and to build creative partnerships that could take potentially disruptive technologies to market.

Stage 2—The Sustainable Corporation and the Natural Resource Based View

Next we hypothesize that while these products appear limited in sustainability terms, that through effective planning and creative governance these and future FPL products can be sustainable. In addition to the more technical "greener" design aspects, organizational structure and stakeholder management issues are central to this second hypothesis. We look at the systematic changes and resulting governance structure required for the FPL to promote sustainable product development.

Figure 5 highlights the current position of FPL. Its central strength is technology development. Many of these technologies have stemmed out of the belief that forest products are superior and are overlooked in the market. According to Dr. Robert Ross, wood is stronger on a per weight basis than concrete or steel. Dr. Ross concedes that in recent times wood has lost market share to steel, even though it is renewable and more environmentally friendly. This passion for and understanding about the advantages of wood has driven many FPL patents. But we have found that no framework has been established that will allow sustainable technologies to be developed in a manner that leverages both the material superiority and renewable attributes of wood, yielding revolutionary products. Sustainable forest products are designed from the outset, not presumed so because of the inherent properties of wood.

Taking pieces from some of the existing literature (see Appendix C for an abbreviated list of suggested references), we restate here several key concepts and provide recommendations that FPL should consider as it goes forward.

The natural resource based view proposes that "a sustainable-development strategy facilitates and accelerates capability development in pollution prevention and product stewardship and vice-versa" (Hart 1995). Pollution prevention and product stewardship are only precursors to sustainable development. From our perspective, FPL understands well how waste minimization and product life-cycle (cradle-to-cradle) management add value to the product development process. To truly benefit society, FPL needs to go beyond its research-based mission to develop a shared vision of sustainability with its partners. In this manner, FPL can help its partners minimize their environmental footprints while providing valued services to their stakeholders. While necessary to sustainable development, life-cycle assessments and pollution prevention are reduced to planning tools for achieving the ultimate vision (Hart 1995).

In striving to create these partnerships and this shared vision, FPL should adopt the commonly held view of sustainability as a journey. Hart acknowledges that implementing sustainability requires a "leap of faith," but he provides a basic diagnostic tool that helps organizations measure how consistent its strategies are with the concept of a sustainable vision. Progress involves balancing internal and external competencies. The move to a vision of sustainability logically follows from initiatives such as pollution prevention, product stewardship, and clean technologies. FPL's view of sustainability expands beyond internal technology development competencies, outward to external relationships with the public, to end users of its technologies, to timber, pulp, and other raw material suppliers, to partner companies, and to government agencies.

Hawken, Lovins, and Lovins (1999) outline four strategies of Natural Capitalism essential for helping FPL envision its future. Radical resource productivity, biomimicry, service and flow economy, and natural capital investment strategies all support a sustainable vision. While detailed discussion of these strategies is beyond the scope of this paper, referencing them provides FPL another avenue for learning about how a renewable resource driven industry can begin to shape a more sustainable vision.

With its wealth of scientists and its affiliation with the U.S. Department of Agriculture and the Forest Service, FPL possesses capacity in understanding radical resource productivity, biomimicry, and natural capital investment. The strategy of optimizing a service and flow economy will be more difficult to implement and will require innovative partnership and shared vision building.

Section 3—Comparison of RWP and Spaceboard Products

In our discussion comparing the potential for commercial success of RWP and Spaceboard, we consider several aspects of each product. Table 1 summarizes these issues and their impacts on potential commercialization.

Table 1—Comparison of commercialization potential for RWP and Spaceboard

Feature	RWP	Spaceboard	Notes
Key product attributes		✓	Product versatility
Product and material costs	✓		Simplicity and familiarity
Product feasibility			
Product testing	✓		Familiarity
IPR	✓		Patent life
Incremental/Disruptive	?		Depends
Sustainability			
Recyclability		✓	
Energy consumption	✓		
Social benefit	?		

We first consider the key product attributes and potential applications for each product. The key product attributes of RWP are its increased strength over non-reinforced wood and its aesthetic appeal over steel or other metal substitutes. The key product attributes of Spaceboard are its high strength-to-weight ratio and flexibility in formation (Spaceboard can be made into many shapes and sizes). These differences in product attributes lead to differences in potential applications. RWP product applications include reinforced doors and reinforcing patches for engineered lumber. Spaceboard product applications are quite varied and include construction applications, furniture, pallets, corrugated containers, and recreational vehicles. RWP is very similar to an existing product (reinforced wood), and thus the potential applications are easy to elucidate. Spaceboard is a radically new product, however, and the applications have yet to be fully discovered. In this respect, we feel that Spaceboard has an advantage in terms of commercialization success, since the product has such versatility of application.

Next we consider production and material costs. Spaceboard has many unknowns with regard to production and material costs since it such a new product, whereas the familiarity and relative simplicity of RWP allows us to roughly estimate its production process and associated costs. These factors are critical in determining commercial success. Spaceboard might offer a perfect solution to current unmet consumer needs, but if the product is prohibitively expensive, commercial success will be elusive.

With regards to product feasibility, we examine both testing issues and intellectual property rights (IPR). Again, because of RWP's familiarity, we have a better idea of the physical product characteristics associated with this product. While we do not know the exact tensile strength of RWP, we do understand its ability to withstand rain, since we know the properties of the lacquered wood that composes the exterior of RWP. We do not have this same understanding of Spaceboard. For example, can Spaceboard be used as refugee housing in a country with monsoon rains? We cannot answer this until we know how Spaceboard resists water damage. Both products require further testing to obtain a clear idea of the commercialization potential, but we expect that RWP will require less extensive testing. With regards to IPR, Spaceboard is again at a disadvantage. While Spaceboard does have an exclusive license with Sonoco, patents on Spaceboard will expire in less than 2 years. Furthermore, Sonoco's prolonged delay in producing Spaceboard must be indicative of prohibitive production costs or another barrier—otherwise this company would have already leveraged its access to this new technology.

As mentioned before, RWP is an incremental technology, and product applications are for existing markets. In contrast, Spaceboard is a radically new technology with great potential to yield disruptive products. This difference could affect commercialization in different ways. RWP offers familiarity—familiarity of markets, consumer needs, distribution channels, competitive landscape, and economies of scale. This familiarity will most likely result in easier commercialization in the short term, since specific product applications can be applied immediately. However, RWP does face stiff competition from traditional products. On the other hand, Spaceboard is radically new. The potential applications of this new product are still unexplored and markets will be created as a result. If a disruptive technology is introduced to the consumer through the appropriate channels, then this technology could be a commercial success, eclipsing any success gained from an incremental good. In essence, the effects of an incremental good versus a radically new good on commercialization could be positive or negative.

A final consideration for commercial success is product sustainability. Spaceboard is superior to RWP in its ability to be recycled, as well its capacity to be manufactured from recycled materials. From an energy consumption perspective, the production of RWP is less energy-intensive and thus RWP has the advantage in this regard. Finally, it is unclear which product provides greater social benefit. Depending on the applications, both products could bring enhanced social welfare, RWP through building stronger structures to withstand disasters, or Spaceboard through providing refugee housing.

In conclusion, Spaceboard has a myriad of applications, but right now too many unknowns exist to guarantee commercial success. With radically new products, we are unsure of market segmentation and assessment, customer characteristics, and competitive landscape—all aspects of new product commercialization, which we must understand to successfully introduce a product. We believe that with more research into potential applications and costs, Spaceboard could offer great potential for commercial success. RWP, which has many less unknowns, also has commercialization potential. With the appropriate development of key partnerships, RWP should also offer commercialization success.

Section 4—Conclusion and Recommendations

We reviewed potential commercialization applications of reinforced wood products. These RWP applications stemmed from four U.S. patents (5,501,054; 5,575,117; 5,720,143; and 5,852,909). For our review we focused on two applications, wooden security doors and engineered wood reinforcing patches. We conclude that the market opportunity for reinforcing patches is the better of the two. Given the expected increase in demand for engineered wood products, we believe that a significant market for reinforcing patches will exist, if proper testing, certification, and education can be completed. The ultimate success of this product will depend on FPL's ability to find partners with the manu-

facturing and commercialization capacity and requisite technical know-how. Suggested partners include 3M and DuPont for materials and manufacturing capacity and Weyerhauser or another engineered lumber manufacturer for marketing and commercialization. Further research on the best potential partners should be conducted.

While both security doors and reinforcing patches have sustainable attributes (increased safety, more efficient materials usage, and reduced waste), true sustainability measures go beyond pollution prevention and better life-cycle management. If these and future FPL products are to be sustainable, vision building and collaboration must occur with stakeholders to ensure a holistic approach to managing for the triple bottom line. This approach is not out of reach; FPL has the potential for leading a sustainable forest products revolution.

We believe FPL maintains an advantage over the private sector in its ability to engineer new forest products. Because FPL exists to serve public welfare, the Laboratory is not subject to the same quarterly criticism that corporations face from shareholders. FPL can adopt longer-term investment horizons in its technologies and more patiently pursue sustainable disruptive technologies. The business of FPL is innovation, and FPL should focus on molding a sustainable perspective around innovation. New technologies must be pursued with criteria in mind for solving environmental problems or creating social benefits.

However, FPL must also adopt an economic outlook within its product portfolio. While the potential to do so exists, FPL currently does not create much economic value with its patents (Fig. 3). This project attempted to address the problem by analyzing market potentials of a few patents, but more robust organizational changes need to be implemented.

We recommend that FPL continue collaborative efforts with business schools. In addition, consideration should be given to hiring a new product development manager. Hiring a summer associate from an MBA program would be a reasonable first step for finding a qualified manager. Ideally the manager would have forest products experience. His/her primary responsibility would be to build partnerships and review patents for commercialization potential. This manager should also manage the portfolio of patents to ensure that FPL is obtaining fair market value for the technologies it licenses; this valuation should include the value of the patents as real options for its licensees.

From our communications with FPL, we see a willingness to change. FPL leaders understand the advantage of sustainable development strategies, and the leap of faith has already been made. Now FPL needs to follow through and begin institutionalizing that understanding.

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Appendix A—RWP Product Application Research Contacts

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National Association of Homebuilders

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Appendix B—New Housing Completions and Characteristics

Year	Total houses completed ($\times 10^3$)	Full or partial basement (%)	Two or more stories (%)
1987	1,123	39	46
1988	1,085	39	49
1989	1,026	37	49
1990	966	38	49
1991	838	40	47
1992	964	42	47
1993	1,039	40	48
1994	1,160	39	47
1995	1,065	39	48
1996	1,129	37	47
1997	1,116	37	49
1998	1,160	37	50
1999	1,270	36	51
2000	1,242	37	52
2001	1,123	NA	NA
2002	1,085	NA	NA
2003	1,026	NA	NA

Appendix C—Membership List of APA–The Engineered Wood Association

Ainsworth Lumber Company Ltd.
Alamco Wood Products, Incorporated
American Laminators, Incorporated
Anthony–Domtar Incorporated
Aserraderos Mininco S.A.
Boise Cascade Corporation
Brochmann Polis Industrial E Florestal
Calvert Company, Incorporated
Compwood Products Ltd.
DF Joists
Duco Lam
Eagle Veneer, Incorporated
Eastern Pacific International, LLC
Fletcher Challenge Forests Ltd.
Floragon Forest Products, Incorporated
Footner Forest Products Ltd.
Fourply, Incorporated
Georgia–Pacific Corporation
Goodlam, Division of Goodfellow Incorporated
Grant Forest Products Incorporated
Hardel Mutual Plywood Corporation
Hood Industries, Incorporated
International Beams Incorporated
International Paper Company
K Ply, Incorporated
Les Chantiers de Chibougamau Ltee.
Louisiana–Pacific Canada Ltd.
LP
Martco Partnership—Plywood
McKenzie Forest Products
Murphy Plywood Company
Nexfor–Norbord Incorporated
Pacific Woodtech Corporation
Pinnacle Wood Products Ltd.
Plum Creek
Potlatch Corporation
Romaro 2000 Ltd.
Rosboro Lumber Company
Rosenburg Forest Products Company
S.D.S. Lumber Company
Scotch Plywood Company of Alabama
Shelton Lam and Deck
Simpson Timber Company
Slocan Forest Products
Standard Structures Incorporated
Stark Truss Company, Incorporated
Stimson Lumber–Shelton
Stimson Lumber Company
Structurlam Products Ltd.
Superior Lumber Company
Textured Forest Products, Incorporated
The G. R. Plume Company
The Geertsen Group Ltd.
Timber Products Company
Tolko Industries Ltd.
Weldwood Engineered Wood Products
Western Archrib
Western Structures, LLC
Weyerhaeuser Canada Ltd.
Weyerhaeuser Company
Willamette Industries, Incorporated

Appendix I—Course Description and Syllabus

New Product Development—Sustainable Forest Products, Winter Term 2002

Course Description

Background

This course will focus on the process of New Product Development and will assess the commercialization potential of new products patented by the USDA Forest Service, Forest Products Laboratory (FPL) in Madison, Wisconsin. The FPL has a distinguished history of conducting research and development focused on the effective and efficient utilization of the nation's forest resources. The course will focus on two specific products (Spaceboard and Reinforced Wood Panels) that have been developed and patented by FPL. This course will review the process of new product development and will evaluate the viability of successful commercialization of the two patents. Particular attention will address the potential of developing a sustainable enterprise based upon products such as Spaceboard and Reinforced Wood Panels.

Course Design

The course will include a seminar on New Product Development and a team project. The seminar portion will focus on the literature of New Product Development and the concept of Sustainability. The team project portion will focus on evaluating the business potential of the two patented products. The class will meet approximately 5 to 6 times during the semester. A kick-off session will be held with the patent attorney for the FPL and the lead researchers holding the patents. A final session will include a presentation of findings to representatives of the Forest Service from Washington, DC.

Course Requirements

The course will require active participation in the seminar portion, based upon a review of the literature of New Product Development and Sustainability, and active participation in the team-based workshop portion. The workshop will focus on developing a business plan to commercialize the product. The course will require that participants assess the potential of the products from multiple perspectives: market potential, economic viability, engineering feasibility, sustainability, and social implications.

Instructor and Participants

The course will be designed and conducted by Dr. Gordon A. Enk, an active member of the Advisory Board of the Center for Sustainable Enterprise. He is President of the Research and Decision Center and Principle of Partners for Strategic Change. His experience includes serving as Director of New Product Development for International Paper Company. The lead patent attorney from FPL, Janet Stockhausen, will participate in the initial and final course meetings and will be available for consultation.

Course Syllabus

Course Purposes

1. To analyze the commercial potential of two patented products developed by the USDA Forest Service, Forest Products Laboratory.
2. To explore the potential of the two patented products to be sustainable products.
3. To review the process of New Product Development.
4. To define an optimal process of New Product Development.
5. To develop and test an Analytical Model to assess the "commercialization potential" of New Product Opportunities.

Course Model

Course participants will be organized to simulate New Product Commercialization Teams for a private corporation (Packaging, Building Supply, and Wood Products) interested in commercializing value-added products.

Course Ground Rules

- Active participation in all class meetings is expected and required.
- Active participation as a team member is expected and required.
- Dr. Enk is available to respond to questions by e-mail at gaenk@aol.com throughout the course.
- Dr. Enk is available to meet with the team(s) or individual on any Friday of the week in which classes are scheduled.

Session 1—Course Overview

A. Why new product development?

B. New product development as part of corporate strategy

C. The two faces of new product development:

   1. The Forest Products Laboratory (FPL) and the USDA Forest Service: *Develop and license*
   2. Forest products industry: *Commercialize*

D. Review of patents for RWP and Spaceboard

Assignment

- Review patents
- Review the life cycle analysis for RWP
- Develop list of key questions for Janet Stockhausen

Session 2—The Developer's Perspective on New Products

Guest Instructor

Janet Stockhausen, Esq., Patent Advisor
USDA Forest Service
Patent and Licensing Program
Madison, WI

A. Overview of the FPL: History, mission, and approach

B. The perspective of the FS Patent and Licensing Program

C. Why RWP, why Spaceboard?

D. Patents and licenses—How they work

E. Need for the analysis of commercialization potential

Assignment

- Review and Critique: Geoffrey A. Moore, *Crossing the Chasm*, Harper Business (Harper Collins), 1991
- Review and Critique: A. W. Ulwick, "Turn Customer Input Into Innovation," *Harvard Business Review,* January 2002 (pp. 91–97)
- Individual Assignment: Write a brief critique (3–5 pages) of the Moore book and Ulwick article
- Team Assignment: Develop a draft model to assess the commercialization potential of a new product

Session 3—The Technologist's Perspective

Note: The following session was included in the course at the University of Michigan, but not at the University of North Carolina (UNC). The assignment was given to UNC students at another session.

Guest Instructor

Robert J. Ross, Project Leader
Wood Engineering and Drying Systems—Design Criteria
USDA Forest Service, Forest Products Laboratory
Madison, WI

A. The practical aspects of developing a new product

B. From the lab to the patent office

C. From the patent office to the market place

Team Assignment

Develop a PowerPoint presentation that summarizes the team's model process to assess the commercial potential of new products and the preliminary results of applying that model to RWP and Spaceboard.

Session 4—An Experienced Based Model of Successful New Product Development and Commercialization

A. The relay race or the Rugby Scrum

B. The product development spectrum

C. The taste of OJ!

Team Assignment

Prepare list of key questions on new product development and commercialization for session with Richard Guldin and Janet Stockhausen

Session 5—Managing New Product Development in the Public Sector, USDA Forest Service

Guest Attendees

Rich Guldin, Ph.D.
Staff Director
Science Policy, Planning, Inventory, and Information
USDA Forest Service
Washington, DC

Janet Stockhausen
USDA Forest Service

A. The view from Washington, managing NPD

B. Student presentations on preliminary evaluation of RWP and Spaceboard

Team Assignment

Develop a business plan that describes your team's approach to pursuing the commercialization of Spaceboard and/or RWP. Assess the commercialization potential of Spaceboard and RWP. Address at least the following issues:

1. What is the potential of the products in both traditional and non-traditional markets?
2. What resources would be necessary to commercialize the products?
3. Are there any significant engineering or manufacturing challenges?
4. What is availability and cost of raw materials for the products?
5. Are the products "sustainable?"
6. How does RWP compare with Spaceboard in terms of potential for commercial success?

Session 6—What Makes a Product Sustainable?

A. Applying the triple bottom line to new products

B. Summary of an effective approach to new product development process

C. Key elements of a business plan for RWP and Spaceboard

Suggested Course Reading Resources

Crossing the Chasm, Goeffrey A. Moore, 1991, Harper Collins.

Wellsprings of Knowledge, Dorothy Leonard–Barton, 1995, Harvard Business School Press.

New Product Development, Robert J. Thomas, 1993, John Wiley & Sons, Inc.

Innovation and Entrepreneurship, Practice and Principles, Peter F. Drucker, 1985, Harper and Row.

Product Leadership, Creating and Launching Superior New Products, Robert G. Cooper, 1998, Perseus Books.

"Turn Customer Input into Innovation," Anthony Ulwick, *Harvard Business Review*, January 2002.

Appendix II—Patents for Reinforced Wood Products and Spaceboard

Reinforced Wood Products

Soltis, L.A.; Ross, R.J. Bolted wood connections.
U.S. Patent 5,501,054 (March 26, 1996).

Soltis, L.A.; Ross, R.J.; von Segen, W.W.
Break-in resistant wood panel door.
U.S. Patent 5,575,117 (November 19, 1996).

Soltis, L.A.; Ross, R.J.; Rammer, D.R.
Localized notch reinforcement for wooden beams.
U.S. Patent 5,720,143 (February 24, 1998)

Soltis, L.A.; Ross, R.J.; Rammer, D.R.
Localized notch reinforcement for wooden beams.
U.S. Patent 5,852,909 (December 29, 1998)

Spaceboard

Hunt, J.F.
Apparatus for molding three-dimensional objects.
U.S. Patent 6,190,151 B1 (February 20, 2001)

Setterholm, V.C.; Hunt, J.F.
Method and apparatus for forming three dimensional structural components from wood fiber.
U.S. Patent 4,702,870 (October 27, 1987)

Gunderson, D.E.; Gleisner, R.L.
Method for forming structural components from dry wood fiber furnish.
U.S. Patent 5,314,654 (May 24, 1994)

Gunderson, D.E.; Gleisner, R.L.
Apparatus for forming structural components from dry wood fiber furnish.
U.S. Patent 5,198,236 (March 30, 1993)

Hunt, J.F.
Methods and apparatus for making grids from fibers.
U.S. Patent 5,277,854 (January 11, 1994)

Gunderson, D.E.
Apparatus for forming uniform density structural fiberboard.
U.S. Patent 4,753,713 (June 28, 1988)