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Wisconsin Flying Trees: Wisconsin Plywood Industry's Contribution to WWII

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WISCONSIN FLYING TREES: WISCONSIN PLYWOOD INDUSTRY'S CONTRIBUTION TO WWII

By Sara Witter Connor

Introduction

War brings challenges and technological changes in many areas, and WWII brought revolutionary changes to the forest products industry. Building on lessons learned from WWI, the plywood industry was central to meeting new challenges posed during the development of aircraft for WWII. In Madison, Wisconsin, the USDA-Forest Products Laboratory's main concern was "teaching wood to fight."[1] In an effort to perfect waterproof plywood glue, chemists raced to the U.S. Patent Office to record their latest findings. The creation of particle board and paper laminates—the precursors of plastics and fiberglass—would evolve into present day full-blown industries. Cold molding of plywood, infrared lighting and hot presses all improved the plywood manufacturing process. The revolutionary plywood manufacturing processes resulted in creation of new products to aid wartime aviation efforts. Over 25,000 trainer aircraft and gliders were made of wood and plywood. While wood was considered a "substitute material in place of the aluminum alloy,"[2] these products were vital to efforts to build stronger and faster aircraft to defeat the enemy.

During WWI, Roddis Lumber and Veneer (RLV) made aircraft plywood, but after WWI it returned to its primary business of making doors for commercial and residential buildings. However, Roddis Lumber and Veneer continued to manufacture aircraft plywood, and was able to expand production to provide veneer and plywood for the WWII invasion gliders that conveyed men, munitions and equipment behind enemy lines during the Allied invasion of Europe. Men landing in gliders were battle ready in self-contained units. The plywood gliders carried the stamps of Wisconsin plywood manufacturers. Henry Kaiser, the creator of the Liberty Ships, would return to Wisconsin to help develop the transport aircraft that we know as the "Spruce Goose" as replacements for the Liberty Ships. Wisconsin plywood would cover the Allied sky with aircraft.

Under the United States-British Lend-Lease Program in place during WWII, Liberty Ships carried Wisconsin veneer and plywood to England to manufacture the British DeHavilland Mosquito, Avro Anson and Gloster aircraft. Roddis Lumber and Veneer Company in Marshfield, WI, worked with the British Ministry of Aircraft Production in 1940 to produce these materials. The shear testing of plywood for RLV was conducted by the USDA-Forest Products

[1] Nelson, Charles. 1971. History of the U.S. Forest Products Laboratory (1910-1963). U.S. Forest Products Laboratory. U.S. D. A. - Forest Service, Madison, WI p. 125.
[2] Ibid.

Laboratory in Madison. By October 30, 1940, Britain had received the first Roddis shipment. Not only was Roddis shipping veneer and plywood to England, but the Liberty Ships themselves would have Wisconsin RLV fireproof doors. The need for veneer and plywood was desperate according to a secret cypher dated October 2, 1941, to the British Supply Council in North America from the Supply Committee.[3]

> *One of four air screw factories has now run out of imported veneers and is on short time. Stocks of veneers for air frame plywood are down to 2 weeks and total stocks of air frame plywood in U.K. ... [would] enable air frame construction to continue till December only. New supplies require three weeks after arrival at port for distribution in U.K. and manufacture into plywood.*
>
> *It seems clear to us that direct contact between Ministry of Supply experts and U.S.A. suppliers of aircraft veneers will be necessary for next three months. Otherwise essential war production of aircraft will be further curtailed.*

Technological Improvements – Glues and Presses

At the advent of WWI, the glue used in the plywood industry was casein-based and derived from milk protein. This dairy glue would be inadequate for the hot and humid Pacific theater. "[T]here is a very serious loss of strength when typical wooden aircraft structures are exposed to tropical temperatures … the loss of strength under test conditions appears to be about 50% …"[4] The problem of developing a suitable plywood glue had to be corrected if plywood was to become a widely used product for wartime efforts.

In 1931, a man with a black top hat and silver tipped cane arrived in Marshfield from Krefeld, Germany. Baron von Maltitz would meet with Hamilton Roddis and his son, William H. Roddis II to sell Roddis a hot-platen press and a water-proof glue. Von Maltitz represented the Siempelkamp Company and carried with him the promise of an all-important waterproof plywood glue, together with a new manufacturing method using longer 16-foot plywood presses.[5] The result of three years of research, Tego glue film was developed during the 1930s by a German chemical firm, Th. Goldschmidt AG, using phenol resins and soda pulp

[3]Cypher dated October 2, 1941. LONUS 13. To-British Supply Council in North America. From-Supply Committee. British National Archives, London, UK.
[4]Bailey, C. M. and B. J. Richards. 1947. The Effects of Temperature on the Strength of Wooden Aircraft Structures." Council for Scientific and Industrial Research; Division of Aeronautics, Aeronautical Laboratory. Commonwealth of Australia, Fishermen's Bend, Melbourne. Report SM95, 1947. USDA-Forest Products Laboratory Archives, Madison, WI 20 pp.
[5]Interview with William H. Roddis, October 2, 2005, Milwaukee, WI

paper to carry the glue. It was ideal for plywood manufacturing because it could be placed in thin layers between the wood veneers and, under high pressure and heat, the glue film and the wood combined perfectly. RLV installed the German hot-platen press in 1936 where it operated at the Roddis Plywood and Veneer Company until its sale to Weyerhaeuser Company in 1961; it continued to operate at the Weyerhaeuser Company until 1986.

The sale of Tego glue and hot-platen presses from Siempelkamp in Germany put RLV in the forefront of quality plywood manufacturing and eventually aircraft plywood. Tego glue was waterproof and, unlike earlier animal-product glues, was resistant to decay and molds and had a very long shelf-life. By 1939, U.S. Plywood Corporation, Roddis Lumber and Veneer Company, and Algoma Lumber Company controlled 60% of the plywood market.

In the U. S. the development of plywood glue was being pursued on several fronts. An industry chemist, Dr. James Nevin with Harbor Plywood (Hoquiam, WA), developed an exterior plywood called Super Harbord that was produced with a phenolic resin glue. This was touted as the "greatest single advancement in the plywood industry … since 1905."[6] To celebrate the development of this glue, Harbor Plywood constructed a small boat and floated it down the Colorado River to demonstrate its waterproof quality.

By 1940, the Forest Products Laboratory also was working to test and develop waterproof glues. At that time, the Forest Products Laboratory had 175 employees and a budget of $600,000. By the end of 1944, the Forest Products Laboratory had grown to 700 employees with a budget of $2.5 million. Much of this growth was focused on the research needed to improve technologies for wood product manufacturers to aid in the war effort. Technical advances developed at the lab, especially in humidification of plywood to reduce buckling during pressing and drying, were important to the development of plywood suitable for aircraft.

Other research in England involved testing glues but their focus was on the urea-formaldehydes. At the beginning of WWII most small cabinet, piano and woodworking shops became involved in the manufacturing of aircraft components – stringers, spars, etc. and gussets. This cottage industry approach could not be based on the film glues and hot presses but required an alternative glue process. It was during this time period that two young chemists—Joseph Schumann, who had worked at U.S. Plywood, and Kenneth Rapala, a graduate of the Institute of Paper Chemistry—changed the Roddis glue from a Tego film phenolic glue to a phenol-formaldehyde glue. This was a product with applica-

[6]Cour, Robert. 2005. A Plywood Age: A History of the Fir Plywood Industry's First Fifty Years. The American Plywood Assoc. -- The Engineered Wood Assoc. Portland, OR p. 92.

tions in paper laminating that paralleled the plywood industry's work on laminating wood veneer plies.

In a search for ever lighter aircraft, paper laminates were being developed as the British hoped to replace aluminum with laminated compressed paper for aircraft. Laminated paper had been used in glider floors but moisture instability made these inferior to aluminum. In the United States, paper laminate research was taking on 'plastic' characteristics. Developed at Consolidated Water & Power Company in Wisconsin Rapids, Wisconsin and manufactured by Consolweld, a subsidiary of Consolidated Water & Power Company, the product would be called 'Formica.' George Mead, whose grandfather developed the "Dura Beauty" process, said, "It was really the U.S. Forest Products Laboratory that developed the paper laminate and assisted us with developing the process." The History of the Forest Products Laboratory confirms Mr. Mead's comments.[7]

> *One of the most promising Forest Products Laboratory wartime developments in the general field of plastics was a paper-base laminated plastic known as 'papreg.' This material, prepared by impregnating special paper with phenolic resins followed by the molding of the paper sheets into a laminated plastic, drew the interest of paper manufacturers and aircraft manufacturers because it was found to be half as heavy as aluminum and yet capable of developing a tensile strength of 35,000 to 50,000 pounds per square inch, which was comparable to that of certain aluminum alloys on a relative weight basis. Besides its high tensile strength, papreg proved to have exceptional dimensional stability, low abrasiveness, and high-impact resistance.*

During WWII, "papreg" was used in over 156 glider floors delivered to Northwestern Aeronautical Corporation, Minneapolis/St. Paul. Paper laminates would also become a critical component in the manufacturing of two of the most important WWII aircraft, gliders and the DeHavilland Mosquito.

Gliders

At the height of the Great Depression and with no financial stability, the aircraft industry in the United States was floundering. The Great Depression had wreaked havoc on the worldwide economy and the aircraft industry was no exception. In 1937, no one saw the economic impact more clearly than John E. Parker, President of Northwestern Aeronautical Corporation. Parker was a young Naval Academy graduate who became an investment banker. In New

[7] Nelson, Charles, p. 125.

York, he formed a partnership, Auchincloss, Parker, and Redpath, with an interest in American aviation firms. Parker's firm acquired Porterfield Aviation Company, and subsequently received a government contract to manufacture experimental gliders and CG-4A WACO gliders. Parker would transform Northwestern Aeronautical Corporation (NAC) into a glider manufacturer, but the conditions and obstacles for producing gliders were overwhelming.[8] Even if the gliders themselves were constructed, difficulty obtaining wheels or crates slowed delivery. Skilled aircraft employees were not available, and there was a steel shortage. Although the contract for 300 gliders had begun in 1942, only one experimental glider and one prototype CG-4A was constructed during that year.

Serious production did not begin until 1943. The plywood for the glider wings would be made from mahogany and come from Wisconsin's RLV. The 'paper floors' made by Consolidated's Consoweld subsidiary were used in these gliders, as was the 'snow glider nose,' ostensibly for sliding across the snow on landing. At the conclusion of the war, it was noted that "…the outstanding record attained by Northwestern Aeronautical Corporation in the production of gliders for the Army Air Forces is an excellent example of the ingenuity exhibited by American industry in converting from peace-time production to the supplying of the implements of war to the Armed Forces of the United States." [9]

Although there were fifteen or sixteen prime glider contractors, there were about fifty sub-contractors making pieces and parts for the gliders. Some companies were natural outgrowths of the products where there were skilled woodworkers such as Steinway & Sons a New York piano manufacturer. Piano production during WWII was not allowed because of the use of metals. During much of WWII, Steinway stayed in business by manufacturing parts for gliders as a sub-contractor for General Aircraft.[10] Ordering their veneer and plywood from May to August of 1943, Steinway and Sons specified that the facing and the core of the plywood be from red gum, which had been tested extensively for tensile strength. Other orders specified mahogany-poplar or birch-birch. All of the pianos in the factory, equipment, wood, etc. were moved to accommodate glider manufacturing. As Steinway tooled up for the war effort, they supplied the plywood and veneer pieces and parts for the gliders to General Aircraft Company. Steinway had their own patents for tools developed to assist with making gliders, as well as patents for plywood glue and glue applications.

[8] Norberg, Arthur. Nd. Interview with John E. Parker. University of Minnesota - Charles Babbage Institute, Minneapolis, MN p. 4.
[9] Anonymous. 1945. The History of the Glider Program at Northwestern Aeronautical Corporation. Management Control Central District –ATSC. September, 1945. University of Minnesota – Charles Babbage Institute, Minneapolis, MN. p. 5.
[10] Day, Charles, Pers. Comm.. October 31, 2006.

The "Cage Nut Tool" patent was filed in November of 1943 and provided a snap clinching action that would securely fasten the 'cage nut' to the plywood skin. Without the cage nut, screws would split the plywood. The cage nut tool placed an anchoring device on the back or within the plywood to prevent wood splitting. Another patent was the work of George Beiter and called "Securing means for Adhesively Held Parts." A succinct description of part of the glider construction noted.[11]

> *In the construction of gliders, or aeroplanes in which veneer of plywood is used as a shell or skin over the framework, such a sheets of plywood are joined in the frame by a suitable adhesive and pressed together until the joint is dry. Such pressing together of the wooden member was carried out by a plurality of nails arranged successively along a strip of wood or canvas, the heads of the driven nails pressing again the wood or canvas which distributes a part of the pressure to the skin and presses it against the framework and the adhesive there between. The removal of such a strip with nails was difficult, in that the canvas strip would tear from the nails or in the case of wood strip, it would break or split requiring separate operations to remove the nails. The invention consists in providing a plurality of adjacent cleats upon a strip of canvas, and each cleat having a bore for the passage of the nail shank, with the diameter of the bore considerably smaller than the diameter of the head of the nail…*

The removal of nails in canvas and wood would not only be a problem in constructing Steinway's gliders. This tool would be a precursor for Howard Hughes' construction of the "Spruce Goose." Hughes Aircraft Company would submit a patent for a similar tool to remove the eight tons of nails after the gluing process.

Cessna Aircraft Company had been building gliders since the 1930's. While the Great Depression had almost bankrupted them, they received a contract to manufacture trainer aircraft from Canada, which saved them from financial ruin.[12] They made 820 Crane-1 "Cranes" for the Canadian Commonwealth Air Training Plan. In the U.S., these were called the A-8 or T-50. Similarly, the AT-17 or UC-78 "Bobcats" trained thousands of pilots for combat. Roddis Lumber and Veneer supplied not only plywood for the Cessna glider wing panels, but also the plywood for the AT-17 Bobcats. Cessna, Beech, and Boeing worked in concert to produce the gliders. Cessna was to build the outer wing panels and Beech was

[11] U. S. Gov't Patent Office, Washington, D. C., Patent Number 2,384,347.

[12] "Cessna Crane" The Nanton Lancaster Society Air Museum, Nanton, Alberta, Canada. Cessna Cranes were used as the primary equipment at six Service Flying Training School, including No. 3 (Calgary) and No. 15 (Claresholm).

assigned to build the inner wing panels, tail surfaces, all forgings and castings. Boeing did the final glider assembly at an aircraft division near Wichita, Kansas. Remarkably, Cessna built an entirely new "108,000 square foot factory in just over 30 days" to complete the glider contract. The cooperative effort of Cessna, Beech, and Boeing resulted in 750 gliders.[13]

Glider Battles

In a 2005 issue of Equipment Echoes, the editor noted that the following was a typical story usually told about gliders:

> *After the glider landed (crashed), the dozer was unloaded and pushed out a grave for the glider pilots who perished in the landing (crash)….I discovered that it was often the load of equipment itself that spelled the demise of the brave and heroic pilots. If the lashing came loose, the airborne equipment in the glider naturally flew forward on impact resulting in the crew being crushed between the frontal impact and the surging load.*

As a British glider pilot, Ken Mills flew WACO gliders in India. Although he was trained in flying another glider, the Horsa, he said that, "You did 2-3 trips and then you were qualified for a glider…gliders were perceived as disposable…They issued pilots with rifles, but the training was very rudimentary. We didn't have survival or ground training, but we were expected to fight… expected to stay with the troops…"[14] Shipped from England to India at Christmas, 1944, it was a 12 day trip in a DC-3. Franklin D. Roosevelt's plan to assist China by liberating Burma in "Operation Thursday," relied on glider infiltration behind Japanese enemy lines.

The 900th Airborne Engineer Aviation Company's role was "to land their equipment by glider and prepare the airstrips behind enemy lines…."[15] The 900th Airborne hacked landing strips out of jungle. Despite frequent glider crashes, high fatalities, water buffalos, elephants, and Burmese logging operations that left questionable landing zones, the 900th succeeded in their mission. For example, at "Broadway," one of five sites, "35 gliders had crashed. All but three gliders were wrecked, 23 men were killed, and 30 injured…Brackett was left with nine men to complete the airstrip." All told, the 900th, Chindits and the 1st ACG made a total of 14 glider landings in nine weeks. Their accomplish-

[13] Phillips, Edward H. 1985. Cessna: A Master's Expression. Flying Books Publishers and Wholesaler, Eagon, MN p. 119
[14] Interview with Mr. Kenneth Mills, February 27, 2006.
[15] "Operation Thursday." Equipment Echoes. Historical Construction Equipment Assoc., No. 77, Summer 2005. Pp. 3, 25-31.

ments in Burma in the spring of 1944 were overshadowed by events that summer in Normandy.

Another famous glider infiltration took place on D-Day, June 6, 1944. The expected casualty rate was 70%; however, the actual figure was 16%. For those who survived the anti-aircraft fire, the problem became the Norman hedgerows. The fields they enclosed were too small for a decent landing zone. Other significant battles that included gliders were the Sicily campaign, "Operation Husky" to capture the Ponte Grande Bridge. Half of the gliders went into the Mediterranean Sea but some of the men were rescued by passing ships to fight another day. Battle after battle, gliders and the men accomplished their mission against all odds in the face of staggering fatalities.

Dura Mold/Cold Moulding

Parallel to the development of the phenolic resins, Haskelite Corporation had been working with the Army in Dayton, Ohio to design a new model plane, one feature of which was the molding of plywood panels to form a streamlined fuselage. Colonel Virginius E. Clark suggested that a molded plywood fuselage would remedy many of the difficulties inherent in metal aircraft construction. The group developed a novel process for forming the shells using a product called Duramold that provided a light weight fuselage and eliminated the exposed rivets making for a speedier plane. The Duramold process was bought by Howard Hughes where it would be tested and refined for the anticipated payload of the "Spruce Goose."[16]

Howard Hughes realized the importance of the revolutionary Duramold technique which would reduce the plywood thickness, reduce the aircraft weight, and increase the airspeed with flush rivets. Although the "Spruce Goose" was constructed in Culver City, California, the veneer was cut by Herman Johnson at Roddis Lumber and Veneer Company in Marshfield, Wisconsin. Leroy Treutel of Stratford, who succeeded Johnson as lathe operator, said, "Johnson told me when he trained me to cut it that thin. You either cut it or you don't…. It is so thin you can see your hand behind it."

The 'Liberty Ship' and the Spruce Goose were the ideas of Henry Kaiser, a genius with a "can do" attitude. He only visited a shipyard once in his life before he became a shipping magnate, but he was undaunted by the job. He had already built the Hoover Dam, the Grand Coulee, the Bonneville Dam, and the Oakland to San Francisco Bay Bridge. Henry Kaiser realized that current shipbuilding was inefficient, too labor intensive, and lacked basic raw materials. He would

[16] Huit, Katherine. 2002. *Hughes Flying Boat: Spruce Goose*. Historic Mechanical Engineering Landmark, Evergreen Aviation Museum, McMineville, OR.

invent a new ship building process, hire and train laborers on the job, and build the newest steel mill at Fontana, California. The Liberty Ship that he designed and built was 441 feet in length. Using 30,000 feet of fir and 700,000 board feet of lumber per ship[17] and new techniques, Kaiser's workers produced 1,509 Liberty Ships for the war effort.

For Henry Kaiser, a problem arose as the German submarines were sinking the Liberty Ships at an alarming rate in the Atlantic Ocean shipping lanes. Henry Kaiser wondered whether the materials could be sent by air to England in a large transport aircraft. In 1942, Kaiser turned to the aviation genius, Howard Hughes, and to Wisconsin and the Roddis Lumber and Veneer Company. Kaiser was told by the War Production Board to build three prototypes. By 1944, it was clear that not only was the aircraft enormous, but so were the production schedule demands. Henry Kaiser and Howard Hughes, the two driving forces behind the Spruce Goose had dissolved their partnership. In the end, it would be Howard Hughes, who would fly the "Made in Wisconsin" Spruce Goose on November 2, 1947.

DeHavilland's Mosquito

The women in the plywood plants knew that the plywood was "going for an airplane." It was being used in American gliders, but the plywood was also being produced for the Dehavilland Mosquito. The British inventor, Sir Geoffrey Dehavilland, was, like Howard Hughes, criticized soundly for his efforts to build a wooden airplane. As Howard Hughes' Spruce Goose was dubbed "The Lumberyard" by detractors, he could also have learned from Dehavilland's experience with the bureaucracy. DeHavilland had started building airplanes as a young man in 1908.

By WWI, Dehavilland was an expert in aviation. Sir Geoffrey Dehavilland (knighted during WWII) had built his Comet in 1934, which won the 11,000 mile MacRobertson Air Race from London to Melbourne with a record time of seventeen hours. His Comet would be re-designed to become the Mosquito. Affectionately known as the "Mossie," it would be the fastest airplane of WWII with a top speed of 450 mph. Pilots were known to polish their "Wooden Wonder" to coax even a few more knots from her. The "Timber Terror" would carry bomb loads of up to 10,000 pounds.

The Air Ministry was convinced that metal airplanes were the only viable option but at the beginning of WWII, aluminum for aircraft was in short supply. The Air Ministry would turn to Dehavilland, and to Dehavilland's staunch ally, Sir Wilfred Freeman, for support. Dehavilland had a Mosquito prototype ready for

[17] Cour, p. 31.

demonstration at Hatfield, where on November 25th, 1940 it wowed the viewers with its capabilities. No airplane had been as fast, or could fly single-engine, or had so quick a turning radius, or could out run the enemy.[18] Britain did not have the metal for airplanes, but it did have cabinet and woodworkers. DeHavilland received the first contract for 150 Mosquito on December 30, 1940, and they built the Mosquitoes with imported Wisconsin plywood. The yellow birch came from Wisconsin forests, particularly Vilas and Price Counties. In Vilas County, Roddis had purchased the Trostel Estate from Albert Trostel and Sons Company on May 7, 1941. The veneer and plywood would be sent to England in crates built by the Phillips Flooring and Veneer Company in Phillips. Eventually, 7,781 "Wooden Wonders" were built.

Northern Hardwood Veneers, Inc. of Butternut provided 35% of the plywood used to build the 'Mosquito' Bomber. It is recorded that one thousand carloads of Butternut veneer 'winged its way over Europe'-- as the 'Mosquito' Bomber. Roddis Lumber and Veneer Company would provide the other 60% for the "Timber Terror," Roddis also supplied veneer and plywood to DeHavilland at 888 Dupont Street, Toronto.[19] The Canadian production of the Mosquitoes initially encountered problems. Eventually, Central Aircraft stepped in and took over Mosquito production. The RAAF received 1,134 Mosquitoes from Canada. Later, the Roddis Company would be recognized for its war efforts when Queen Elizabeth came to Canada for her first official visit and recognized this valuable contribution to the war effort.

DeHavilland used the already well-established "Duramold" process for construction of the Mosquito. Today, we know the process as cold molding. It made manufacturing and assembly efficient because the two halves of the fuselage provided easy access for wiring and control cable installation during the assembly process. "The fuselage was made in left and right halves…[layering] balsa wood between two layers of birch plywood...Cement was applied between the layers and they were held together with metal bands until set." This technique became known as "sandwich construction."[20] The rest of the airframe was primarily Canadian spruce, with birch covering. The wing was built in one piece and attached to the fuselage later; 550 brass screws held the aircraft together, along with the glue.

The war effort would be both American and British. The British Mosquito would be "superior to the metal equivalent." The fuselage would be 5/8 inch thick, but the wing plies would be even thinner. The Mosquito, if it was damaged in battle

[18] http://www.diggerhistory.info/pages-air-support/ww2-allied/mosquito.htm
[19] Ibid.
[20] Hoff, N. J. and S. E. Mautner. 1944. "Sandwich Construction." Paper presented at the National Light Aircraft meeting of the Institute of Aeronautical Sciences in Detroit, MI, August 27-28, 1944. U.S.D.A. Forest Products Laboratory Archives, Madison, WI and http://www.anu.edu.au/Forestry/wood/wfp/mosquito/Mosquito.html

could be repaired with simple carpentry skills. The two thin plywood birch skins with balsa between had cross-banding laid at 45 degree angles for extra strength. Each wing could support forty-one tons. New waterproof glues meant that the plywood composition was strong and sturdy.

As the Mosquito was developed to have a service ceiling of 44,600 feet and bomb loads of over 10,000 pounds, the long range implications for air tactical warfare were significant.[21] Had WWII continued, the English Lancaster, American B-17, and B-24's likely would have become obsolete.[22] The Mosquito, with a crew of two and the same range, could carry a bomb load equivalent to the larger bombers that required crews of fifteen or more. The British would come to dominate the sky over England and then Europe, and conquer the enemy with the "Made in Wisconsin" Mosquito. The British owed a huge debt of gratitude to Sir Geoffrey Dehavilland. The Mosquito was the quintessential war aircraft -- versatile, efficient, fast, stealthy, and sleek. Battle after battle, Britain slowly reconquered the skies over Britain and over Europe. This extraordinary story of sacrifice and success began in Central Wisconsin and had an international impact on the outcome of WWII. Wisconsin's "Flying Trees" covered the Allied sky.

Conclusion

The story of "Wisconsin's Flying Trees: Wisconsin Plywood Industry's Contribution to WWII" is a story about people rising to the challenges of war. Whether the story is about the women, who toiled long hours, or the brave men and women involved as soldiers, nurses and pilots, they were doing "their duty" to protect our freedoms. Men and women worked hard in the forest products industry. Occasionally they were recognized and honored with Victory Flags, but for the most part, they were ordinary people doing an extraordinary job to survive World War II.

The revolutionary changes in the plywood industry rising out of the ashes of the Great Depression included changes in glue formulas, gluing techniques, and the development of hot presses. For plywood manufacturing, the development of waterproof phenol-formaldehyde resins was the beginning of even more sophisticated synthetic resins. Again, these developments followed the story of men in industry and at the U.S. Forest Products Laboratory laboring to rush these products to market and to assist with aircraft development.

Plywood manufacturing changes carried the United States into WWII with an advantage that would seal our victory. These changes included the beginning of

[21] Sweetman, B. 1981. Mosquito. Crown Publishers, New York, pp. 19-21.
[22] http://www.2worldwar2.com/mosquito-2.htm.

"Modern Logging" to meet the war effort -- bulldozers, the power saw, and Caterpillar tractors. By the end of the war, trucks were hauling logs directly to mills for plywood manufacturing. Over 215 billion board feet of lumber was used during WWII, and some of it provided the basis for a revolutionary approach to manufacturing military aircraft..

As war facilitates technological change and innovations, it also gives rise to geniuses and innovators. In aircraft development, the war effort would have been stymied without the brilliance of Henry Kaiser. His Liberty Ships provided Britain with much needed war materiel and goods not available in a war torn nation. The idea of the "Spruce Goose" was conceived as a large transport aircraft for the war. Although peace was declared before the H-4 was ready, Howard Hughes' designs would revolutionize transport aviation. Today, we know the large transport aircraft as C-130's and C-5A's and as a vital part of the rescue and invading U.S. Armed Forces. Hughes' designs are still incorporated in these aircraft.

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