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The Contributions of Vincent Justus Burnelli

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ABSTRACT

A review of the contributions and the professional life of Vincent Justus Burnelli are presented. Burnelli was an inventor, aircraft designer and a leading pioneer in early aviation within the United States. A discussion of many of his leading accomplishments are discussed, including hid design of the first commercial twin engine transport, invent of the lifting-body/lifting-fuselage aircraft. He was one of the first to put into practice retractable landing gear, variable area and camber wings, winglets, and full span flaps for twin engine aircraft. A review of a number of his sixty patents is presented and discussed as they relate to his eleven aircraft designs that were produced. A brief discussion of his accomplishments and contributions, as they relate to present aircraft design trends is also presented.

INTRODUCTION

A review of the literature shows that for decades, the scientific and aeronautic communities have not fully recognized the contributions of Vincent Burnelli. Burnelli spent most of his career developing aircraft design concepts that maximize the lifting efficiency of aircraft. A basic design premise of the time was that in order to maximize the efficiency of an aircraft all elements/components of the aircraft must contribute to the aircraft lift. In pursuit of this goal Burnelli developed a number of lifting-fuselage/lifting-body aircraft between 1919 and 1945[1-5]. It is important to note that Burnelli was not alone in the development of all-lifting vehicle technology during this period of time. From 1920 to 1955 there were fifty-seven (57) all-lifting aircraft developed[6].

To solve the present challenges and future goals of the air transportation system; that of increased efficiency, passenger safety, and productivity combined with greater personal mobility and expanded transportation capability, the community is now turning to the lifting-body and flying-wing aircraft and design concepts invented and developed by Vincent Burnelli from 1919 to 1964. The basic elements of the Burnelli design principle are just now being considered and utilized by the aeronautical community for a variety of vehicle classes that vary from personal air vehicles (PAVs) to jumbo transports[6-9]. In reflection, it may be argued that if the initial concepts of Vincent Burnelli had been adopted one could envision a dramatically altered and improved commercial air transportation system. The safer and more fuel-efficient aircraft resulting from the Burnelli design principle allows for an increase in the utilization of the air transportation system for the movement of people and goods. A Burnelli design would also provide increased payload fraction and a dramatically improved short take-off and landing (STOL) capability, over conventionally designed aircraft,[1, 4-8, 10-44] allowing for an equally dramatic de-centralization of the air transportation system and thus a measurable reduction in transportation costs. Eliminating or significantly reducing the chance for serious, life threatening, injury [6, 38, 45-48] would remove the stigma of aircraft accidents and increase consumer confidence in the expanded use of air transportation system.

Similar arguments as those presented above can also be made in the context of military aircraft and the design of aerospace vehicles. Aircraft and aerospace vehicle designers, working on future transportation systems, are just now developing systems that mimic the designs of Vincent Burnelli. The most recent example is seen in a comparison of the Burnelli GB-888 from 1962 [49] and the National Aeronautics and Space Administration (NASA) X-43B vehicle of 2002 [50]. The military and aerospace vehicle design environment could have benefited greatly from Burnelli aircraft design concepts and technology that provides improved payload fraction, STOL capability, increased aerodynamic performance and enhanced survivability.

The development of all-lifting aircraft in the United States began with notable work by Burnelli, Staldman, and Northrop in the 1920s and 1930s[6]. Burnelli designed his first lifting-body/lifting fuselage (all-lifting) concept in 1919 and continued to develop his design principles until his death in 1964. In contrast, Northrop did not see his initial flying wing

(with tail) take to the air until 1929. The interest in flying wings decreased significantly during the 1960s and 1970s as focus shifted from flight vehicle development to space vehicle development. The only exception to this trend was the brief activity in the 1950s directed at lifting-body/all-lifting vehicles that supported the design of space reentry vehicles.

History has proved that Vincent Burnelli (1895 to 1964) was a man before his time [51-56]. An innovator with sixty (60) U. S. patents [57-116] and numerous international patents spanning the time period of 1921 to 1964. But as it is with those of great vision, their peers seldom appreciate them. To quote Mark Twain, "The man with the new idea is a crank.....until the new idea succeeds." Unfortunately he never realized the success he earned during his life. In the case of Vincent Burnelli the roadblocks to success were not technical merit but appear to have been related to a combination of public relations, politics, and economics. The paper will review the rich aeronautical legacy of Vincent Burnelli and discuss the design lessons of the past.

THE EARLY YEARS, 1914 to 1917

Figure 1. Photograph of Vincent Burnelli

Vincent Justus Burnelli (see figure 1) was born in Temple, Texas in 1895 and first learned of manned flight from a schoolmate in 1903. By 1908 his family moved to the New York area and Vincent continued to pursue his passion in aviation. Upon his arrival in New York he immediately began designing and building model airplanes and was a member of the famous National Aero Club [117]. Even at this young age he broke with the design convention of his peers, which followed the concepts of the Wright brothers, which included pusher propeller with forward mounted controls. Vincent Burnelli's designs and models were configured with a tractor propeller and aft controls so that he could assess the relative performance benefits of the two design approaches. It was during these early years than he became interested in the idea of very large aircraft [35].

By 1915 he had achieved acclaim as a champion model aircraft builder, a hang-glider and was the assistant technical editor of Aircraft magazine. He continued to pursue his dream in 1915 when he formed the Burnelli Aircraft Company in the hopes of developing aircraft for the government in response to World War I. He proceeded to design and construct his first powered aircraft with his friend John Carisi. The Burnelli-Carisi bi-plane, shown in figure 2[118], was not purchased by the government, but it did become the first aircraft owned by the New York City Police Department.

Figure 2. Photograph of the Burnelli-Carisi bi-plane.

In 1916, at the age of twenty, he became the chief designer for the International Aircraft Company in Washington, D.C. and by 1917 he had joined the Continental Aircraft Company located on Long Island, NY as the chief engineer and superintendent. Between 1917 and 1918 he designed and built several successful aircraft, including the KB-1 Continental Pusher [119], a military trainer (see figure 3).

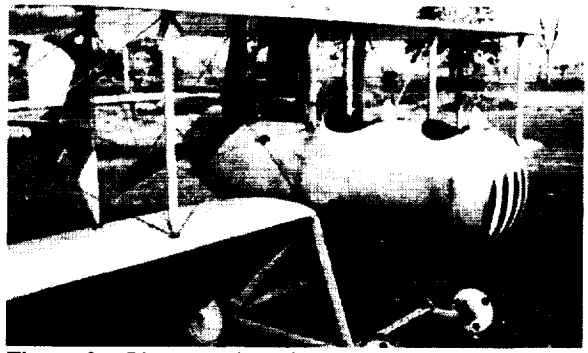


Figure 3. Photograph of the KB-1 Continental Pusher.

This was followed by the KB-3 [49], a tractor design that was similar to the Curtis JN-4 [51]. A number of the Continental KB-3s were delivered to the U.S. Army. Unfortunately Vincent Burnelli's work at Continental is most noted for his involvement with Dr. William Whitney Christmas, and the notorious Christmas Bullet Aircraft [56,119], see figure 4. The Christmas Bullet was a doomed vehicle with irrational construction techniques of Dr. Christmas design[119]. Two of the vehicles were built and both vehicles crashed on their maiden flights, killing their test pilots. Vincent Burnelli who was an unwilling participant in the Christmas Bullet project, walked away from the Continental Aircraft Company as his final act in a failed attempt to stop the flight test of the aircraft. Unfortunately the crash of the Christmas Bullet was not attributed to Dr. Christmas but was directed at Vincent Burnelli and others at Continental.

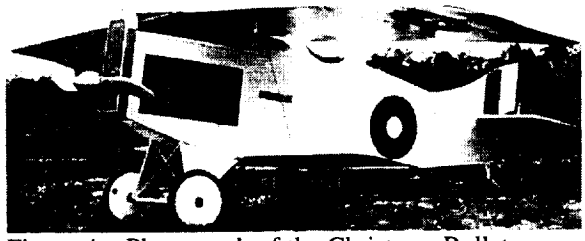


Figure 4. Photograph of the Christmas Bullet.

THE BIRTH OF THE LIFTING FUSELAGE, 1918 to 1927

A turning point in Vincent Burnelli's career occurred when he went to work for the Lawson Airplane Company of Green Bay and Milwaukee, WI in 1918 as the chief engineer and superintendent. The primary focus of Burnelli at this time was to build airplanes for peace instead of war. The war was winding down and the airplane had proved itself capable of carrying large loads, long distances, very quickly. Alfred W. Lawson, a self described genius and owner of Lawson Airplane Company shared Burnelli's vision of the future with aircraft transporting people and goods around the country and around the world. However, Lawson did not share Burnelli's knowledge of aeronautics and aircraft design. It was therefore fortunate that as Burnelli set to work building America's first twin-engine airliner, the Lawson Air-Line, Lawson set out to secure financial backing. The result was the Burnelli designed Lawson C-2 Airliner [49], completed in 1919, see figure 5.

Besides being the America's first twin-engine commercial transport aircraft, it was also the first to have an enclosed cockpit for the pilot [1]. The bi-plane was very large, capable of carrying 26 passengers. Burnelli designed the fuselage with load carrying

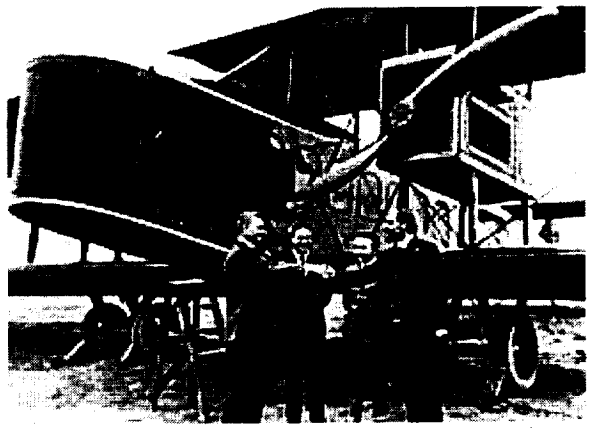
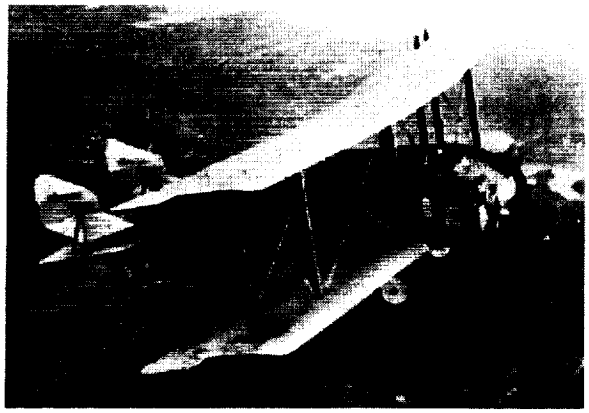


Figure 5. Photograph of the Lawson C-2 Air Line.

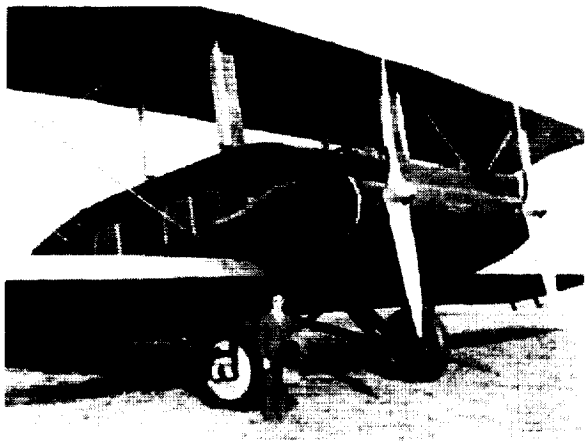
internal bulkheads made of laminated plywood in order to open up the fuselage compartment and remove the traditionally used cross braces and wires. Unfortunately when it came time to showcase the Lawson Airliner, its namesake imposed his will resulting in a series of critical logistic and economic errors that doomed the company and the aircraft.

Although he was proud of his technical accomplishment, Burnelli was never fully satisfied with his design and was frustrated with the working environment at the Lawson Airplane Company. He had a vision of aircraft with greater aerodynamic efficiency and left Lawson in 1920 to pursue his unique design interests. He initially took a position at the Nebraska Aircraft Company in Lincoln Nebraska but soon found himself back on Long Island, New York and partnered with T. T. Remington to form the Airliner Engineering Corporation in 1920. It was here that he could explore his unique vision for large aircraft, the lifting-fuselage concept.

Depicted at the top of figure 6 is the RB-1[1], Burnelli's first design that incorporated his lifting-fuselage principle [62]. Burnelli applied for a patent on the lifting-fuselage (lifting-body) concept in 1921 but had to wait nine years for the issuance of patent number 1,758,498 [62]. Built in 1920 the RB-1 was a 74 foot span, twin engine, bi-plane transport capable of carrying 32 passengers in its huge slab sided, airfoil shaped fuselage. The fuselage also housed two engines that were completely buried to eliminate the parasite drag of the propulsion system. The lifting-fuselage was designed to contribute a significant portion of the aircraft lift allowing for reduced take-off and landing speeds, thereby increasing flight safety. Flight tests of the RB-1 proved the Burnelli design principles and identified a number of stability and control issues.



RB-1



RB-2

Figure 6. Photographs of the RB-1 and RB-2 lifting-body aircraft

The following year he formed the Remington-Burnelli Company and in 1923 he designed and built the RB-2 [1], a slightly larger version of the RB-1 with improved control surfaces and larger engines, as shown at the bottom of figure 6. The RB-2 was the world's largest air freighter at the time capable of carrying over 6000 pounds of freight with a three-man crew. The load carrying capability of the aircraft was demonstrated when it carried two automobiles and, for brief period of time in 1924 the RB-2 served as the flying showroom for Essex Automobiles. As with the RB-1, the RB-2 also suffered from inadequate control due the placement of the elevators and rudder on the fuselage trailing edge.

The RB-2 was Burnelli's last bi-plane to utilize his lifting body principle with all subsequent designs being mono-planes. However, all future design would take advantage of the design criteria developed and proven with the RB-1 and RB-2. A summary of the criteria is listed below, as summarized from reference 1.

1. Propellers located close together in front of the lifting fuselage to provide improved flight efficiency, excellent single-engine controllability, and improved safety from propeller failure or crash.
2. Engine location in front of passenger compartment results in design with extra structure in the front bulkhead that protects the pilots and passengers in case of crash.
3. Pilot and mechanic compartment provide access to engines and landing gear for maintenance and repair.
4. Aerofoil fuselage section provides 50% of the lift at cruising speed, reducing non-lifting body air resistance. More than 60% of the weight and structure surrounds and protect the passenger cabin section during a crash.
5. Wings are of a reduced span and area owing to body lift, reducing drag and weight. Bending moments due to overhang lift are reduced about 40% at the wing roots.
6. Fuel tanks are installed at a greater distance from, and out of line with, the engine, thus reducing the risk of fire.
7. The baggage and freight compartment is accessible for in-flight inspection and servicing.
8. Twin tail booms support the tail surfaces with maximum rigidity and minimum weight. Initial objections to twin boom design were caused by twisting of the center section of the wings.
9. Windows are located below the upper wings permitting unobstructed views from the cabin. The wide body provides large cubic capacity for payload. In the event of ditching the flotation qualities of the wide body are advantageous.

Despite his technical success Burnelli continued having difficulty marketing his designs and as a result his partner T. T. Remington pulled out from the company in 1924 and over the next few years Burnelli joined forces with Thomas Garvin and formed the Garvin-Burnelli Aircraft Corporation in 1924 and then with Inglis M. Uppercu in the late 20s.

TECHNICAL INNOVATIONS, 1928 to 1934

Over the next six years Vincent Burnelli was a prolific designer and inventor in which he was granted patents relating to; variable area and camber wings [71,78], retractable landing gear [68], short take off and landing aircraft [80], buried engines [79], winglets [67], all-wing design [84,85], and the lifting-body design [70,73] to

name a few. Vincent Burnelli translated these innovations into a number of advanced aircraft concepts; CB-16, GX-3, UB-20, and UB-14, see figures 7, 8, 9, and 10 respectively [119,49].

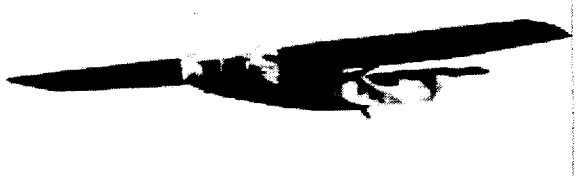


Figure 7. Photograph of the CB-16 lifting–body mono-plane.

Burnelli's transitioning of the lifting-body design principle from bi-planes to mono-planes began in 1924 and was realized in 1928 when he designed and built his first lifting-body mono-plane for Paul W, Chapman, the president of Sky Lines Incorporated. The CB-16 [10,119], shown in figure 7, was a high-wing, twin-engine, aircraft constructed with twin-booms to support the tail and control surfaces. The twin boom design was adopted to correct the stability deficiencies encountered with the RB-1 and RB-2 designs. As with his earlier designs, Burnelli continued to push the design limits of his day by being the first to incorporate retractable landing gear into a twin-engine aircraft and by designing the CB-16 to be the first twin-engine aircraft capable of sustaining level flight, at full payload, with one engine. The CB-16 was known at the time as the first executive airliner and was luxuriously appointed. The aircraft could carry twenty passengers, each passenger having a large cushioned, swiveling and reclining seat. The cabin also had a lounge area with a galley and washroom.

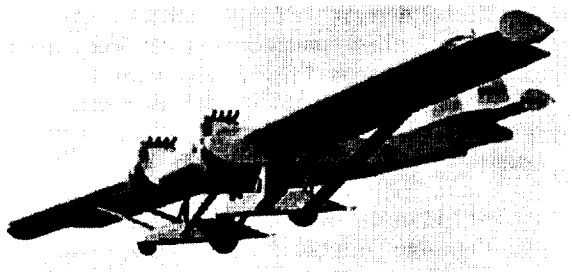


Figure 8. Photograph of the GX-3, the 1929 Guggenheim Safe Aircraft Competition.

As his lifting-body design principles had been demonstrated Burnelli set off to design an aircraft for the 1929 Guggenheim Safe Aircraft Competition [10,46,47]. Burnelli's design for the competition is shown in figure 8 and was the designated the GX-3 (aka UB-SS) [45,79,80]. The design included the lifting-body principle, but more noteworthy was that the GX-3 was the first twin-engine aircraft to have a variable area and variable camber wing [71,78], full-span high-lift flaps[78], winglets[67], and pivoting wingtip ailerons[67], see figure 8. Although the GX-3 arrived late for the competition and did not participate it did demonstrate its outstanding STOL performance capabilities [10,46]. The aircraft demonstrated take-off and landings of less than 300 feet and a landing speed as low as 30 m.p.h..

Figure 9. Photograph of the UB-20 lifting–body mono-plane.

In 1929 Burnelli teamed with Inglis M. Uppercu and formed the Uppercu-Burnelli Aircraft Corporation with Burnelli serving as the Vice President and General Manager. The focus of the partnership was to produce sport airplanes and to continue development of the Burnelli lifting-body design principle. The first aircraft developed under this partnership was the UB-20, shown in figure 9[70,79,119], similar in design to the CB-16 but with several advanced structural improvements. The UB-20 was the first American transport with smooth flat-metal stressed-skin construction[2]. The UB-20, which was recognized for its load carrying capacity and large passenger cabin, first flew in 1930.

Despite the accepted safety and structural advantages of the lifting-body design the community had raised a number of technical concerns related to the large fuselage and the impact on aerodynamics [12]. Primary among these concerns was the negative aerodynamic drag effects attributed to the lifting-body fuselage due the increased fuselage frontal area and the negative fuselage wing interference. An analysis of the concept was performed in 1931 by Wertenson[11,12] to address the concerns. The analysis showed that the Burnelli design concept results in less frontal area than a conventional twin-engine transport and that the negative fuselage to wing interference is more than compensated by the increased lift of the fuselage. Subsequent analysis performed at the time also supported the findings of Wertenson [14-17].

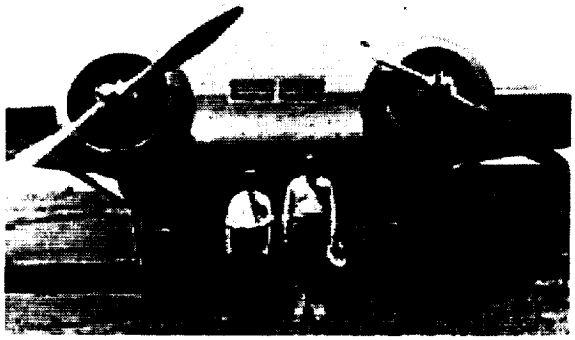


Figure 10. Photograph of the UB-14 lifting–body mono-plane.

Shown in figure 10 is Burnelli's next design, the UB-14 [16,70,79]. Built in 1934 the 14 passenger transport aircraft was similar in appearance and construction to the UB-20. The primary differences between the UB-20 and UB-14 were retractable landing gear and had an enclosed cockpit. Other differences included a tapered wing and partially exposed engines fitted with cowlings. As with his other designs the UB-14 had excellent load carrying capacity and STOL performance.

DESIGNING THE FUTURE, 1935 to 1964

After fifteen years of development and technical achievement it appeared that the Burnelli lifting-body design principle was gaining acceptance by the public and the aeronautical community. The scientific community was also taking notice and performed a number of independent analysis of the design concept that validated the claims of the designer [18-26,29-34,36-39]. He had gained the support of many highly respected individuals that included Dr. G. V. Lachman[8], Dr. Alexamder Klemin[15], Dr. Max Munk[32], and GeneraL H. H. Arnold[31,34]. Despite the position of prominence achieved by Vincent Burnelli financial success continued to be elusive.

In 1935 Burnelli's financial backer and partner, Uppercu, suffered great financial losses that prohibited the production of the UB-14 aircraft. Unable to generate sufficient interest in the aircraft in the United States, Burnelli turned to Europe and found interest from several foreign countries. In 1936 the UB-14 design was licensed to the Scottish Aircraft and Engineering Company [3]. Unfortunately the company went bankrupt in 1937 and construction was stopped. The following year, in 1938, the rights to the design were obtained by the Cunliffe-Owen Aircraft Ltd. of England. To assist the development of the British version of the UB-14 Vincent Burnelli agreed to serve as a consultant. Cunliffe-Owen redesigned the UB-14 and designated the aircraft OA-1[27]. Even though the OA-1 was a completely new design it did maintain all of the salient features of the Burnelli lifting-body design principle. Unfortunately only one of the aircraft was produced.

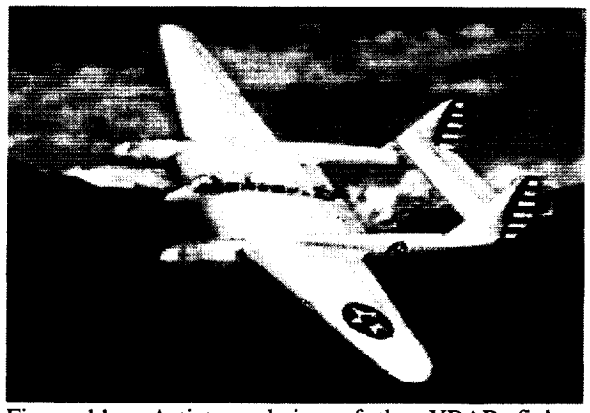


Figure 11. Artist rendering of the XBAB fighter bomber.

With the money from the licensing of the UB-14 Vincent Burnelli was able to sustain The Burnelli Aircraft Company and focus on several new designs in support of the U.S. war effort. Over the next few years he produced a number of innovative fighter and fighter/bomber designs [86,103-105], see figure 11. Each of these designs were shown to have outstanding performance [25,26,29,30] but for a variety of reasons were never accepted by the military.

In 1940 Burnelli served as a consultant to the Higgins Aircraft Company of New Orleans and in 1941 served in a similar capacity to the Canadian Car and Foundry. He also remained active during this time period producing a number of patented technologies and aircraft designs. Of note is his design of cargo aircraft that utilize containers and rear access doors for efficient operations [92-94,106]. As with most of his innovations, the community did not accept the cargo aircraft design concepts until several decades had passed.

At the end of the WW II Burnelli went to work for the Cancargo Aircraft Manufacturing Company, a subsidiary of the Canadian Car and Foundry Company, to develop the CBY-3 Loadmaster [4], see figure 12. This was the last aircraft designed and constructed by Burnelli using his lifting-body principle. The CBY-03 was similar in design to the UB-14 with increased performance and load carrying capacity. As with his other designs the CBY-03 was not put into production and only one was built. First flight of the Loadmaster was in 1945 and it spent over 15 years in service for a variety of companies both within and outside the U.S.

Figure 12. Photograph of the CBY-03 cargo aircraft.

In 1944 Burnelli was recognized by the aeronautics community when he received the Fawcett Honor Award for his " Major Contributions to the Scientific Advancement of Aviation". Over the next two decades he continued to design and innovate addressing such diverse technical issues as boundary layer control, flush inlets, jet propulsion, and all-wing designs for a two-person sport plane and a 1000 passenger transport aircraft [94-102,108-116]. A photograph of a Burnelli transport model is depicted in figure 13.

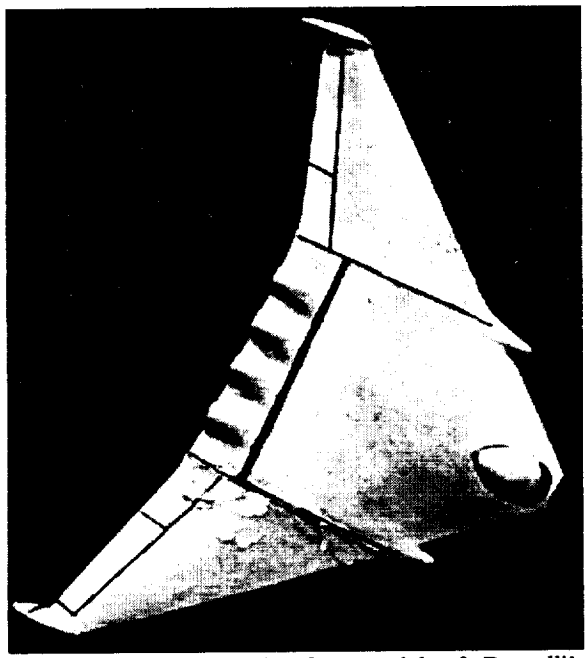
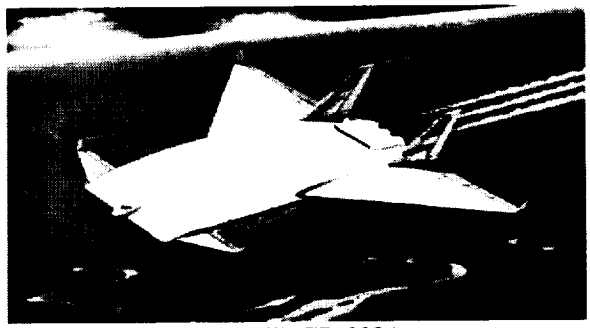


Figure 13. Photograph of a model of Burnelli's advanced transport design from 1951.

It is interesting to note the strong linkage between the recent all-lifting vehicle designs of today and the designs of Burnelli from the 1940s to 1960s. Shown in figure 13 is the Burnelli design of advanced transport from 1951,which has a similar planform to the Blended Wing Body (BWB) [6] of today. A comparison of the Burnelli high-speed transport design from 1964 to the Boeing/NASA X-43B concept of 2002, is shown in figure 14. These two designs are strikingly similar. A dichotomy of conclusions may be drawn from the images presented in figures 13 and 14, either a good design is timeless, to the experience collected in the past is either unknown, forgotten, or at the least ill-judged



Burnelli, GB-888A

Boeing/NASA, X-43B

Figure 14. Artist renderings of the 1964 Burnelli and the 2002 Boeing/NASA high speed designs.

CONCLUDING REMARKS

A review of the numerous and significant contributions made by Vincent Burnelli to the scientific advancement of aviation has been presented which highlights the breadth and creativity of this early pioneer. Most notable of these innovations is the lifting-body concept invented and developed by Vincent Burnelli in 1920. This basic element of the Burnelli design principle is just now being considered and utilized by the aeronautical community for a variety of vehicle classes that vary from personal air vehicles (PAVs) to jumbo transports. Perhaps Burnelli was correct when he stated in 1950. "Aviation is still in its infancy; give it a chance to grow up, and they will see that I am right. The lifting fuselage is the first new configuration since streamlining was first introduced, and my plane carries more, carries it faster and safer."

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