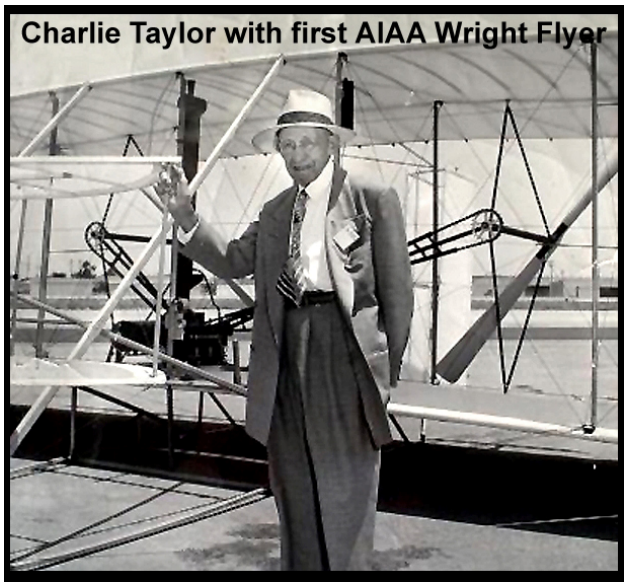
# THE AIAA WRIGHT *FLYER* PROJECT 1978-2008

## I. Origins of the AIAA Wright *Flyer* Project

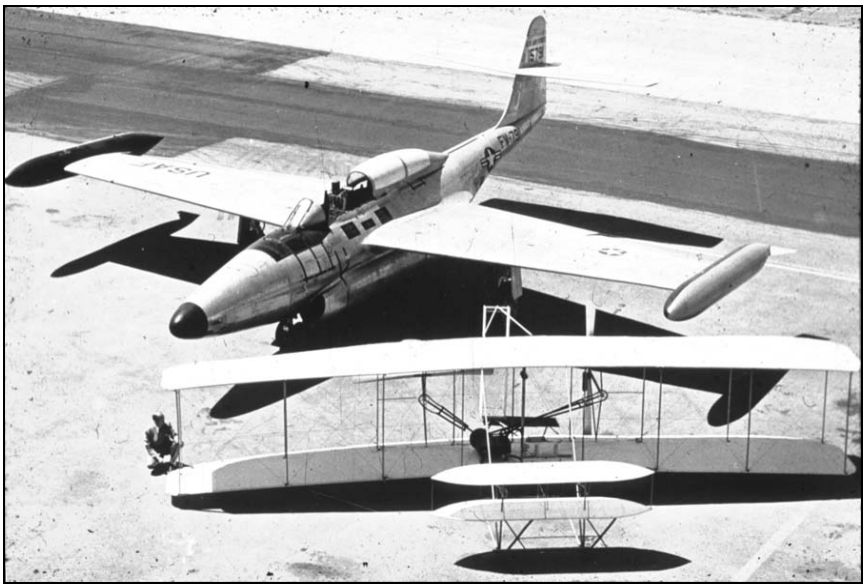
The Los Angeles Section of the American Institute of Aeronautics and Astronautics has a 50-year history of celebrating the accomplishments of the Wright Brothers. Current activities include completion of a full-scale replica of the 1903 *Flyer* to be flown publicly in 2009. Those flights will mark the culmination of a thirty year project devoted to construction, technical and educational programs commemorating the first great R & D program of the twentieth century; the beginning of flight; and the founding of the aerospace field.

In 1978, the Los Angeles Section of the American Institute of Aeronautics and Astronautics began a project to build two replicas of the Wright Brothers' first successful powered aircraft, the 1903 *Flyer*. The first aircraft was an aerodynamically precise replica constructed as a wind tunnel test aircraft. Two weeks of successful tests of the airplane were carried out in March, 1999. The second aircraft, currently being constructed, is a minimally modified flying replica of the 1903 *Flyer*. At the beginning of this project, the AIAA group agreed that one of its primary objectives would be construction of a flyable *Flyer* to be flown publicly and in multiple occasions to give a faithful impression of the first controlled, man-carrying flights of 17 December 1903. This document is a brief history and description of the project.

In 1951 the aircraft industry of Southern California, led by the Lockheed Aircraft Company, resolved to construct a precise replica of the Wright 1903 *Flyer* in celebration of the Wrights' first powered flight. In a ceremony on 17 December 1953, the aircraft was presented to the public. Figure 1 has photographs of the aircraft with Charlie Taylor, the Wrights' machinist, and with a Northrop F-89. Construction of the replica was commissioned by the IAS, the Los Angeles Section of the Institute of Aeronautical Sciences which later merged with the American Rocket Society to form the American Institute of Aeronautics and Astronautics (AIAA).




(a)



(b)

**Figure 1**

After being displayed for 20 years in the AIAA Section Headquarters in Los Angeles, the *Flyer* was loaned to the San Diego Aerospace Museum. It remained there until destroyed in a tragic fire in 1978.

Upon receipt of $20,000 insurance claim for the loss, Howard Marx, then Chairman of the Special Events Committee of the AIAA Section, proposed building a full-scale flying replica. Following Howard's announcement in the Section newsletter, Fred Culick was first to respond, offering results of his planned wind tunnel tests of a 1/6-scale model of the *Flyer* to the Project in return for the privilege of being First Pilot of the flying replica. Howard advised that he should also be Project Engineer. After a few more key volunteers had joined, the AIAA Wright *Flyer* Project officially began with an all-day initiation meeting in April 1979. Approximately sixty people attended, nearly all active or retired professionals in the aerospace field.

Plans were soon modified when the opportunity was offered to test a full-scale replica of the 1903 *Flyer* in the 40'x80' wind tunnel at the NASA Ames Research Center, Moffett Field, CA. Accordingly, the Project objectives were formulated in 1980.

## AIAA WRIGHT *FLYER* PROJECT OBJECTIVES

1. **Construct and test a full-scale wind tunnel model of the Wright 1903 *Flyer*.**
2. **Construct and fly a full-scale replica of the Wright 1903 *Flyer*, to give a faithful impression publicly of the first flights.**
3. **Document all activities of the Project as contributions to technical history and education.**

These objectives remain unchanged and are being successfully met. Soon after the Project was defined by those objectives, Howard Marx' duties as an officer in the AIAA Section caused his resignation as Chairman of the Project. Jack Cherne replaced him, with Howard as Deputy Chairman, an arrangement that continued until Jack's death in 2004. Marx served briefly as interim Chairman until Fred Culick agreed to take the position. Bud Chamberlain serves as overall supervisor and ,until her move to Texas, Marilyn Ramsey, handled the bulk of our relations with the press and sponsors.

Lindbergh with "Bud" Gurney, at Lincoln, Nebraska, where they both learned to fly.

**1922** **1981**

**Figure 2**

The Project is a remarkable example of an extended volunteer activity, successful due to the dedication and collegiality of the participants drawn together primarily by their shared love of airplanes and aviation. Along the way the Project has lost fourteen members by deaths: Arvin Basnight, Bic Bickford, Jack Cherne, Gene Coates, Carl Friend, Dave Gold, Harlan 'Bud' Gurney, Fred Hooven, Wally Perry, Henry Rezler, Wendall Seward, Mel Shorr, and Bob Trelease. Four marriages have been celebrated in the Project: John Latz, Ed Marin, Howard Marx, and Steve Shackleford.

The completed wind tunnel model, now on display in the FAA building in Los Angeles, is dedicated to the memory of Bud Gurney (Figure 2) who was a skillful constructor and restorer of aircraft, and Charles Lindberg's closest flying buddy. He is shown in Figure 2 with Lindberg in 1922 and in Figure 3 with Koon Wah Lim and components of the *Flyer* during its construction.

During the Project's life, members have come and gone. A few have formed a continuous core. Much of the work has actually been done by people occasionally unable to maintain their own continuous participation, for various personal reasons, but not for lack of interest. A chronology, given in Attachment A, of the main accomplishments is the best summary of the Project's success since 1979.

## II. Early Construction of the First Full-Scale Replica

The decision to build two replicas of the *Flyer* didn't affect matters of construction because we would build them in series, the wind tunnel model first. There was no urgency to decide on the revisions to be incorporated in the flying version, and because the wind tunnel tests had not been scheduled, there was no external pressure to hasten construction of the wind tunnel mode. That was a fortunate circumstance, for three reasons: 1) almost no one in the Project had experience building a wood, wire and fabric aircraft. 2) we had no place to build and assemble the structure; 3) with entirely volunteer labor, almost all of whom were busy with other activities, construction proceeded very deliberately.

Fortunately, we did have two members who knew well what to do about construction — Fred Erb of the Northrop Corporation and Bud Gurney who had retired in 1968 as a Captain of DC-8s for United Airlines. Bud had experience with fabric covered aircraft since the early 1920's, including restoration of several of his own. He donated a large part of the wood used in our *Flyer* and construction began in his garage. For the early stages of construction, we created a small cottage industry. The Northrop Corporation provided an area in a factory in Torrance, CA., where we could assemble the aircraft. At times, the repetitive construction requirements became tedious—someone in the Project counted more than 8400 parts of the airplane.

Our construction program proceeded well and the uncovered aircraft was fully assembled in 1983. It remained in that state for several years. We moved the aircraft on two occasions for public display.

Special components caused special problems. For example, after two years of searching unsuccessfully for muslin covering material, we were able to share in an order procured by the National Air and Space Museum for re-covering their original *Flyer*. We were even more fortunate with the chain drive. The Diamond Chain Company who had made the chain for the Wrights still had the tooling to make the now non-standard chain and manufactured ours.

A problem arose, however, because the new 'old' chain was too stiff to cross. Crossed chain, in tubular guides, is required to produce counter-rotation of the propellers. To remove the stiffness we chose to run-in the chain with an applied side load. In fact, the procedure is better described as 'wear-in' because it was necessary to keep the chain dirty and without lubrication to loosen the joints. We ran the chain in this manner, in a rig designed and built by Cherne, for about one year (off and on) before it functioned properly (good construction and good material).

The Wright Brothers' use of a sprocket/chain drive for the propulsion system—likely inspired by their experiences with bicycles—was a good choice. Like others who have worked

with the Wrights' design, we have found this to be a very robust system. It operated without difficulty throughout our static tests and many hours in the wind tunnel. The only problems we had were overheated bearings, due to depleted lubrication.

In the early to mid 1980s we maintained occasional contacts with those responsible for the full-scale wind tunnels at NASA Ames. They were enthusiastic about the prospect of testing our aircraft in their 80'×120' tunnel. Following several meetings, we established the changes required in the aircraft necessary to mount it on three vertical struts extending from the floor of the tunnel. We also had to satisfy several requirements before we could conduct a test program. For mounting the airplane in the tunnel, we designed and fabricated a special internal wing structure comprising mainly two steel ribs, ten inch wide boxes, installed in the center section of the lower wing at the joints with the other panels. Two of the ball-joints in the tunnel struts would fasten there, and the third would be attached to a steel cross bar on the landing skid. The last was normally located at the tail of a test aircraft, but for our purpose the turntable in the floor of the tunnel would be rotated 180 degrees.

The requirements we had to satisfy were related to structural strength and integrity. Carl Friend, a retired engineer from Lockheed, did a thorough analysis of the entire aircraft. NASA normally requires that no part of the aircraft in a wind tunnel should fail at five times the maximum load experienced during a test. For our airplane, the critical load factor was reduced, by agreement with NASA, from five to three. Friend's analysis revealed several weaknesses. As a result, we constructed the canard outriggers of steel, and the material in several pieces of the vertical tail was changed from wood to aluminum. Also, the wing warp wire and pulley guides were strengthened.

We made another minor structural change for practical reasons rather than due to structural weakness. Rigging the biplane cell can be a tedious and lengthy process. The Wrights cut their diagonal truss wires exactly to predicted sizes, a procedure that doesn't allow for stretching which must occur during both the static tests and the wind tunnel tests. We therefore chose to use adjustable turnbuckles supplied to us by the Bell-Memphis, Inc.

## III. Covering and Static Load Tests

Over a period of about four years, we covered the airplane, which was finally assembled in 1992. For the long seams, Philip's Draperies in Pasadena donated a considerable amount of their labor. Figure 3 shows attachment of fabric to one outer wing panel. To prove our structural analysis, we had to carry out a static load test. That required assembling the aircraft inverted and supported at the three attachment points in a test rig. To simulate the loads with the load factor required by NASA, more than 3000 plastic bags were filled with 3000 pounds of sand and distributed over the wing and canard surfaces. Construction of the support rig took more than a year; the test was performed in February 1993.

**Figure 3**

**Figure 4**

In fact, a static test of this sort requires a great deal of planning: Miscalculations, poor planning, or errors in execution of the test procedure, could lead to catastrophic failure. The execution must be well choreographed to avoid undesirable differential loading. Fifty people participated in the actual test, placing six different sizes of weighted bags on each rib, in each of four increments: 24 bags per rib (Figures 4 and 5). The first attempt to test failed within a few hundred pounds of maximum load when two strut fittings pulled from the wing span. Poor quality control was the reason: Screws of the wrong size and type had been used. Two weeks later the test was successful. Howard Marx planned the static load test and prepared the report.

**Figure 5**

Following the static test, the aircraft was removed from the rig and rotated upright. Shortly after that event, Northrop informed us that we could no longer have our space because they were vacating the factory. We were extremely fortunate that a very good friend of the Project, Mr. 'Bic' Bickford, immediately offered us even more (and cleaner) space in his company quarters, International Die Casting, Inc. in Compton—a convenient central location, free of rent. We moved there in 1993 and stayed until the Fall of 1997, when we moved to the Able Corporation in Yorba Linda, where we did final tests of the propulsion system. For the wind tunnel tests, NASA required us to use electric power rather than a internal combustion engine. The Able

Corporation was one of the few locations in the LA area where we could access the required power. And the owner, Mr. not only provided the power, but space to work at no cost to the Project.

The airplane remained at the Able Corporation until we transported it to Moffett Field in March 1998.

## IV. Preparations for Testing After 1993

In September 1993, eight members of the Wright *Flyer* Project visited Ames Research Center for a meeting with test personnel. All participants were enthusiastic about the tests, likely to occur within 12–18 months, depending on the scheduled use of the 80×120 tunnel. Then sometime in 1993, as NASA's budget declined, decisions at the highest level of management at Ames led to cancellation of our opportunity to test. We were notified of the decision while we were beginning the last phase preparing the airplane for the tests. We had an airplane—but no place to go.

We contacted Langley Research Center and heard a similar story: We could test in their 30×60 tunnel, but at a price we could not possibly afford—more than $500,000.00—which would be extremely difficult to accumulate with gifts and fund-raising. Culick's investigation of facilities around the world led to the discovery that there was only one other wind tunnel that we could use. It is located in the TsAGI complex in the town of Zhukovski [1], close to Moscow. We conceived the idea of generating more sympathy to our cause within NASA if we seriously discussed a possible test program at TsAGI.

As an Academician in the International Academy of Aeronautics (IAA), Cherne had long known a fellow Academician and well-known mathematician/aerodynamicist, Vladimir Chernyi of Moscow State University. Chernyi arranged a connection with the Director of TsAGI and Culick visited there for a day in September 1994. Their test group was as enthusiastic as NASA's, and wanted the work. With plans of the airplane in hand, they spent three months determining the technical feasibility of the proposed tests, and how the tasks would be distributed between TsAGI and the Wright *Flyer* Project to accomplish the interfaces for mechanical, electrical and instrumentation systems.

In December 1994, Culick returned to TsAGI to find everything proceeding well, including drawings of hardware that would have to be fabricated.[2] Agreement was reached to press on with planning. The group at TsAGI would also prepare a budget which turned out later to be between $150,000.00 and $200,000.00 depending on the extent of the tests and of the supporting effort. In addition, of course, we would be faced with the task of getting our airplane there.

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[1] The name of the town had been changed from the centenary, 1947, of Zhukovski's birth. Zhukovski is a direct transcription from the Russian.; the spelling Joukowski was used in early translations from Russian to Polish, German, French, and English. Zhukovski was also one of the founders of TsAGI, the Central Aero-Gasdynamic Institute.

[2] An interesting tangential point is that the TsAGI group had constructed and tested a model of a Muzhaiskii airplane designed and alleged (by some Russian historians) to have flown before the Wrights. The TsAGI engineers say that their tests showed that the airplane could not have successfully flown: They credit the Wrights with the invention of the powered airplane.

Meanwhile we had informed NASA Headquarters (both Dan Goldin, Administrator, and Wes Harris, the Associate Administrator for Aeronautics) of our plans and intentions. At a 1994 meeting of the IAA, Goldin had informed Cherne that he would find a way for us to test at Ames. NASA could not allow us to carry out the first wind tunnel tests of the first airplane in Russia! Eventually the arrangements were made through NASA's Educational Outreach Program, with much of the NASA work effort provided by volunteers.

Thus the possibility of testing at TsAGI vanished, much to the disappointment of the Russians involved. We had also hoped that we would have the opportunity to collaborate with TsAGI on propeller tests of Wright propellers. Our plans for aninternational test program are forever shelved.

The Wright *Flyer* Project resumed serious planning with the test group at NASA Ames, now led by Pete Zell. Meetings at Ames led to the decision to mount the airplane on a sting attached to the underside of the lower wing. The principle reason was that the aerodynamic forces and moments generated by the Wright *Flyer* would barely be resolvable at the low end of the load ranges covered by the balance system associated with the strut mountings. The sting contained a six-component strain gage balance.

However, this change of measurement system brought with it substantial work on design and fabrication. The large load concentrated in the center section of the wing required that the wood spars[3] be replaced by aluminum, and the steel ribs would be removed. A heavy steel structure was designed and built to make the interface between the sting and the wing. Votaw Manufacturing Company and the Marfab Corporation fabricated the parts at no cost.

After the construction work was completed (including a further donation of sewing by Philip's Draperies), the airplane was moved to the Able Corporation. There we completed the instrumentation and data acquisition system and carried out propulsion tests of the complete configuration of the *Flyer* to be used in the tests at Ames.

## V. The Move to Ames

Transporting the *Flyer* is relatively straightforward in some respects but does present some practical difficulties. The canard with outrigger is attached with cleverly designed joints at the wing leading edge and the skid. Thus the entire assembly, as well as the rudder assembly with support connections to the upper wing and the skid, can be removed from the wing cell.

Marilyn Ramsey and Steve Shackelford of the Los Angeles FAA office were able to arrange transportation in two new 50-foot air ride trailer trucks with all costs donated (equivalent value $40,000) by American Red Ball Moving and Storage Company and De Vries Moving and Storage. The biplane cell occupied one trailer; the other trailer carried the canard and tail assemblies, and various pieces of equipment. The entire move from the Able Corporation in

[3] Two breaks in the spars had already been discovered, likely caused during the move between facilities. The change to aluminum spars had therefore been contemplated before the decision to test on a sting.

Yorba Linda to Moffett Field was executed flawlessly by the truly professional personnel of the two trucking companies.

As part of the Project's Public Relations and Educational Outreach Activities, directed by Ramsey and Shackleford, the trip to Moffett Field took seven days. Marilyn, Steve, and several other members of the Project accompanied the two semi-trailer trucks: Arvin Basnight, Bud Chamberlain, Don Dotson, Bill Haynes, Joe Lander, Wendall Seward, and Bob Trelease. They stopped at eight schools and airports on the way to give public talks to about 5000 people, most of them young students. Presentations were given at Cal Poly Pomona (two engineering classes); Chino Airport; Flabob Airport, home of EAA Chapter #1; Bakersfield; Fresno Maer Elementary School; Clovis Clark Middle School; San Jose Toyon Elementary School; and to a group of Boy Scouts at Moffet Filed.

On the seventh day, the *Flyer* arrived at Moffett Field. It was unloaded and assembled in historical Hangar No. 1, former home of the U.S. Navy's rigid airship fleet in the 1930s. The interior is large enough to hold three *Titanics* side-by-side, and is longer than Wilbur's longest flight of 852 feet on 17 December 1903.

On 15 April 1996, NASA held a press conference to announce the test program. The event was covered by media in the Bay Area and by reporters from national radio and television organizations. Figure 6 is a picture of the event, taken by a photographer for the San Jose *Mercury*.

**Figure 6**

The *Flyer* remained in a fenced area in Hangar No. 1 and was the site for many educational meetings with teachers and students. Members of the Project made regular visits to complete work on the airplane's control and data collection system, under the direction of Jack Cherne.

## VI. Installation of the AIAA Wright *Flyer* in the Ames 40×80 Tunnel

To ensure that the airplane could be assembled and operated on the sting in the tunnel, a Pathfinder test was carried out in the former airship hangar. The sting assembly was moved from the tunnel and the airplane was mounted with a dummy balance, the balance block and the interface assembly. It was then operated through the entire range of angle of attack planned for the tests.

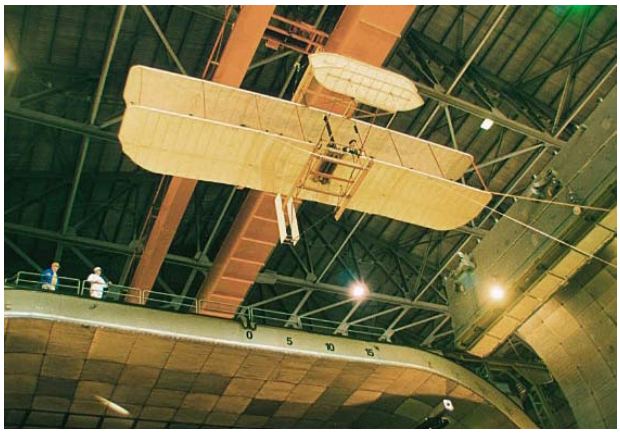
By the fall of 1998, it became clear that the tunnel would become available sometime early in 1999. That tends to be a wet season in the Bay Area. The 80×120 tunnel is an open system, drawing air from the outside. That is not a good situation for the untreated fabric covering in the *Flyer* so the tests were rescheduled for the 40×80 section placed in a closed loop.

The change to the 40×80 section meant that the airplane would be lifted from the building floor roughly 100 feet (ten stories) over the top of the test section and lowered into the tunnel. That exercise required a hoisting sling to be designed, fabricated and proof-tested for the expected load.

In February 1999, the airplane was once again disassembled and trucked one mile from Hangar 1 to the wind tunnel building where the airplane was re-assembled on the floor. Final calibrations were made of the LVDTs supplied by Lucas Aerospace for measuring the position of the controls. The last test prior to mounting the aircraft in the tunnel was operation of the propulsion system to ensure that it would work with the NASA power supply and to train the NASA operator. That two-hour test was completely successful.

## VII. The Ames Tests (March 1999)

On 1 March 1999, NASA personnel hoisted the AIAA Wright 1903 *Flyer* into the 40×80 test section. The procedure was accompanied live on the Web by an explanatory conversation between Fred Culick and a member of the Ames Public Relations Office. During the installation, they answered questions from school children and youth. It was indeed, an emotional event, the climax of 20 years work.



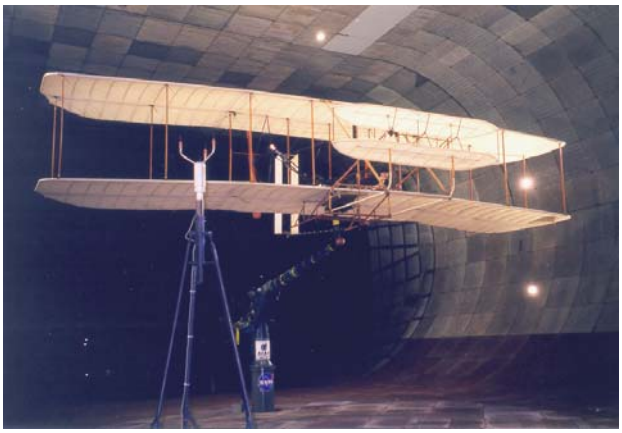


**Figure 7**

Four days later, NASA opened the tunnel to the media to display the first airplane now mounted on the sting in one of the world's largest wind tunnels. The event was reported in hundreds of newspapers, magazines and TV stations around the world.[4]

Simultaneously with the open house, NASA maintained a live Web site on which key people involved in the Project were interviewed during the entire test program and subsequently, the web site provided interviews, chat rooms, data and suggested projects for students K-12.

The 40×80ft wind tunnel has a maximum test section airspeed capability of 300 knots. Airspeed is adjusted using a set of six variable blade angle and rpm fans. The very low airspeed requirement of 25 knots for the 1903 Wright *Flyer* test raised two concerns during test planning. First, would the facility produce uniform flow through the test section at the extreme low end of the operating envelope? And second, was the existing facility wind speed measurement system adequate to meet data accuracy requirements?

The 90 highly twisted fan blades of the 40×80ft wind tunnel are optimized to operate near maximum blade angle and rpm. The 25 knots required for the 1903 Wright *Flyer* test was achieved by operating the fans at 36 rpm (20% of max.) and 16.5° blade angle (52° is max.). It is expected that a large portion of each fan blade is stalled during such low speed operations and that the outflow of the six fans is extremely non-uniform.

A test section survey was conducted using a hand-held wind anemometer to assess flow uniformity. The facility produced a relatively flat velocity distribution, implying that the Wright *Flyer* would be exposed to a uniform flow, wing-tip to wing-tip, during testing. Flow unsteadiness was apparent during the test section velocity survey. This effect was due to random turbulence; data sampling times could be optimized to eliminate any effects on measurements.

The existing facility dynamic pressure/velocity system was deemed inadequate to measure the low airspeed for the 1903 Wright *Flyer* Test. The solution was to use two atmospheric sonic wind sensors near the entrance to the test section, ahead of the *Flyer*. These sensors were mounted on 15' tall struts that raised them to the elevation of the model at 0° angle of attack. They were also mounted laterally approximately ±15' from centerline. The readings from the sensors were averaged and used to set tunnel conditions for the test. NASA worked with the sensor manufacturer to improve measurement accuracy of the anemometers to approximately ±0.1 knot.

Balance selection for wind tunnel testing is generally a process that involves compromise. It is rare to find an existing balance with capacities in all six components that are ideal for the planned test envelope. The 1903 Wright *Flyer* was no exception. A four-inch diameter Mark II internal balance was selected after determining that the large facility external balance would not meet data accuracy requirements. This balance was confirmed to have acceptable accuracy and

[4] It was reported as well by the Voice of America beamed to Moscow.

repeatability in the lower 10% of the normal (lift), axial (drag), and side force ranges. Expected pitching and yawing moments were also found to be well within the capacity of the Mark II.

The ratio of the span of the model (40') to the diameter of the Mark II balance (4") was 120 to one. Rolling moment predictions for full wing warping showed that the full balance capacity of 16,000 in-lbs would be required during the test. Operating the balance at nearly full rolling moment capacity while measuring the other five balance components at the very low end of range raised concerns about interaction errors. This was evaluated by examining offsets with the balance loaded to capacity in roll. Interactions were determined to be manageable however, at full roll capacity, the balance was found to deflect over 1.25°. This deflection is addressed in the equations for data reduction. The concern was that this balance "softness" in roll could result in dynamic excitation of the model during testing. Mechanical roll stops were thus integrated into the model mounting hardware to protect against inadvertent balance overload.

Operating the facility so far off of the optimum running line combined with a large-span model mounted on a soft balance to create some excitement during early runs. The *Flyer* was observed to rock and roll randomly with occasional large excursions (up to ±6 inches at the wing-tips). This rocking caused data alias problems with 30-second duration data points. Efforts to operate the facility at higher fan rpm (closer to the optimum running line) did not improve flow conditions. Data point sampling durations were extended to two minutes, resulting in acceptable data quality. Time history data was also acquired to allow for potential post-test data processing to filter the effects of flow unsteadiness.

Acquiring balance data for a full two minutes per data point made it impossible to meet pre-test productivity expectations. Yet, the goal to measure accurately relatively small forces and moments from a 40' wingspan, wood and fabric 1903 Wright *Flyer* model with props rotating was achieved.

Cherne, Zell and Culick give a description of general preparations for the tests in AIAA Paper No. 200-0511. In AIAA Paper No. 2000-0512, Jex, Hange, Latz and Grimm summarize the results of the full-scale tests conducted at Ames Research Center during two weeks in March 1999. Comparisons with the data obtained from the earlier tests with the 1/6- and 1/8-scale models are given.

The 1/6-scale model hangs in Fred Culick's living room; the 1/8-scale model is in on display at our current work-space at the Riverside Airport, to be put on public display later at the Riverside Airport Terminal; and the full-scale wind tunnel model is on indefinite loan for display in the FAA Building in Los Angeles. The full-scale replica of the *Flyer*, built to fly, is in the last stages of assembly.

## Attachment A

## A CHRONOLOGY OF THE WRIGHT *FLYER* PROJECT

1) **1979** April. Formal establishment of the Project: 'kick-off' meeting.

2) **1980** December. 1/6-scale flexible model of the 1903 *Flyer* constructed and tested by F.E.C. Culick in the ten-foot GALCIT wind tunnel at the California Institute of Technology (Figure A-1). The results are documented in GALCIT Report No. 1034.

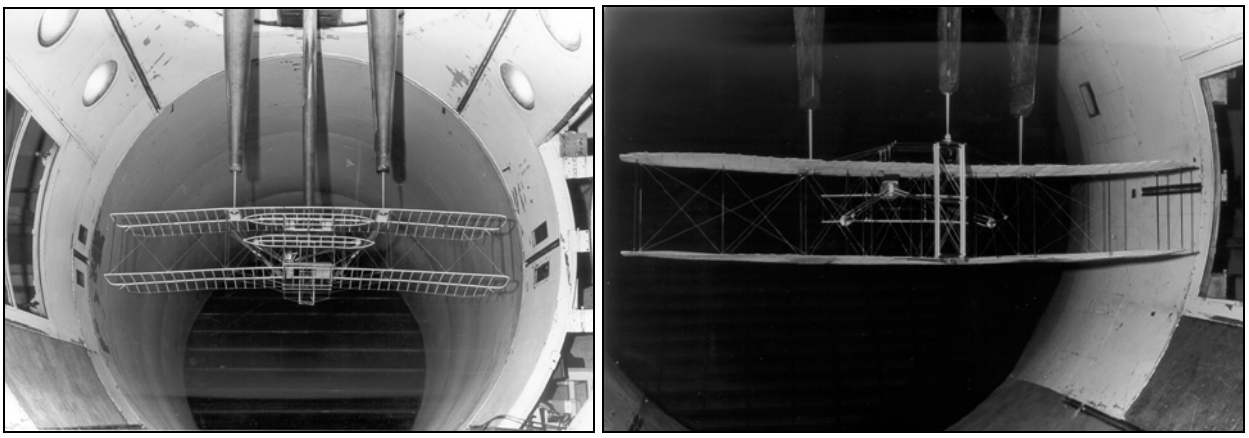


**Figure A-1**

3) **1981** 1/8-scale stainless steel model constructed and tested by young engineering staff as a training exercise at the high speed wind tunnel facility at the Northrop Corporation (Figure A-2). The results are documented in an informal Northrop report.

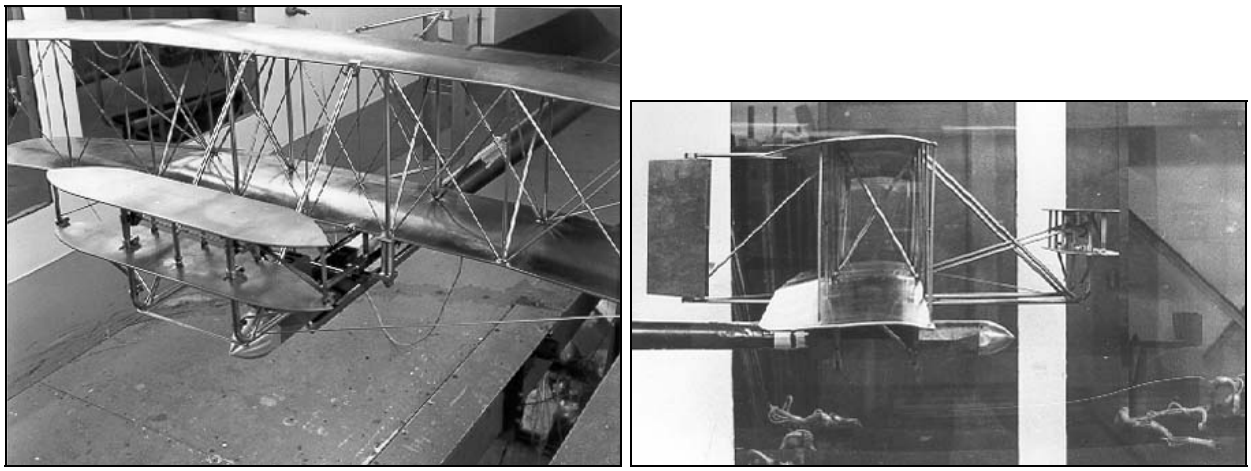


**Figure A-2**

4) **1982** A report, *Analysis of Lift, Drag, and Pitching Moment of the 1903 Wright Flyer*, was prepared by Charles McPhail, then Chairman of the Project's Aerodynamics Committee. This document, available in edited form on the Project's website, is a

detailed discussion of many characteristics of the airplane examined within the classical principles of applied aerodynamics and aircraft design.

5) **1983** December. A paper prepared by F.E.C. Culick and H.R. Jex, *Aerodynamics, Stability and Control of the 1903 Wright Flyer* presented at the 1983 Symposium *The Wright Flyer – an Engineering Perspective* held at the National Air and Space Museum, commemorating the 80th anniversary of the Wright's first powered flights. Based on the data taken with the sub-scale models, this was the first ever quantitative analysis of the control and stability of the 1903 *Flyer*. The results explain almost all flying characteristics of the airplane, in particular those which rendered the original *Flyer* difficult to fly.

6) **1984–1986** The uncovered but assembled 1903 *Flyer* was publicly displayed on two occasions. Figure A-3 shows the aircraft in the space donated free of charge by the Northrop Corporation (1979–1994). Fred Erb supervised the construction and was primarily responsible for completing the structure.

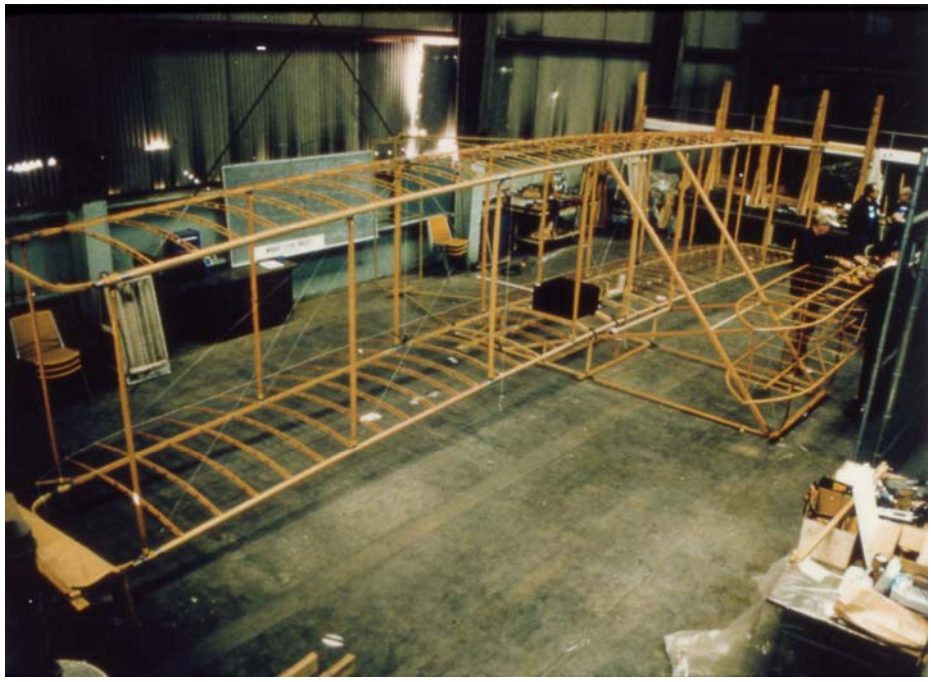


**Figure A-3**

7) **1986–1987** Construction and flight of a 1/8-scale radio controlled replica of the *Flyer*, shown in Figure A-4. A gyroscope was installed to aid control of the unstable model in pitch. Intended to test design changes, the model had several successful flights but was severely damaged in a crash when the over-confident professional R/C pilot turned off the gyro and could not control the aircraft. The flights were recorded on video tape. No tests have been attempted since; the model, partially rebuilt, is displayed at the current work site.

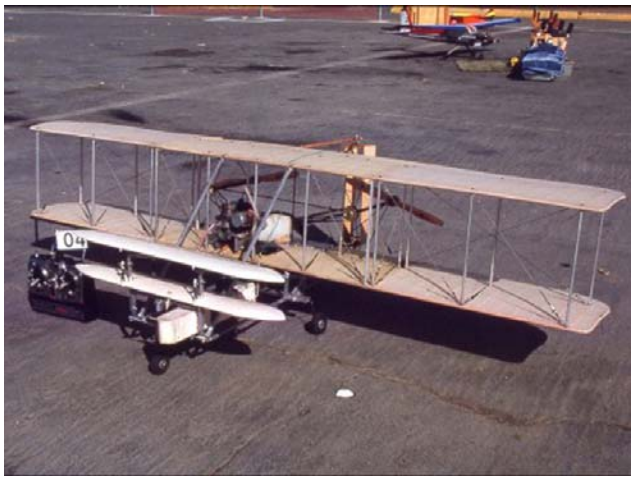


**Figure A-4**

8) **1987** Completion, by Carl Friend, of a report covering loads and stress analysis of the original 1903 *Flyer* as part of preparations for wind tunnel tests. As a result, some changes of materials were made to strengthen some critical components.

9) **1988–1991** The *Flyer* is covered with fabric purchased as part of the lot provided to the Smithsonian National Air and Space Museum to re-cover the original *Flyer*.

10) **1993** February. After Project personnel constructed a test stand to support the inverted aircraft, static load tests were carried out under the supervision of Howard Marx. The results prove that the AIAA replica of the 1903 *Flyer* possesses a load factor of 3.0 as required by agreement with NASA Ames for the wind tunnel tests.

11) **1994** Northrop closed the factory in Torrance where the AIAA site was located. The Project is moved to a space donated by Mr. 'Bic' Bickford, owner of the small factory, International Die Casting.

12) **1994–1996** Due to budget restrictions in NASA, plans to test the aircraft at Ames were cancelled in 1994. As a result of negotiations with Jack Cherne and a proposed alternative plan to test the AIAA *Flyer* in Russia, Dan Goldin, Administrator of NASA, approves the tests. NASA agrees to sponsor the test program on grounds of their outreach, educational and historical value.

13) **1997** The *Flyer* wing structure was reinforced to permit mounting on a sting instead of a 3-point support, in either the Ames 40' × 80' or 80' × 120' wind tunnel. An aluminum spar replaces the original wooden spar in the lower wing.

14) **1998** April. The AIAA *Flyer*, accompanied by six members of the Project, is transported from the Able Corporation, Yorba Linda, CA, where tests of the propulsion system were completed, to Moffett Field in two semi-trailer trucks. On the way, the Project makes eight stops and gave presentations to a total of approximately 5,000 school children. Jack Cherne and Henry McDonald, Director of Ames, sign a Space Act agreement for testing the Wright *Flyer*. On 18 April, the airplane is presented publicly in a ceremony attended by many representatives of the media (Figure A-5).

**Figure A-5**

15) **1999** March. A two-week test program is successfully carried out in the NASA Ames 40' × 80' full-scale tunnel. The event was widely reported in the national and international press including pictures of the *Flyer* in the tunnel (Figure A-6). The NASA website, http://quest.arc.nasa.gov/aero/wright, contains lengthy descriptions of the activities.

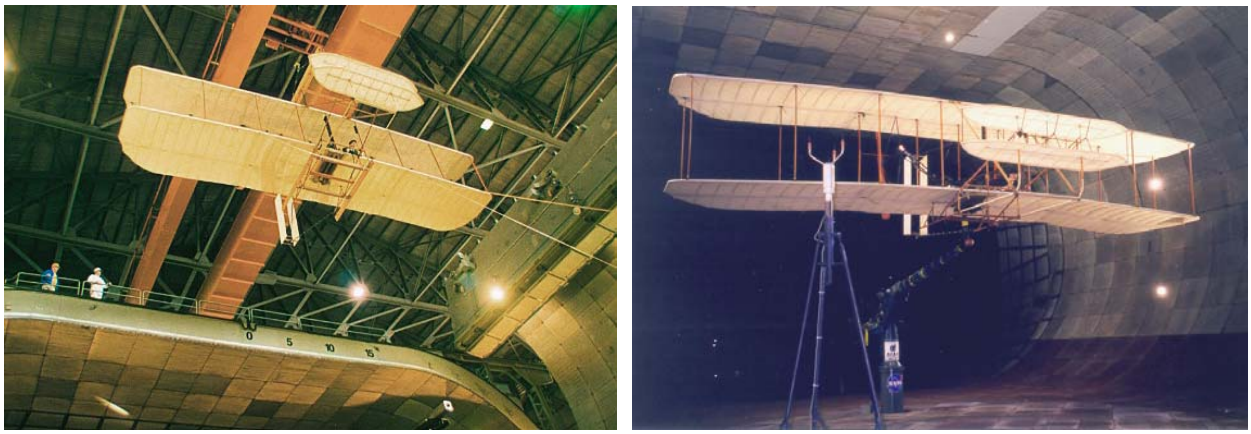


**Figure A-6**

16) **1998** December. Agreement is reached between the AIAA Wright *Flyer* Project and the Western Pacific Region of the FAA to loan the *Flyer* for display in the Flight Deck Museum in the FAA Regional Headquarters Building, El Segundo, CA.

17) **1999** April. The airplane is removed from NASA Ames and transported back to Los Angeles. Figure A-7 shows the *Flyer* in the FAA Flight Deck Museum.

**Figure A-7**

18) **2000** After several months in a temporary location at Northrop in Hawthorne, the Project moved to a new work area in Microcosm, Inc. courtesy of Jim Wertz.

19) **2001** April. The proposed AIAA modified 1903 *Flyer* is chosen as one of the projects for the 2001 class at the Air Force Test Pilot School, Edwards Air Force Base. Aerodynamic data from the full-scale tests, and changes defining the modified design, were used as the basis for a ground simulator and for the Veridian variable stability in-flight simulator, a Learjet 24. The project is successfully completed and is reported in a lengthy document. It is especially interesting that the Wright *Flyer* seemed to have been the most popular of the semester's projects, at least partly because the six students, all active Air Force pilots, have an unusual opportunity to fly (or at least try to fly) an unstable aircraft with no stability augmentation.

20) **2000–2005** After briefly occupying a space in the Northrop facility in Hawthorne, CA, the Project moved to a new area generously made available to us by Jim Wertz and his firm, Microcosm, Inc, in El Segundo, CA. Construction and covering of the aircraft are nearly completed during this period. Development tests of the propulsion system are carried out with the Revmaster engine originally purchased, with a gearbox, in 1982.

21) **2003** From December 2002 to December 2003 the Project took the wind tunnel aircraft on national tour ending at the FAA building in El Segundo, where it remains on display (Figure A-6) During the tour, extended stops were made at: Western FAA Regulations Office, Hawthorne, CA; Nellis AFB Airshow, Las Vegas, NV; World Space Congress, Houston, TX; New England Air Museum, Hartford, CT; Kennedy Space Center, FL; Fayetteville Center of Flight Celebration Airshow, Fayetteville, NC; Van Nuys Airshow, Van Nuys, CA; Dayton Airshow, Dayton, OH; Edwards AFB Airshow, CA; and the Northrop-Grumman Corporation, Hawthorne, CA.

22) **2005** After some months of rumor, we finally learn that approximately at the end of 2005 the Project would have to move. The building rented by Microcosm was to be sold. Inquires among friends, and unproductive leads at two other airports, finally led to a live possibility at Riverside Airport, 55 air miles east of LAX. Through a friend, Hank Schnerl, we met the owner of Riverside Air Service. He agreed to give us space in a hangar, just two hundred yards from the east-west runway. We planned to move before August 2005, but before we started to plan details of the move, Riverside Air Service was sold. At the earliest opportunity, Culick had lunch with the new owner, Zach and Thai Greenfield, and the original plans were restored. In August 2005 the AIAA Project moved to a workplace in a hangar belonging to Zenith Flight Support. (Figure A-8) It's the most comfortable of our many locations, even including a conference room! The new space meets our needs perfectly!

23) **2006** Covering is complete and assembly is underway in the Zenith hangar. The completed flying replica, the AIAA Wright *Flyer*, will be dedicated to the memory of Jack Cherne.

24) **2006** In the fall of 2006 Zack Greenfield warns Fred Culick that Zenith will soon need the space occupied by the Project. After pleas by Fred, attending two meetings of the Riverside Airport Commission, and earnest efforts by the Airport Manager, Jack Ripley, we were unsuccessful in our search to find space on the airport property. Then Hank Schnerl (again!) suggested we inquire about possibilities at Flabob Airport located at the northeast edge of the Riverside control zone.


**Figure A-8**

25) **2006** So one Saturday in November, Bob Sechrist went with Fred to investigate Flabob, accompanied by Hank. It happened that Monday was Veteran's Day, and that weekend Flabob was having an Open House and air show. Bob and Fred found nobody to speak with, but the people in charge would be back on Sunday. Fred returned on Sunday and met Tom Wathen and John Lyons. That meeting began the final chapter in the wanderings of the Wright Flyer Project.

26) **2007** We had some meetings and discussions with Tom and John, and quickly reached agreement to move the AIAA Project to Flabob. It's as close to an ideal location as we could hope to find. The one negative point is the location so far from our preferred areas closer to Los Angeles, but after the time at Riverside Airport, we're more or less used to all the driving. Otherwise, things are really great! For the full story of Flabob, see the Airport's web site. Briefly, the airport is owned by the Wathen Foundation, and is no longer in danger of becoming a housing development. Tom, retired after many years as CEO of the Pinkerton Agency, and long committed to supporting general aviation, bought the property in 2000. The Foundation has a Charter High School on the airport property, now attended by 60 students. Education of the younger generation has become a second main objective of the airport, joining the original one of supporting restoration and flying of historical aircraft.

27 **2008** Presently we occupy (and rent) half of a hangar. We anticipate that eventually we will occupy, possibly sharing, a hangar on the flightline, perhaps eighty meters from the Airport Café. Our plans are to complete the airplane by early next year, followed, of course, by first flights. Giancarlo Zanardo (check his website) has agreed to be first test pilot. Our intention is to give public demonstration flights a few times each year.

Flabob Airport, Looking North

**Attachment B**

## ACCOMPLISHMENT OF THE PROJECT OBJECTIVES

This Project began in 1979 with $20,000 in its bank account. Other than the full-scale wind tunnel model, current assets include another set of propellers and a modern engine which we may or may not use in the flying replica. We received an additional financial donation from the ALAA to support the tour around the US in 2003. We have also received much help in the form of goods and services at reduced cost or free of charge, which have helped considerably. The largest costs were workspace, and transporting the aircraft to-and-from NASA Ames, courtesy of Red Ball Express; the wind tunnel test program and associated public relations, arranged and supported by NASA Ames; and space to construct and assemble the aircraft.

From the beginning in 1979 to 1994, Northrop Corporation provided space without charge in Torrance, CA. From 1994 to October 1997 the Project occupied a space donated by International Die Casting in Compton, CA. For the period during which final preparations were made for the wind tunnel tests, space was provided by the Able Corporation in Yorba Linda, CA., where access to the electrical power necessary for final tests of the propulsion system was available. Following the wind tunnel tests at Ames, and after a brief period in space at Northrop Corporation, Hawthorne, CA, the Project moved to space donated by Microcosm, Inc. owned by Jim Wertz. The Project occupied space at Microcosm, Inc. in El Segundo, CA, from 2000 to 2005. We constructed the second AIAA Flyer, intended to give public flying demonstrations of the aircraft. We are now located in a hangar owned by Zenith Flight Support at Riverside Airport, Riverside, CA.

The First Project Objective has been met. Construction of the aircraft to meet the Second Objective has been underway for five years. In the interests of safety for making multiple public flights, and because we anticipate that several pilots may fly the aircraft, minor changes of geometry (airfoil, canard and vertical tail), and some substitution of materials, will be made to the original design. This is not intended to be a pristine museum piece, but an operating replica; it must be able to withstand the wear and tear of testing and demonstration flights. Construction has been completed and final assembly will be accomplished in late 2006.

The Third Objective—documentation and education—will continue to receive the Project's keen attention, through print, pictures, filming and oral presentation. In addition to thousands of photographs and miles of videotape of construction of the first aircraft, members have been active preparing papers and giving public lectures. The complete list of papers by participants gives a comprehensive coverage of the Project and related history:

- Hooven, F.J. (1978) "The Wright Brothers' Flight Control System," *Scientific American*, (December).

- Culick, F.E.C. (1979) "The Origins of the First Powered, Man-Carrying Airplane," *Scientific American*, (December).

- McPhail, C.D. (1982) "Analysis of Lift, Drag, and Pitching Moment of the 1903 Wright *Flyer*," internal Project memo.

- Bettes, W.H. and Culick, F.E.C. (1982) "Report on Wind Tunnel Tests of a 1/6-Scale Model of the 1903 Wright *Flyer*," Guggenheim Aeronautical Laboratory, California Institute of Technology, GALCIT Report No. 1034.

- Howe, D. et al. (1982) "1903 Wright Flyer 1/8-Scale Wind Tunnel Aerodynamic Data."

- Culick, F.E.C. and Jex, H.R. (1983) "Aerodynamics, Stability and Control of the 1903 Wright *Flyer*," in proceedings of *The Wright Flyer: An Engineering Perspective*, National Air and Space Museum, Smithsonian Institution.

- Hooven, F. (1983) "Longitudinal Dynamics of the Wright Brothers Early Flyers," in proceedings of *The Wright Flyer: An Engineering Perspective*, National Air and Space Museum, Smithsonian Institution.

- Jex, H.R. and Culick, F.E.C. (1985) "Flight Control Dynamics of the 1903 Wright *Flyer*," 12th AIAA Atmospheric Flight Mechanics Conference, AIAA Paper No. 85-1804-CP.

- Friend, C. (1987) "Safety Analysis of the 1903 Wright *Flyer*," internal Project memo.

- Culick, F.E.C. (1988) "Building a 1903 Wright *Flyer* – By Committee," 26th AIAA Aerospace Sciences Meeting, AIAA Paper No. 88-0094.

- Marx, H. (1993) "Static Proof Load Test of a Full-Scale 1903 Wright *Flyer* Fitted for Wind Tunnel Testing," AIAA Aircraft Design Systems and Operations Meeting, AIAA Paper No.93-3937.

- Jex, H.R. and Culick, F.E.C. (1999) "Results of Wind Tunnel Tests of the 1903 Wright *Flyer*: Stability, Control and Flying Qualities," SAE Aerospace Control and Guidance Systems Committee, Meeting No 84 (Best Paper Award).

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- Jex, H.R., Grimm, R., Latz, J. and Hange, C. (2000) "Full-Scale 1903 Wright *Flyer* Wind Tunnel Test Results from the NASA Ames Research Center," 38th AIAA Aerospace Sciences Meeting, AIAA Paper No. 2000-0512.

- Jex, H.R., Magdaleno, R.E. and Lee, D. (2000) "Virtual Reality Simulation of the '03 Wright *Flyer* Using Full-Scale Test Data," AIAA Modeling and Simulation Technologies Conference, Denver, CO, AIAA Paper 2000-4088.

- Trelease, R. (2000) "Enabling Technologies Beginning with Kitty Hawk 1900," AIAA Space 2000 Conference and Exposition, AIAA Paper No. 2000-5232.

- Marx, H. (2001) "Unlocking the Secrets of the First Airplane to Fly: The Wright *Flyer* Project Story," *Technology in Society*, Vol. 23, pp. 1–9.

- Colebank, J.E., Jansen, M.M., Haug, R.L., Johansen, K.H., Jorris, K.H. and Casado, J.L. (2001) "A Limited Handling Qualities Evaluation of an In-Flight Simulation of the 2003 Wright *Flyer*," U.S. Air Force Test Pilot School, Report AFFIC-TIM-01-07.

- Culick, F.E.C. (2001) "What the Wright Brothers Did and Did Not Understand About Flight Mechanics in Modern Terms," 37th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, Paper No. AIAA-2001-3385.

- Culick, F.E.C. (2001) "Wright Brothers: The First Aeronautical Engineers and Test Pilots" 45th Symposium of the Society of Experimental Test Pilots, Los Angeles (September); also given at a meeting of the SAE Committee on Aerospace Guidance and Control (March 2002).

- Culick, F.E.C. and Dunmore, S. (2001) *On Great White Wings: The Wright Brothers and the Race for Flight*, Hyperion Press, Inc.

- Culick, F.E.C. (2003) "Wright Brothers: First Aeronautical Engineers and Test Pilots," AIAA J., Vol. 41, No. 6, pp. 985–1006, June 2003.


Members of the Project have given over 50 public lectures and talks to AIAA Sections, universities, public schools and public service organizations on the history of the Wright Brothers' accomplishments and the progress of our Project. These lectures have covered the entire United States and Europe.

Based on the three wind tunnel test programs and our static loads analysis and tests, written materials covering the structural properties as well as the aerodynamics, stability and control of the Wright 1903 *Flyer* are unlikely ever to be surpassed.

The legacy of this Project will be two successful replicas of the Wright 1903 *Flyer*, and thorough documentation both of the Project and, more importantly, of the historical and technical story of the Wrights' work 1899–1909.

Activities of the AIAA Wright *Flyer* Project and short biographies of active participants may be found on the website http://www.wrightflyer.org. Most of the documents produced by the Project are accessible at that location. (John Latz, Webmaster).

F.E.C. Culick