June 22, 1977

Dr. Richard Whitcomb
Head, Transonic Aerodynamics BR.
NASA/Langley
Mail Stop 359
Hampton, Virginia 23665

Dear Dr. Whitcomb:

Thank you for agreeing to write the editorial section for the Fall issue of the AIAA Student Journal. Since we will be addressing the topic of modeling, I would like to have you write an editorial of approximately one thousand words and describe how modeling has saved us money, lives, and gross errors by testing a model before the prototype is built. I plan to have articles on: How to Model an Ornithopter, RPV, Tornadoes, Aircraft Spins, and Hydrofoils. Therefore, we will be covering a variety of topics dealing with how does one model a phenomenon successfully? Therefore, you should write a general article that will summarize why we attempt to model something rather than build a faulty prototype.

I have enclosed our manuscript requirements for the Student Journal and a sample copy of the Student Journal with a particularly good editorial. I would like to have your editorial along with your picture and biography by July 8th. I look forward to hearing from you. If you have any further questions, please feel free to contact me.

Sincerely,

[Signature]

Jeffrey Irons
Director of Student Programs

JJI:1ph
Enclosures
EXPERIMENTAL AERODYNAMIC MODELING

From the earliest days of aircraft development experimental models have been used to approximately define the aerodynamic characteristics of aircraft configurations before the actual full size vehicles are built and flown. It is well known that the Wright brothers constructed a small wind tunnel and tested a number of airfoil model shapes before building their gliders and airplane. Langley built and flew a model of his airplane before initiating the construction of the full scale vehicle. With the increase in speed of aircraft the aerodynamic design problems have become progressively more complex and the need for testing experimental models has become significantly greater. At present model experiments are a key part of aircraft development. Almost all of these experiments are now conducted in wind tunnels rather than in flight since it has been found that such a procedure is the most convenient and reliable. To conduct such experiments hundreds of wind tunnels have been built throughout the world and tens of thousands of hours of testing are conducted each year. Usually the wind tunnels are designed to conduct model investigations in particular speed ranges, such as subsonic, transonic, supersonic, or hypersonic.

Wind tunnel model experiments generally are directed toward two primary objectives: first to explore advanced approaches to the design of aircraft components such as new wing airfoil and planform shapes, and secondly to determine the aerodynamic characteristics of complete aircraft and space vehicle designs. The use of wind tunnel models to initially investigate new concepts allows a detailed study of the aerodynamic flow phenomena and a systematic evaluation of variables. Building or modifying full scale airplanes to accomplish these objectives would be prohibitively costly and time consuming.
However, particularly promising new approaches are sometimes flight tested as "proofs of concept". For example, various versions of the NASA supercritical wing were investigated in flight using Navy F-8, T-2C, and Air Force F-111 as test beds.

The major portion of wind tunnel model investigations are directed toward determining the full scale flight characteristics of new airplane designs before experimental or prototype full scale versions are built. Investigations are usually made to determine the aerodynamic performance, stability, controllability, loads, buffet and flutter for the entire flight envelope, including landing and takeoff characteristics with high lift systems deployed. Many thousands of hours of wind tunnel experiments are conducted on various models of a design in different wind tunnels. From these investigations the airplane designer determines whether the airplane configuration will have the desired performance characteristics.

In almost every case the wind tunnel results have shown that the airplane configuration as initially designed had certain shortcomings. Modifications in the design have been made to overcome these problems. This procedure is much less expensive and time consuming than would be the case if the problems were detected only after the full scale flight prototype were built and this vehicle had to be modified. For example, the prototype of the Air Force F-102 supersonic fighter was designed and built before adequate wind tunnel model data was obtained. Because of excessive drag this airplane could not fly at supersonic speed as intended. Subsequent wind tunnel experiments indicated the source of the problem. A second prototype with a completely new design was built and flown successfully.

Far more importantly, the deficiencies in the design can be such that the airplane is unsafe to fly. In the earlier years of aeronautical development,
only limited preliminary wind tunnel model experiments were conducted for most airplane designs. As a result, in many cases severe problems were not recognized and a number of experimental aircraft crashed. For example, the initial probings of the transonic flight regime before transonic wind tunnel facilities were available were conducted by diving existing aircraft. A number of airplanes could not recover from the dives and many pilots were killed. Transonic wind tunnel model investigations indicated the source and solution of the problem and later airplanes were designed to eliminate this problem. With the present policy of thorough preliminary wind tunnel model investigations of new designs the safety record of new prototype aircraft has been much improved.

Substantial wind tunnel model experiments are also conducted for space vehicles. Since these vehicles must move through the atmosphere during launch and return they usually encounter aerodynamic problems similar to those for aircraft. In some cases these problems can be severe. For example, during the early days of the space program before a policy of thorough wind tunnel model investigations of such vehicles was established many of these vehicles disintegrated during the early phases of the launches. Wind tunnel model experiments indicated that these failures were due to greater than expected air loads on the vehicles. More recently, many thousands of hours of wind tunnel model experiments have been conducted on the launch and return configurations of the space shuttle.

Although wind tunnel model experiments provide reasonably close indications of the full size airplane characteristics the predictions are not exact. It is recognized that the boundary layer growth over a configuration and, as a result, its aerodynamic characteristics is a function of the Reynolds number. This parameter varies directly with the streamwise configuration dimensions, the air
velocity, and the air density, but inversely with the air viscosity. Usually it cannot be made as large for a wind tunnel model as for the corresponding full size airplane. Several techniques are used to increase the Reynolds number for the model. The most widely used has been to increase the pressure of the air in the wind tunnel. Another method, presently being investigated extensively, is to reduce the temperature of the air in the tunnel. When a combination of the two techniques is used, full scale Reynolds numbers associated with large airplanes can be achieved with relatively small models. A wind tunnel utilizing these combined approaches is now under construction at the Langley Research Center. This facility should eliminate the major shortcoming of wind tunnel modeling.

The advent of high speed computers and the recent development of codes to calculate complex aerodynamic flows, including the effects of the boundary layer, have provided powerful new tools for the prediction of the aerodynamic characteristics of aircraft configurations. However, they still cannot fully define all of the flight characteristics of complete configurations. For the foreseeable future at least wind tunnel model investigations will still be required to determine these characteristics.