Progress Report from the Flight Research Institute - 1983

by

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Introduction

An article by Jan Scott (Ref. 1) in a recent issue of Soaring magazine describes a 1982 visit to an Idaflieg (Interessengemeinschaft fur Deutche Akademische Fliegergruppen) gathering in Germany. Scott wrote:

> "It is an embarrasing fact of life that any American soaring pilot hoping to make a decent showing in a major contest must fly a German sailplane."

Scott then goes on to extol the German Akaflieg (Akademische Fliegergruppen) system and the recent research activities of eight of them. He then ends with the comment:

> "And maybe the American soaring community will follow the example of the Akafliegs and bring research down to a more effective level by taking advantage of one of our best resources - our youth."

While members of the Soaring Society of America can only applaud Scott's appeal, it would appear that he has not spent much time on a modern American university campus nor has he read a recent account (Ref. 2) of efforts in the Seattle area to devlop an Americanized equivalent of an Akaflieg. Such an organization does exist, it is now in its third year of operation and has finally developed to the point where very concrete progress can be reported. It is called the Flight Research Institute (FRI).

The FRI is a nonprofit organization incorporated in the state of Washington. Its stated purpose is to encourage and support avocational scientific research and education of general public interest related to the aeronautical sciences. In its third year of existence, the FRI has approximately 160 members, a range of resources and facilities and seven very active projects ranging from the design and construction of an ultralight self-launching sailplane to a solid fuel ramjet experimental program. The purpose of this paper is to outline progress on the projects and the status of the Institute itself.

Background

There are several independent threads which eventually led to the formation of the FRI, but the basic origin was in two projects - one successful, one not - here in the Seattle area. The first of these was Bob Lamson's Alcor sailplane project begun in the early 1970's (Ref. 3). This was one of those prodigious, almost one-man-efforts which actually reached fruition. Lamson, with advice and assistance from several Boeing people, set out to build an advanced high-performance, fiberglass, research sailplane - and did.

In retrospect, Lamson realized that the project was fun, educational, and that the effort was worth the challenge. But it also had been difficult, moreso than necessary had there been access to the kind of data/experience base available to students in the Akafliegs. Since the early 1920's, these students have been doing just what Lamson accomplished. Why not here in the United States?

During 1977, the author and several colleagues at Boeing began discussing the possibilities of an attempt at the Kremer prize for human-powered flight. This led to the tentative design for an HPA called Seattle Slow (Ref. 4). Its designers felt that in order to go beyond past failures, use of several Boeing computer programs would be necessary in the detail design phase. The programs involved - airfoil and wing analysis - were in common workaday use by members of the group, but it turned out that there was no legal way these programs could be used by the same people "after hours.". While the Boeing policy seemed short-sighted, there was no good way to circumvent it and that was one of the causes of collapse of the effort.

There was one positive outcome of the abortive Seattle Slow project, however. A memorandum was written "to whom it may concern" within The Boeing Company pointing out that a more liberal policy on computer program usage would be very desirable for a variety of reasons. This memo reached several people who eventually became pivotal in the formation of the FRI.

In the meantime, Lamson and McMasters began talking to several University of Washington faculty members about the German Akaflieg system and questioning why one couldn't be started in the U.S., and in the Seattle area specifically. They were listened to with courtesy and patience and then told without much enthusiasm that it was a nice idea but it really wasn't feasible because ... (read a list of twenty rationalizations). Basically, most modern engineering schools teach differential equations - so many differential equations that the average student has no time for anything but his/her studies. All other worthy enterprises must await graduation.

But if that is true, then why has the Akaflieg system worked in Germany? Surely, in the higher realms of technical education, differential equations are differential equations, and <u>some</u> German students still find time for sailplane building while getting a traditional education as well. We remain indebted to Otto Maurer of the Caesar Creek Soaring Club in Dayton, Ohio, for providing a reasonable explanation.

Maurer, a member of the Stuttgart Akaflieg in the 1950's, pointed out that until quite recently, German university students had more time than their U.S. counterparts. Those who were lucky enough to get into a university in the first place and did not have to work to support themselves while there, did not have to take the same staggering course loads of their American counterparts. This was because German students in general had a far superior grammar and high school education than we generally provide in the public schools in this country. Thus, for example, when entering a university to study engineering, they had already had adequate education in languages (German and foreign), history, etc., and basic mathematics, physics, and so on. Many of these courses must be taught either for the first time or as remediation to most U.S. university students, and this burden, added to the university level technical courses, pretty much fill all the time available to American students. Even so, participation in an Akaflieg may cost a German student an extra year at the university before he/she receives a degree.

The point of this discourse is not to extol the virtues of the German educational system versus the American. It merely serves to point out the reasons why the faculty at the University of Washington were unenthusiastic about the prospects for success of a university-based equivalent of the Akaflieg system in this country. After two fruitless years of effort to gain support for a university-based U.S. Akflieg in Seattle, the approach was abandoned and new avenues sought. During this time, Mike Henderson, the author, and their low-speed research group at Boeing became involved in an airfoil design effort intended to assist the composite glider program at Rensselar Polytechnic Institute (RPI) in Troy, New York. When the author first heard of the RPI effort in 1979, it appeared that a young German (ex-Darmstadt Akaflieg) professor, Guenter Helwig, had managed do what the Seattle group had failed to accomplished: a group of students at RPI were going to design and build a small glider using advanced composite materials and structural techniques - for college credit. (RPI had received a joint grant from the NASA and the Air Force Office of Scientific Research to institute this program.) The initial result of the program was the RP-1 CAPGLIDE ultralight glider (Ref. 5).

During the Third NASA/SSA International Symposium on the Technology and Science of Low Speed and Motorless Flight (Ref. 6) held at NASA's Langley Research Center in Virginia, Helwig inquired about the possibility of use of Boeing airfoil design programs (written by Henderson) to derive a better airfoil than the Wortmann FX 63-137 used on the RP-1. The new profile would be for a second-generation version then being contemplated. Recalling the problem with Seattle Slow, the author had to reply that it probably wasn't possible.

Not to be so simply thwarted, Helwig went back to RPI and discussed the situation with the chairman of the Aeronautical Engineering Department, Dr. Robert Loewy. Dr. Loewy, it turned out, was a friend of Mark Kirchner, Chief of the Aerodynamics Staff in The Boeing Commercial Airplane Company (and the author's and Henderson's boss thrice removed). Dr. Loewy contacted Kirchner and explained the nature of what RPI wanted, and mentioned that RPI and Boeing already had a joint arrangement directed at developing a prototype composite-material horizontal stabilizer for a Boeing transport.

After some discussion, Kirchner agreed that the Rensselaer problem was intriguing, would represent a valid test case for the then-emerging airfoil design methodology, and was within the spirit of Boeing cooperation/ encouragement of engineering education. Thus, Henderson, the author and their research group were directed to help RPI on a low-priority, limited resources, one-shot basis. The outcome was the Boeing variable-thickness airfoil described in Reference 7. In addition, the Flight Research Institute idea finally emerged.

THE BIRTH OF THE FLIGHT RESEARCH INSTITUTE

Early in 1980, members of the author's research group met with Mark Kirchner to review the outcome of the RPI airfoil design effort. (If any one individual can be identified as the motivating force behind the FRI it must be Mark Kirchner. Kirchner had been active in soaring in the 1950's, had been one of the recipients of the Seattle Slow memorandum, and, at the time of the meeting, was one of the group homebuilding a Christen "Eagle" aerobatic airplane. From this latter happy experience, Kirchner recognized the merits of the basic Akaflieg idea.) Following the presentation of the RPI airfoil results, the discussion turned to more philosophical issues. At that time, Boeing and the aerospace industry in general were on a crest of a wave of prosperity. There were job opportunities for all types of engineers and the universities were in high gear turning them out. But to everyone's bewilderment, these new engineers were en masse ranking airplane companies a low number three (behind oil companies, and the auto industry) in job preference. Of even greater concern was how a company like Boeing could retain experienced people in a "sellers market" for engineers. Higher salaries alone were not an adequate answer. Some new, more creative "fringe benfits" needed to be devised. At this point, a whole range of factors came into focus. First, there were important aspects of the school and industry interface:

- o Newly-graduated engineers often come to industry with no practical knowledge of what an airplane really is and how one is designed and built. Their education is inadequate and a good deal of on-the-job training is required in consequence.

- o The traditional university structure (facilities, faculty background and experience) is often inadequate to provide this broader education to those who want it. While an Akaflieg-type enterprise might work at some universities, it probably would not work at most because students are highly transient and the universities alone lacked the necessary resources to support that sort of thing, etc. etc.

Equally important were the interrelationships of the FRI and the Boeing industrial complex, with its relatively stable base of 12,000 engineers with expertise in almost anything (and local industries with more of the same kind of people):

- o Many of these people have aviation-related hobbies (soaring, hang gliding, EAA, model airplanes, and rocket, etc.) Most of these hobbies are technical and the technical literature in some areas is miserably archaic or inadequate. In addition, there is little or no research money available to advance these activities.

- o One of the penalties of working in a big company on complex projects is that most work is done in large groups, and individuals are often frustrated by lack of adequate recognition or opportunities to work on a whole problem.

- o The best tools and equipment in the industry are available to Boeing engineers at work, but no way existed to make these same tools available for application to hobby/after-hours activities.

All these considerations led to the conclusion: Why not construct, on a stable base, some sort of organization which would provide technical tools, advice, some money, etc. to professional engineers and students alike who want to pursue their hobby/recreational interests at the highest technical level possible? Why not a Flight Research Institute devoted to the encouragement and support of avocational research and education related to the aeronautical sciences - not an organization based on the shifting sands of a transient student population like an Akaflieg, but one based on the entire engineering/technical community in the Puget Sound area. And if it worked here, the idea should be highly exportable to any other area of the country where the necessary technical/industrial/university base exists.

THE FORMATION OF THE FLIGHT RESEARCH INSTITUTE

Armed with what seemed like a good basic idea, Kirchner, Lamson, McMasters and Henderson began a series of discussions on how to make the whole thing happen. How should it be organized? Who should be involved? What bases of support existed and how should they be approached? Where could seed money be obtained to support an initial slate of projects? What should these projects be? These and many other questions were debated for several months during the spring of 1980.

The next basic decision made was that the Institute should be a free-standing, independent organization. It should not be just another Boeing recreation club, an arm of the local American Institute of Aeronautics and Astronautics, the Experimental Aircraft Association, or a branch of any other existing organization. Further, while the ostensible purpose was to support the "aeronautical" sciences, the institute would support a very wide range of technical projects. By stretching the definition of "aeronautical" a little, we could easily accommodate individual interests in sailboats or streamlined bicycles. The key word was to be accommodation of individual technical interests.

Considerable time was spent setting up an organization. Individuals of stature who would represent industry, the university, and the sport aviation community at large were sought for a required three-man Board of Directors. Enlisted were W. T. Hamilton, a Boeing vice-president; Lamson, the chairman of SSA's Technical Board; and Dr. Fred Thieme, recently Colorado University president and one-time Washington University provost. At the working level, Mark Kirchner was installed as Institute president to head a team including a business manager and three vice-presidents (programs, program support, and communications).

With a working (though still unofficial) organization identified, the next step was to approach Boeing at the corporate level, to seek its blessing, to hopefully receive some initial financial support, and lay the foundation for eventual access to computer resources. Boeing tends to be conservative in these matters and is not a "give-away" to crack-brained schemes presented to it, no matter how much stature the individuals involved may have. It was clear that if the approach wasn't made carefully, an initial no could kill the whole enterprise on the spot.

In August 1980, Fred Theime informed the group that a high-ranking friend of his in the National Science Foundation intended to make a trip to Seattle the following month and would like very much to hear details of the proposed organization. Thus a meeting was held with Mark Kirchner, the visitor, and several others to discuss the plans made so far. The NSF man was enthusiastic and indicated that to his knowledge what was proposed was, at that time, unique within the U.S. He further indicated that when incorporated, the FRI would likely be a legal conduit for NSF money for specific types of projects.

Armed with this first-class report card, a formal letter was sent to Boeing corporate headquarters recommending that Boeing recognize the FRI and support it with a grant of $15,000 for 1981. In addition, it was recommended that if it could be shown that Boeing computer usage by the FRI could be done at no incremental cost to the company and the proprietary interests of the company would not be compromised, such usage at some future date should be formally authorized.

To finish the story: Boeing granted the full $15,000, blessed the FRI, and left the computer question open. The incorporation of the institute was completed in December 1980 and a bonafide Flight Research Institute was on its way!

WHERE THE FRI STANDS TODAY

The first year of operation (1981) was spent solidifying the organization and selecting and organizing an initial range of projects. Boeing gave a second $15,000 for 1982 and $10,00 in 1983. An additional private donation of $6,000 was made in 1983. Thus the FRI has entered its third year of operations on a sound footing, with membership continuing to grow.

The primary role of the institute in project activity is that of responding to member interests by providing resources to project teams requesting the support. The process by which this takes place is described briefly later. The resources of the Institute at this time are:

Funding: Limited funds for program support are available. In general, these funds are for project materials and supplies and are not used for manpower or work compensation. The level of funding is generally in the order of $3,000 - $4,000 per year for major construction projects and $200-$300 for small programs. If the Institute pays for the materials and supplies, the ownership of the resulting hardware will rest with the Institute. Otherwise, the ownership will generally rest with the party providing the material and supplies.

Technical Consultation: Technical consultants can often be enlisted from industrial and university backgrounds to enhance the expertise applied to project groups desiring such assistance.

Shop & Office: The Institute has a centrally located shop facility and small office for general use of the membership. Tools are being accumulated as funding allows.

Mainframe Computer: Special arrangements have been made with The Boeing Company for limited usage of the company's mainframe computer (several Cybers and a CRAY I) off-hours in a way that creates minimum incremental cost to the company for such usage. However, special conditions must be met in order to gain approval in each individual case.

- The usage must be in conjunction with an approved Flight Research Institute program.

- The user must be a Flight Research Institute member.

- The user must be a Boeing employee who normally has authority to run the computer program to be used. Other members of the project team need not be Boeing employees, however.

- The supervisor of the Boeing-employee user must agree that such usage is not adverse to The Boeing Company's interest.

- All of the above must be coordinated through the Flight Research Institute-Boeing Computer Interface Manager for authorization and monitoring.

This may sound a bit cumbersome, and it is, but it works and does deliver a major benefit to the FRI membership.

INSTITUTE PROGRAMS AND OPERATIONS

Since the Institute's basic purpose is to encourage and support programs related to the aeronautical sciences, an important task is the evaluation and prioritization of programs proposed by members seeking support. A Technical Steering Committee, chaired by the Vice President, Programs, considers the technical/educational contribution of each proposal relative to the amount of resources required and available. Programs selected for sponsorship by the Institute will be managed under guidelines that vary, depending on the complexity of the program. However, all programs contribute to seminars consisting of reports for programs in progress and final reports for completed programs. Final written reports on each program are to be published by the Institute for a permanent Institute library.

Members interested in proposing programs are requested to fill out simple application forms which are then forwarded for consideration to the Vice President, Programs. Complex projects such as design-build-test flight articles will be funded on a phased basis. For example, the results of a preliminary design phase must be approved before the detail design phase is initiated; the detail design phase must be accepted and approved before the construction phase is initiated, and so on. Continued support by the Institute from one phase to the next is contingent upon satisfactory performance as judged by the Technical Steering Committee.

In addition to formal projects, seminars, open to the public, are held about three times a year. Besides brief program reports, a feature speaker presents a talk on a subject of major current interest. Past examples have been Dennis Conner describing his successful defense of the America's Cup in 1980; Ron Clark, one of the pilots on the transpacific flight of the Double Eagle V helium balloon; and Dr. Paul B. MacCready Jr., who described his human-and solar-powered aircraft projects.

Newsletters are sent to all members bimonthly. These keep the membership generally informed as to the activities within the Institute and summarize the status of the various current programs. Members are invited to contact project leaders to inquire about participation in programs that may interest them.

Membership in the Institute is open to anyone, but it must be realized that the bulk of the material benefits of membership (shop and computer access, tools, etc.) are available mainly to those in the Seattle area.

There are three grades of membership available. Full membership allows full privileges including voting right, and costs $10 per year. A student membership is available for $5 per year and gives everything but voting rights. Associate memberships are also available at $5 per year (newsletter/announcement of activities mailing list only).

CURRENT INSTITUTE PROJECTS

At present there are seven active Institute projects covering a wide range of member interests. These projects are:

Ultralight Sailplane

This project was originally conceived by the author and M. L. Henderson (the project leader) as an effort to explore the following aspects of the design and construction of a light-weight, self-launching sailplane at canard configuration:

- Can a light sailplane with the layout advantages of a canard configuration be designed which will have adequate performance and handling characteristics? Can such a configuration be developed with appropriate high-lift devices (i.e., flaps)?

- Can the proposed aircraft be built of an optimum combination of advanced composite materials (e.g., carbon fiber, Kevlar) under normal home construction conditions on a safe, reliable basis? What techniques must be employed to do so?

The configuration developed is shown in Figure 1 and progress to date has been as follows:

- Due to uncertainties regarding handling characteristics of an "unconventional" configuration in "extreme" altitudes, the decision was made to construct a dynamically scaled, one-quarter scale radio-controlled model. Wind tunnel facilities are not yet available to the FRI and the radio controlled model approach seemed prudent prior to commitment to full-scale prototype construction. Flight testing of the model began in early 1983 and had led to several small but significant modifications to the configuration which appear to solve a dutch-roll instability problem encountered during approach-to-stall maneuvers. With these modifications the model displays quite benign handling characteristics in all flight modes evaluated. A decision on construction of a full scale prototype will be made during the summer of 1983.

- The power plant selected for the full-scale prototype, after a thorough survey of engines available, is a Xenoah 250 cc, 30 HP two-stroke. This engine has been purchased and work is underway on design and construction of a suitable propeller, and powerplant test stand.

- o Numerous experiments have been conducted on ways to manufacture heat treated graphite-expoxy wing spars, etc. under homebuilt condition with simple inexpensive equipment. Suitable techniques, have been devised for the construction, but no full adequate means of quality verification have been found. A subsequent assessment led to conclusion that while homebuilt fabrication of graphite-epoxy structures is feasible, they cannot be safely recommended. Substitution of simpler fiber-glass materials leads to a small, well justified weight penalty and will thus be used in any full scale construction.

FRI/University of Washington Wind Tunnel

Led by Paul Robertson, an effort is underway to design a high quality low speed wind tunnel for installation in a building to be made available on the University of Washington campus. This tunnel will be available to the university for teaching/research purposes and to authorized FRI members.

The circuit aerodynamic design is finished with the exception of the contraction section. Three different test sections are proposed. These include a general purpose test section 5 ft. high by 7.5 ft. wide; a 2-D test section 7 ft. high by 3 ft. wide; and a test section for half-models, 7 ft. high by 5.25 ft. wide. With these three test sections a wide variety of testing can be done. The interchangeable test sections allow a small wind tunnel to reach model Reynolds numbers that are the same as a conventional 7 ft. x 10 ft. tunnel in some cases. The 2-D test section is the same size as a typical 7 ft. x 10 ft. tunnel with a 2-D insert installed. The half-model test section allows testing at the same Reynolds number that would be run with a full model in a 7 ft. x 10 ft. tunnel. The general purpose test section is large enough to test complete 3-D airplane models and a wide variety of other models at reasonable Reynolds numbers.

The speed capabilities of the tunnel depend upon the power available and it now appears that large (500 HP) motors and controllers are readily available at little or no cost. Many of these motors have been surplused due to plant modernization and plant closures. With 500 HP the tunnel performance is quite good, 220 mph in the 5 ft. x 7.5 ft. and 7 ft. x 5.25 ft. test sections.

Construction of a one-quarter scale model tunnel was started in January 1983. This model will be used to verify and improve the design of the tunnel.

Sailboat Studies

Studies contributing to the design of a 1983 America's Cup yacht contender for Dennis Conner, winner of the America's Cup in 1983 have been conducted under the direction of Arvel Gentry of the FRI since 1981.

The United States has held a firm grasp on the America's Cup for 132 years. Challengers from other countries have tried 24 times to win this highest yachting prize. Dennis Conner, with the 12-meter yacht "Freedom" was the successful defender in the 1980 America's Cup races against Australia. Conner and the "Freedom" team spent almost two years in development and testing for the 1980 races. His effort is sponsored by the non-profit Freedom Foundation organization operated by the New York Maritime College at Fort Schuyler.

Conner planned that two new boats be built for trials against the 1980 winnder "Freedom." As he described in the 1981 fall FRI seminar, the two designers were asked to be bold in their designs, and to try new ideas that might give breakthroughs in boat speed.

The boat designed by Sparkman & Stephens was named "Spirit of America," and tried a new thick keel with low wetted area and high righting moment. The boat designed by Johan Valentijn was named "Magic," and explored the other end of the design spectrum. "Magic" was a lighter and smaller 12-meter yacht than had ever been built before.

The Flight Research Institute study conducted by Arvel Gentry and Bob Eilers supported the design of "Magic." The first phase involved analysis of various sail planforms so that Valentijn could perform his boat size trade studies. Next, a panel aerodynamics computer program was applied to the underwater portions of the boat to give pressure distributions and flow properties about the hull and keel. This resulted in a new keel design that was used on "Magic."

Extensive sailing trials of "Spirit" and "Magic" against "Freedom" have indicated that neither of the two new boats were breakthroughs as was hoped. Each was better than "Freedom" in some sailing conditions, but suffered deficiencies in others. As a result, "Spirit" was extensively modified with a new underbody and new keel to make her into a more conventional 12-meter. "Magic" turned out to be just too tender (not enough righting moment because of her small size and light weight).

In an unprecedented move, Conner has built a third new boat. The FRI America's Cup Research Project is involved in supporting the design of this new 12-meter. This includes the adaptation of "Magic's" keel design concepts to the new boat, plus the design of a new mast to be used on all of the Freedom Campaign boats.

Investigations of Boundary Layers on a Sailplane Wing

The intent of this project is to develop simple inexpensive high technology instrumentation to measure the boundary layer characteristics on the wing of a modern sailplane under actual flight conditions. Institute support has involved funding for the instrumentation and its use in prototype form in actual full scale testing. Three institute members are directly involved in the project and the results to date have been sufficiently encouraging that the project leader, Harry C. Higgins, was invited to consult on a proposed NASA/Wichita State University flight test experiment on laminar flow characteristics of a business jet wing, wherein technology very similar to that developed in the Institute project may be used. The nature of the experiments conducted under FRI auspices to date were reported in Reference 8.

Human Powered Airplane Project

This project, led by Wayne Bliesner involves the design and construction of an aircraft which will compete in 1983 for the new series of British Kremer prizes announced in May 1983. This machine (Bliesner's seventh) is shown in Figure 2. Construction should be completed by July 1983.

Global Range Airplane

During 1982 a project was initiated for a feasibility and design study of a manned airplane capable of flying non-stop around the world without refueling. This project is being conducted under the auspices of the Institute in cooperation with Dr. Paul B. MacCready Jr. (a member of the FRI) and his company, Aerovironment Inc. of Pasadena, California. The author and Mark Kirchner are the principal FRI consultants.

Funds ($25,000) for the initial feasibility study phase of the project have been provided by a donor who wishes to remain anonymous at this time. The feasibility study is presently nearing completion and a decision on the future of the program will be made in the summer of 1983. The contents of the study are presently proprietary to the sponsor, but will be made available to the public approximately one year after completion. A competing design by Burt Rutan is shown in Fig. 3.

It is expected that the actual implementation of the design into hardware and the execution of the task will be accomplished outside of the Flight Research Institute. An as yet unspecified company will sponsor the construction of what will prove to be a most unique and challenging aircraft.

Solid Fuel Ramjet

The purpose of this project, led by Larry Fink, is to develop a rocket boosted solid fuel ramjet device to efficiently and economically lift small research instrumentation payloads to high altitude. Work during 1982 involved design of the ramjet unit and the development of the boost and recovery systems.

One of the noteworthy accomplishments so far has been the successful flight test (in a model rocket) of the planned instrumentation for the flight test vehicle. The instrumentation is an acceleration recording circuit which stores a numerical representation of the acceleration time-history in computer memory integrated circuits. This recording system was described in the July and October 1982 issues of California Rocketry magazine.

A flight test vehicle has been designed and scale drawings made of each part. A full size cardboard and balsa wood mockup of the SFRJ has been constructed for the purpose of testing manufacturing techniques and for testing the recovery system. Later, the mockup will be flown using model rocket engines to flight test the recovery system, instrumentation, and to serve as a check on stability and drag estimates.

A load cell instrumentation system has been constructed for the purpose of measuring and recording thrust of the rocket motor during future static tests. The system uses a computer directly connected to the load cell to record and reduce the data under program control.

All ingredients, and most of the casting equipment for construction of the solid ramjet fuel grain and the rocket propellant grain have been acquired. Small batches of ramjet fuel and rocket propellant have been successfully mixed and cured.

The full size SFRJ mockup will continue to be used for refinement of the recovery deployment system design. Work to improve the sensor used in the acceleration recording circuit is in progress, and a radio transmitter to aid in the location of the instrumentation package after its return to earth is under construction. Once the recovery system, sensor, and transmitter have been completed, they will be flown in the SFRJ mockup.

CONCLUDING COMMENTS

An overview of the funding, and current activities and resources of the Seattle-based Flight Research Institute has been presented. Having found a way to construct an organization with many of the same objectives of a German Akaflieg, but tailored to the requirements of the sport aviation and university environment in the United States, it is the hope of the founders of the FRI that similar organizations across the country can be developed. The success demonstrated by the FRI so far must be considered highly promising and indicates the potential of such enterprises. It remains clear, however, that largely German sailplanes will continue to be flown in most competitions for some time to come.

REFERENCES

1. Scott, J., "Sailplanes on the Track," Soaring, April 1983, pp. 16-19.

2. McMasters, J. H. and Lamson, R. T., "The Flight Research Institute," Soaring, July 1982, pp. 24-29.

3. Lamson, R. T., "ALCOR - The First Pressurized Sailplane," Soaring, Nov. 1973, pp. 16-20.

4. McMasters, J. H. and McLean, J. D., "The Formation Flight of Human Powered Aircraft Across the English Channel in the Spring," Aero Revue, Dec. 1979, Feb. 1980, and April 1980.

5. Helvig, H. G., "CAPGLIDE and the RP-1," Soaring, Feb. 1980, pp. 22-25.

6. "Science and Technology of Low-Speed and Motorless Flight," NASA CP 2085, June 1980.

7. McMasters, J. H., Nordvik, R. H., Henderson, M. L. and Sandvig, J. H., "Two Airfoil Sections Designed for Low Reynolds Numbers," Tech. Soaring, Vol. VI, No. 4, June 1981, pp. 2-24.

8. Higgins, H. C., "Flight Measurement of Sailplane Boundary Laminar Transition," Proceedings of the SSA Convention, Reno Nevada, March 1983.

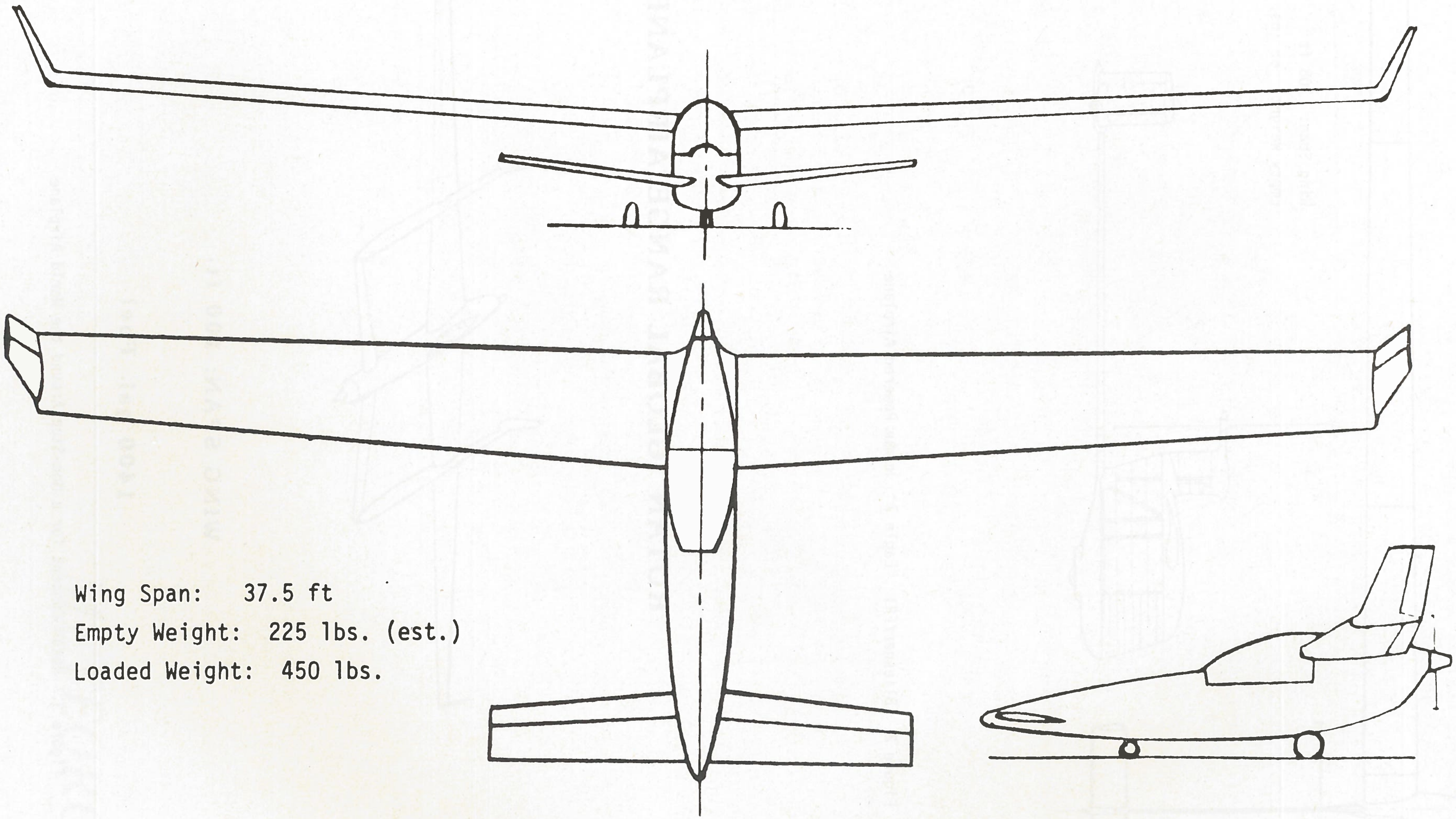

Figure 1. Flight Research Institute Self-Launching Ultralight Sailplane

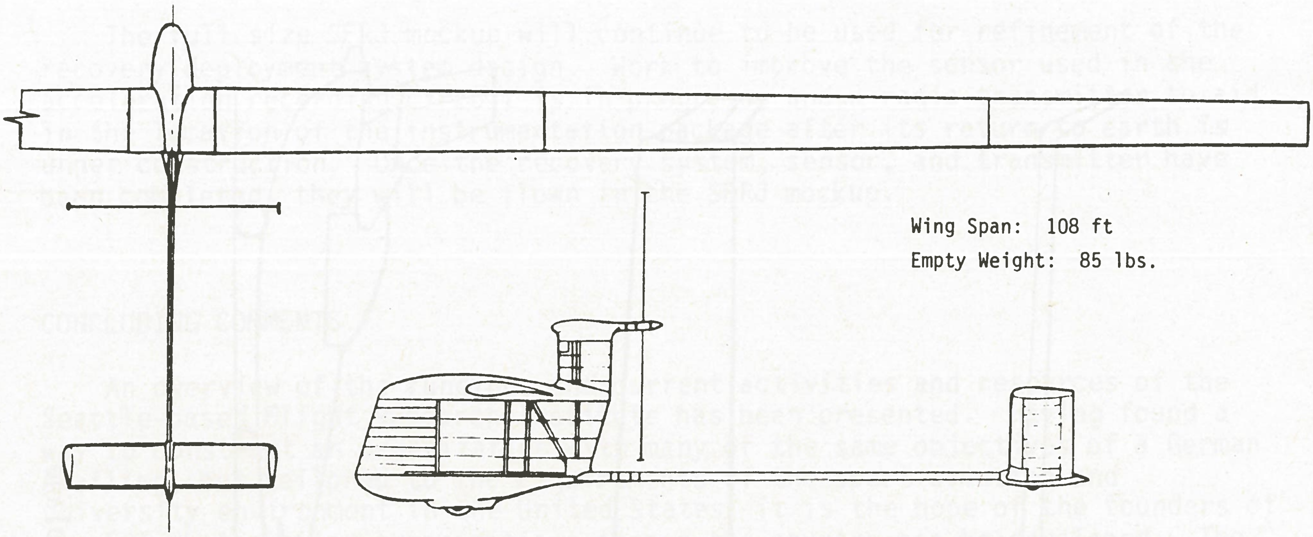

Figure 2. Bliesner/FRI "Eagle 7" Human Powered Airplane

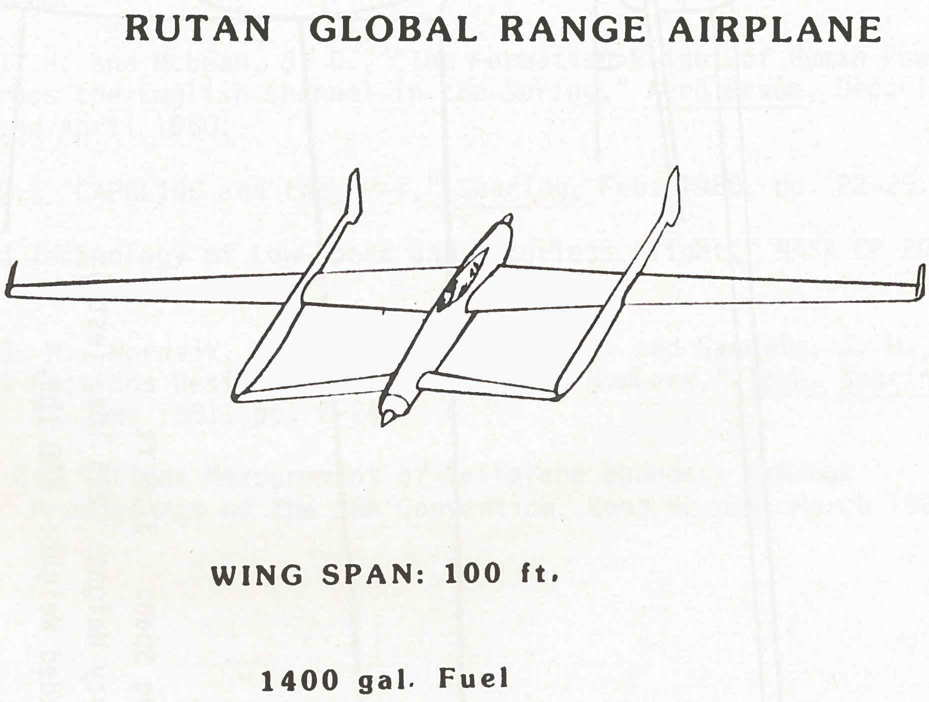

Figure 3. Rutan Concept for a Non-Stop Around the World Airplane