# Aging Aircraft Research Infrastructure of the National Institute for Aviation Research

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## Final Report

### Project Summary

The United States has been the world leader in aviation throughout the 20th Century. The aviation industry in this country has designed and built commercial, general aviation, and military aircraft used around the world, with exports resulting in a net favorable trade balance. Today, the aviation industry must compete in a global economic environment far different from that of the past. New challenges to our leadership are arising from aircraft manufacturers in Europe, the Pacific Rim, and Brazil. For example, the commercial airplane industry must now compete against the European union (13 countries). Furthermore, new foreign government-supported research and test facilities, particularly in Europe, are attracting business from United States aircraft companies because of availability, quality of results, rapid response and low cost.

To address this competition, the nation's research and development base in aircraft design and manufacturing must be expanded with support from the federal sector in partnership with the aviation industry and state governments. The need for federal support of new research and test facilities and equipment is as acute as it is for basic and applied research. It is through research and the application of new technology in aerodynamics, materials, structures, sensors, and safety that the U.S. will be able to maintain its leading position in aviation in the 21st century, and enhance homeland security.

Wichita and Kansas are unique in the nation among high-tech metros because of the high concentration of aviation manufacturing. Based upon the report by the Commission on the Future of the United States Aerospace Industry, Wichita was cited as having the largest concentration of aerospace and aviation industry jobs in the nation, accounting for one out of every five jobs. Factors that are important to the location and retention of high-tech firms include the proximity to excellent educational facilities and research institutes. The National Institute for Aviation Research (NIAR) at Wichita State University was established in 1985 to help address the aviation industry's research needs, and has become a model for federal-state-industry-university partnerships.

The National Institute for Aviation Research at Wichita State University has been providing research, testing, and technology transfer to the aviation industry and to federal agencies since 1990. The Institute has been recognized for the quality of its work by the FAA, which awarded NIAR the 2001 Excellence in Research Award. In making this award, the FAA also cited the Institute's ability to form partnerships with industry, government agencies, and other universities to solve aviation problems.

With the aid of its Industry Advisory Board, consisting of representatives from Spirit Aerosystems, Boeing IDS, Bombardier-Learjet, Cessna, Hawker Beechcraft, and other smaller companies, NIAR has developed certain thrust areas in which it maintains faculty expertise and state-of-the-art equipment. These thrust areas are aerodynamics, composite materials and structures, crash dynamics, aging aircraft, and advanced joining and manufacturing. Other important research areas within NIAR which support its research and testing mission include the Computer Aided Design and Manufacturing Laboratory and the Computational Mechanics Laboratory, both of which are computation and simulation facilities.

The aviation industry is continually developing their next generation of products that require new technologies. Our partnership has led to implementation of a long-term plan from which centers of excellence are emerging. In December 2003, the FAA established the Center of Excellence for Composites and Advanced Materials (CECAM) at NIAR. CECAM plays a key role in the Center of Innovation concept as the strategic integration of these new technologies cannot be achieved within existing structures. With WSU as its lead university, CECAM is composed of a team of universities that complement each other's interests and expertise in research areas associated with advanced materials: an area that continues to be critical to the future of the aviation industry and the FAA. The overall objectives of the Center of Excellence are to perform basic and applied research within specific technology areas and facilitate growth and education of the use of advanced materials while supporting the safety and certification issues involved in airworthiness assurance. CECAM will also fulfill the FAA need to advance the state-of-the-art in composite technology documentation related to FAA certification policy, guidance and training.

NIAR and its laboratories are at a critical juncture in that the Institute is approached more frequently by potential clients with projects that are large in scope and require more and better equipment. In order to respond in a way that is of greatest assistance to the aviation industry as well as to research requested by the FAA, upgrades of our laboratories are necessary. This proposal requests $340,000 of a $686,000 congressional appropriation to purchase equipment to increase the capabilities of specific NIAR laboratories.

## Project Description

Fatigue and Fracture Laboratory / Materials Laboratory

In response to the aviation industry and FAA needs, NIAR developed a new laboratory designated as the Fatigue and Fracture Laboratory to investigate various methods to improve long-term durability and damage tolerance of current and future aircraft materials. Various surface treatments such as shot peening, laser peening, cold working and others were applied to the surface of the material for the purpose of retarding the crack growth rate by introducing a layer of compressive residual stresses. This concept has been well documented for a variety of aircraft materials and environments, but insufficient data existed for high cycle fatigue rotorcraft applications, especially near the threshold regime. Thus, new data needed to be accumulated to evaluate the effectiveness of a residual stress field for typical rotorcraft materials and to support and help evaluate fatigue crack growth (FCG) analysis model development work that the FAA will be conducting with other

contractors. AC23-13 (Fatigue and Fail-Safe Evaluation of Flight Structure and Pressurized Cabin for Part 23 Airplanes) currently references AFS-120-73-2 (Fatigue Evaluation of Wing and Associated Structure on small Airplanes), published in 1973. The current AFS-120-73-2 fatigue life evaluation methodology uses Miner's linear damage rule with S-N curves from full-scale test results. The procedure is to first determine from the load exceedance curves the gust, maneuver, taxi, landing and gag cycles. This information is then tabulated to determine the Miner's rule factor n/N for each individual condition. The total of the n/N calculated for various operations is then added and the total fatigue safe life is calculated.

The FAA Fatigue Working Group has noted that this approach often produces unrealistic estimates for fatigue life. All of the AFS-120-73-2 S-N data are based on full-scale constant amplitude fatigue testing of surplus 1950's military aircraft wings. There is no means of directly accounting for stress concentrations and load transfer effects, which in general are configuration dependent. There is also additional conservatism in the loads spectra and the use of a scatter factor. The end result is fatigue life estimates that do not correlate well with either manufacturer's in-house test data or fleet service data.

In 1991, Congress mandated that the Federal Aviation Administration (FAA) establish an Aging Airplane Program. The focus of this program is age-related structural problems with airplanes used in public transportation. At the time, Congress specifically excluded the general aviation (GA) fleet of airplanes from the mandate. However, the FAA determined that as the GA fleet continues to age, there is a concern about ensuring the continued airworthiness of the diverse GA fleet. To guide our future efforts in addressing the effects of aging on GA airplanes, the Small Airplane Directorate developed an FAA Aging GA Roadmap (Roadmap). This Roadmap will serve as a guide to proactively manage the overall airworthiness of aging GA airplanes. One of the four major focus areas of the Roadmap is "Data Driven Risk Assessment and Risk management". The data and results from this project's research will be used to develop methodologies for the risk assessment and risk management for small airplane's continued operational safety.

Research that will be conducted in this laboratory consisted of developing operational usage statistical models and statistical exceedance spectra and conducting constant amplitude and spectrum loading tests with load transfer coupons, notched specimen, and box beams. The fatigue life data obtained from the tests of simple structural elements and their assemblies (open-hole, notched specimens, load transfer coupons, etc) was used to predict the lives of built up structures under spectrum loading. The new approach accounted for the effects of operational usage and structural design details. The methodology was verified for simpler structural assemblies ( e.g., load transfer specimens) under spectrum loading and subsequently used for a box-beam structure under combined loading scenarios.

Funding was requested to purchase an additional hydraulic load frame and supporting hydraulic power unit to support this testing.

Aircraft Structural Testing and Evaluation Center (ASTEC)

During the last year, NIAR and WSU also embarked upon another enterprise in establishing the Aircraft Structural Testing and Evaluation Center (ASTEC). The center was created as part of an agreement with Hawker Beechcraft Company (formerly Raytheon) in which the Institute occupies and provides testing services in the full-scale structural test laboratory at Hawker's manufacturing campus in Wichita, Kansas. Included in the center are 46,000 square feet of hangar space, access to an 8,000-foot runway and approximately $10 million in reliable test equipment which was donated to WSU by Hawker. This laboratory strengthens NIAR's structural testing and aircraft evaluation capabilities and allows NIAR to offer expanded services to all aviation manufacturers and designers from around the world who utilize our research facilities and team. In addition to the acquired facilities, NIAR hired 18 additional full-time staff members whose cumulative expertise in structural testing exceeds 300 years, making the laboratory one of the most experienced structural testing centers in the world. The facility houses both the Aging Aircraft Laboratory as well as the newly created Full-Scale Structural Testing Laboratory.

Aging Aircraft Research Laboratory

Current economic and market conditions are requiring airline companies to use commercial and military airplanes far beyond their original design life objectives. This aging airplane concern is being amplified as more companies use aging aircraft and rely on standard inspection practices for a guarantee of airworthiness assurance. Standard practices to ensure continuing airplane structural integrity include scheduled inspection and maintenance tasks contained in maintenance manuals, Instructions for Continued Airworthiness (ICA), and service bulletins. This procedure is not just limited to structural integrity but extends to wiring and systems integrity as well. These initiatives have provided timely preventive maintenance recommendations that permit continued safe operation of aging airplanes until retirement from service from an economic perspective. The Aging Aircraft Research Laboratory at NIAR has been working over the past two years with the FAA Technical Center to provide insight into the condition of typical general aviation aged airplanes, to see if there is a correlation between maintenance and apparent condition and to address any aging concerns regarding these general aviation airplanes. Funding for this project purchased equipment for chemical paint removal tanks needed to perform structural aircraft teardowns.

**Summary**

To summarize, the requests for equipment and personnel outlined above were reviewed by representatives of the aviation industry, and confirmed to be directly related to research and testing projects conducted at NIAR for the FAA and the industry. The requests were consistent with the NIAR long-range plan to upgrade capabilities in the major thrust areas that support aviation safety and the continual development of new aircraft.