Federal Aviation Administration

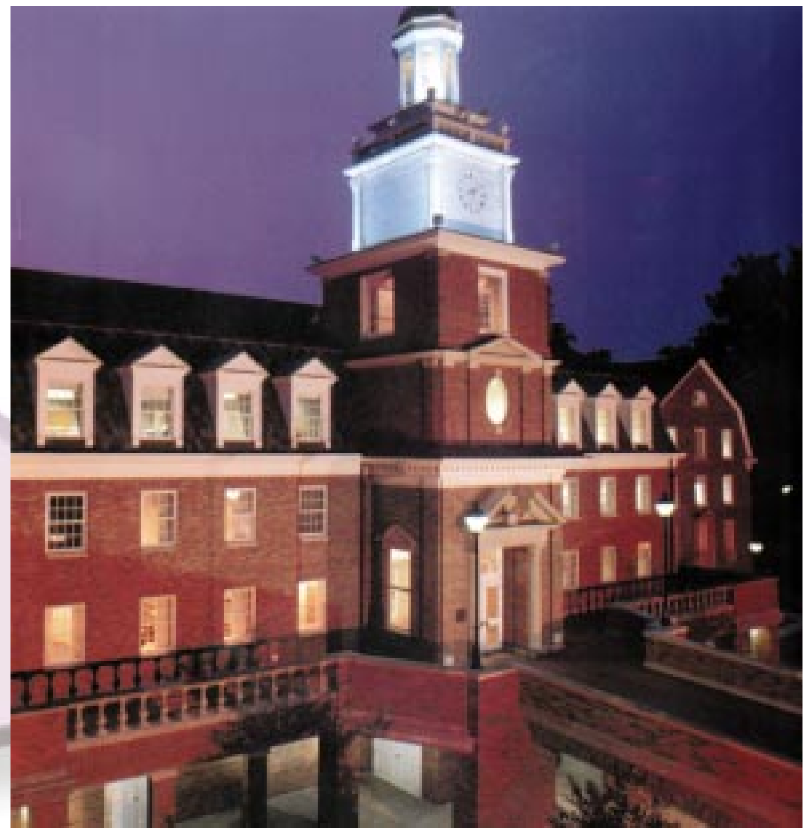
AVIATION RESEARCH GRANTS PROGRAM

"Partnerships for Success"
Avionics Engineering Center Ohio University

Ohio University's Avionics Engineering Center recently developed and successfully flight-tested technology that increases the availability and accuracy of the Global Positioning System (GPS) and its Local Area Augmentation System (LAAS) for Category II and III approaches and landings. This technological breakthrough is the result of a 5-year aviation research grant provided by the FAA to the Avionics Center to design, implement, and test an advanced prototype GPS-based approach, landing, and surface movement guidance system.

AVIATION RESEARCH GRANTS PROGRAM:

The FAA is committed to supporting a technologically advanced future aviation system. The research grants program provides a vehicle to test new and innovative ideas to implement the vision while satisfying congressionally mandated research requirements. The program awards short and long-term grants to fund research in specific areas that are crucial to the long-term technical growth of civil aviation. By working cooperatively with our nation's leading universities and research organizations, the FAA will reap the maximum return on its overall investment in aviation research and development. A FAA research grant can last from one to several years, depending on the scope of the project. There is no limit on the awarded amount of an individual grant. However, the total funds available for research grants may change from year to year.



C. Paul and Beth K. Stocker Engineering and Technology Center, home of the Avionics Engineering Center.

AVIONICS ENGINEERING CENTER:

Established in 1963, Ohio University's Avionics Engineering Center specializes in the research, development, and evaluation of electronic navigational, communication, and surveillance systems. Dedicated to improving the safety and efficiency of air transportation and to the education of high-quality students who will advance the frontiers of aviation technology, the Center has earned an international reputation in aircraft navigation and landing systems research and development.

FAA/OHIO UNIVERSITY AVIONICS ENGINEERING CENTER PARTNERSHIP:

Since 1983, Ohio University has been involved with the design and flight testing of differential GPS systems for aircraft precision approach and landing operations. Ohio University initially partnered with NASA Ames Research Center to use GPS for helicopter landings. Researchers subsequently broadened this effort to design a tactical differential GPS (DGPS) system for helicopters. In 1992, Ohio University expanded its research efforts to include commercial aircraft under a grant from NASA's Langley Research Center to develop a flight reference/autoland system using kinematic GPS techniques for NASA's Boeing 737 research aircraft.

In 1993 Ohio University applied the experience obtained during those efforts to new research begun under a 5-year grant awarded by the FAA. Under that award, the

Avionics Center supported the FAA's LAAS program to exploit emerging satellite technologies to provide cost-effective navigation and approach/landing services that would have a high level of integrity, reliability, availability, and coverage.

BACKGROUND:

LAAS, along with the Wide Area Augmentation System (WAAS), augments the GPS signal. The LAAS is intended to complement the WAAS to supply users of the U.S. national airspace system with seamless satellite based navigation for all phases of flight. In practical terms, this means that at locations where the WAAS is unable to meet existing navigation and landing requirements (such as availability), the LAAS can fulfill those requirements. In addition, the LAAS will meet the more stringent Category II/III requirements that exist at selected locations throughout the U.S. Beyond Category III, the LAAS will provide the user with a navigation signal that can be used as an all weather surface navigation capability enabling the potential use of LAAS as a component of a surface navigation system and an input to surface surveillance/traffic management systems. The LAAS will broadcast its correction message via very high frequency (VHF) radio data link from a ground-based transmitter. LAAS will yield the extremely high accuracy, availability, and integrity necessary for Category II/III precision approaches. It is fully expected that the end-state configuration will pinpoint the aircraft's position to within one meter or less and at a significant improvement in service flexibility, and user operating costs.

THE RESEARCH PROGRAM:

A next-generation aircraft precision approach, landing, and surface movement guidance system must perform well in several key technical areas and must also allow for a transition from the current systems, such as the Instrument Landing Systems (ILS) and the Microwave Landing System (MLS). Ohio University's research team, led by Principal Investigator Professor Frank van Graas, structured the university's efforts to include:

- Architecture Design
- Prototype System Implementation
- Very-High Frequency Data Broadcast.
- Pseudolite Augmentation
- Aircraft Surface Movement Guidance Test Bed

ARCHITECTURE DESIGN:

The LAAS architecture required high levels of accuracy and integrity-the ability of the system to provide timely warnings to pilots when the system should not be used for navigation. Researchers improved accuracy by using

Principal Investigator Professor Frank van Graas and Research Scientist David Diggle during B-757 flight tests (October 1994).

extended smoothing of the noisy GPS code measurements with the GPS carrier signals. They also installed the reference facility antennas close to the ground to reduce multipath error caused by ground reflections. Dr. David Diggle and Steven Hill, a graduate student, completed the initial LAAS architecture.

Principal Investigator Frank van Graas and graduate student Steven Hill - assembling the DGPS ground station inside UPS B-757 (October 1994).

Pilots from United Parcel Service (UPS) flight tested the new architecture in October 1994, using a UPS Boeing 757, completing a total of 50 automated landings. During those tests, researchers integrated DGPS into the Boeing 757 autoland system by making the DGPS guidance signals look like

One of fifty automatic landings during the FAA/UPS/Ohio University DGPS Autoland Flight Tests in October 1994.

signals from an ILS receiver. To validate the tests, the pilots flew several approaches using ILS for vertical guidance and differential GPS for lateral guidance. The pilots did not notice the difference, indicating that it is possible to transition from ILS to DGPS or to combine the two systems during a transition period. Dr. Frank van Graas subsequently presented the results of those tests to the International Civil Aviation Organization (ICAO).

Once they established the feasibility of using DGPS for aircraft precision approach and landing, the researchers next focused their efforts on further reducing the ground multipath error, an essential step in achieving the required level of integrity and to provide for an antenna installation more suited for operational use. To reduce multipath error, Ohio University's scientists designed a multipath-limiting antenna system consisting of a vertical dipole array antenna and a helibowl antenna. The dipole antenna tracks satellites with elevation angles between 5 and 35 degrees with respect to the ground. The helibowl antenna tracks satellites with elevation angles between 30 degrees and zenith. Starting with the initial antenna concept, it took researcher Michael DiBenedetto and Ph.D. student Chris Bartone only 4 months for the design, implementation, and field testing of the new antenna system. In August 1997, researchers flight-tested the new LAAS architecture with multipath antennas and integrity equations using FAA's Boeing 727.

PROTOTYPE SYSTEM IMPLEMENTATION:

During the development of the LAAS architecture, a prototype LAAS was installed and maintained at the Ohio University airport. This prototype installation was used to implement and evaluate the performance of different antenna systems as well as integrity equations. The prototype installation continues to operate using the latest LAAS technology and serves the purpose of collecting both short-term and long-term performance data. The continuous availability of the LAAS broadcast data also supports the testing of an aircraft surface movement guidance system.

VERY-HIGH FREQUENCY DATA BROADCAST (VDB):

One of the key architecture elements of the LAAS is the VDB. Introduction of the VDB into the VHF band requires a detailed assessment of the spectral compatibility in this band. Research Scientist Trent Skidmore established an automated laboratory test configuration for determining the interaction of the VDB with the existing Very-High Frequency Omni Range (VOR) and ILS services. VDB equipment from several vendors underwent testing and the results are being used to establish frequency assignment criteria for the VDB. The VDB was flight-tested at Ohio University and at the FAA William J. Hughes Technical Center in August of 1997.

FAA B-727 and Ohio University LAAS research vehicles (August 1994).

PSEUDOLITE AUGMENTATION:

Airport pseudolites (APL) are the preferred LAAS augmentation to increase availability, if necessary. A GPS-like signal is broadcast from a ground-based transmitter on the airport surface. Several technical challenges have delayed the use of APLs for aircraft precision approaches. Some of these challenges are: the near-far problem, ground multipath, aircraft signal reception in the top-mounted GPS antenna, ranging accuracy equivalent to GPS satellites, and spectral compatibility with GPS. Ph.D. student Chris Bartone developed a unique approach to the pseudolite challenges by using a pulsed, on-frequency, differentially-corrected pseudolite. Researchers paid much attention to the design of the pseudolite amplifier and pulser circuitry to ensure high quality ranging signals. The signal transmission used a custom-designed dipole array antenna similar to the one used for the reception of the GPS satellites in the LAAS ground facility. In the aircraft, special measures to control the received pseudolite power came through the use of a fast automatic gain control circuit.

Several developmental flight tests, using Ohio University's DC-3 research aircraft, commenced in August of 1997. Following every flight test, researchers were able to improve the design of the APL. Finally, in February of 1998, the flight tests were successful. Pseudolite ranging accuracy's of 0.25 m (rms) occurred on the ground and the availability of the airborne position solution increased.

AIRCRAFT SURFACE MOVEMENT GUIDANCE TEST BED:

To investigate the requirements for aircraft surface movement guidance using the LAAS, graduate student Gerhard Berz and researcher Maarten Uijt de Haag integrated an Inertial Navigation System (INS) with differential GPS and an advanced cockpit display. INS data provided attitude and heading information to the taxi guidance display. In addition, the differential GPS position solution calibrated the INS position drift errors. Preliminary van testing shows that the integrated system is capable of providing robust, sub-meter horizontal positioning accuracy. Efforts are currently underway to install the system in Ohio University's DC-3 research aircraft.

MEASURABLE SUCCESSES:

Firsts

- In October of 1994, Ohio University completed the design and flight-tested the first code-phase differential GPS system that satisfied both sensor accuracy and total system error for Category IIIb approach and landing using a Boeing 757 from the United Parcel Service (UPS). A total of 50 automatic landings were performed. The same flight test was successfully repeated in early 1995.

- In August of 1997, Ohio University completed the design and flight-tested the first prototype (LAAS) with an integrity system for Category IIIb approach and landing using FAA's Boeing 727. A total of 60 approaches were flown.

FAA, UPS, and Ohio University flight test crew (October 1994).

- In February of 1998, Ohio University completed the design and flight-tested the first differentially-corrected pseudolite integrated in the LAAS to increase availability for Category II and III approach and landing using Ohio University's DC-3 Research Aircraft.

Awards and Recognitions

Michael S. Braasch, **1992 RTCA William E. Jackson Award** for Outstanding Contribution to Aviation for Ph.D. Dissertation: "On the Characterization of Multipath Errors in Satellite-Based Precision Approach and Landing Systems".

David Diggle, **1994 William E. Jackson Award** for Outstanding Contribution to Aviation for Ph.D. Dissertation: "An Investigation into the Use of Satellite-Based Positioning Systems for Flight Reference and Aircraft Autoland Operations".

Chris Bartone, **1998 RTCA William E. Jackson Award** for Outstanding Contribution to Aviation for Ph.D. Dissertation: "Ranging Airport Pseudolite for Local Area Augmentation Using the Global Positioning System".

Frank van Graas, **Johannes Kepler Award** for Sustained and Significant Contributions to Satellite Navigation, from the Satellite Division of The Institute of Navigation, 20 September 1996.

Advanced Pseudolite for Dual-Use Precision Approach Applications, Chris Bartone, **Best Session Paper Award**, 9th International Technical Meeting of the Satellite Division of The Institute of Navigation.

For additional technical information regarding this success story, please contact: Mr. Ray Swider at (202) 493-4744

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