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Maturation and Hardening of the Stabilized Radiometer Platforms (STRAPS) Field Campaign Report

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Maturation and Hardening of the Stabilized Radiometer Platforms (STRAPS) Final Campaign Report

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Acronyms and Abbreviations

AAF	ARM Aerial Facility
ARM	Atmospheric Radiation Measurement Climate Research Facility
CIRPAS	Center for Interdisciplinary Remotely Piloted Aircraft Studies
DOE	U.S. Department of Energy
GPS	Global Positioning System
Hz	hertz
INS	inertial navigation system
MS	Microsoft Corporation
NRL	Naval Research Laboratory
ONR	Office of Naval Research
PI	Principal Investigator
STRAP	STabilized RAdiometer Platform

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1.0 Background

Measurements of solar and infrared irradiance by instruments rigidly mounted to an aircraft have historically been plagued by the introduction of offsets and fluctuations into the data that are solely due to the pitch and roll movements of the aircraft. Two STabilized RAdiometer Platforms (STRAPs) were developed for the U.S. Navy in the early to mid-2000s to address this problem. The development was a collaborative effort between the Naval Research Laboratory (NRL), the Naval Postgraduate School Center for Interdisciplinary Remotely Piloted Aircraft Studies (CIRPAS), and the U.S. Department of Energy (DOE) Sandia National Laboratories. The STRAPs were designed and built by L-3 Communications Sonoma EO (formerly the small business Sonoma Design Group).

Each STRAP can be mounted on the top or bottom of an aircraft and each uses a self-contained, coupled Inertial Navigation System (INS)-Global Positioning System (GPS) pair to actively keep a set of uplooking, or downlooking, radiometers horizontally level to within ±0.020 for aircraft pitch and roll angles of up to approximately ±100. The system update rate of 100 hertz (Hz) is fast enough to allow the STRAPs to compensate for most pitch and roll changes experienced in normal flight and in turbulence.

The STRAPs were previously flown in a handful of field campaigns and test flights that illustrated their ability to work extremely well, greatly increasing the accuracy and quantity of solar and IR irradiance measurements from aircraft (Bucholtz et al. 2008, Guan et al. 2010). However, the STRAPs also experienced various failures during these flights that highlighted the need to increase their reliability. Flight testing revealed that the major limitations to reliability lay with the first-generation INS solution originally employed by the STRAPs (i.e., the hardware and software that controls and levels the platforms), and with the Microsoft (MS) Windows-based operating system.

We therefore proposed to the U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Climate Research Facility's Aerial Facility (AAF) program for the maturation and hardening of the two Navy STRAP instruments. Specifically, we proposed upgrading the navigational computer hardware components, the platform control software, and the operating system of each of the STRAPs. The mechanical hardware components were sound. In May 2011 the AAF approved the funding for this project to make the STRAPs more robust and better suited for use in field studies or routine flights. The money was accepted by NRL in August, 2011. NRL then set up a subcontract to L-3 Comm-Sonoma EO that was finally approved in July 2012. The work was successfully completed by L-3 Comm-Sonoma EO in December 2012.

2.0 Description of Work Performed

2.1 Original Proposal Objectives

The overall objective of the work proposed was the maturation and hardening of the two Navy STRAPs to make them robust and reliable enough for use in field studies or routine flights. This overall objective was broken down into the following specific objectives:

- Upgrade the navigational computer system currently used on the STRAPs with the latest-generation hardware.

- Upgrade the control and analysis software with a new, more robust and flexible code.
- Replace the MS Windows-based operating system on the STRAPs with a more stable, UNIX-like, real-time operating system.
- Perform functional tests of the upgraded STRAPs under simulated flight conditions.

All of these objectives were met.

2.2 Work Completed

The approach to achieve the objectives was straightforward. L-3 Comm-Sonoma EO, the original designers and builders of the STRAPs, performed the following upgrades to the two units. The Principal Investigator (PI), Dr. Anthony Bucholtz, oversaw the project, collaborating with L-3 Comm-Sonoma EO to ensure specifications were met.

The following work to upgrade and test the platforms was successfully completed:

2.2.1 Initial Inspection and Testing

The following inspection and functional testing of the two STRAPs was performed prior to making any modifications to the units:

- Visual inspection and inventory of current components.
- Functional testing consisting of power-up and operational status.
- Inspection for operational errors and documentation of any failures.

This inspection and testing confirmed that the major limitations to the reliability of the STRAPs lay with the original INS solution and with the MS Windows-based operating system. No additional problems or issues were found.

2.2.2 Design and Documentation

The design and documentation of the modifications required to replace the navigational system hardware was performed, including designing and specifying the new bracketry and internal harnessing required for interfacing the existing hardware with the new INS hardware.

2.2.3 Upgrade of the Navigational Hardware

The navigational computer hardware components were upgraded to a more robust system on both units. This new hardware is identical to that flown on other L-3 Comm-Sonoma systems where it has been shown to be reliable and accurate over thousands of flight hours. The hardware upgrade included:

- Removing the original NAVSYS INS system components from both units.
- Installing the required components of the new GEN II GIB INS stack on both units.

The GEN II GIB INS stack is a proprietary solution developed by L-3 Communications Sonoma EO, Inc. The specifications of the GIB II are equal to or exceed that of the previous NAVSYS INS solution.

2.2.4 Upgrade of the Navigational Control and Analysis Software

The STRAPs originally used an old version of commercially available software (InterNav by NAVSYS) to keep the platforms level by analysis of the INS-GPS data. That software was found to have some fundamental problems that caused failures of the STRAPs. However, it was impossible to fix these problems because the software was proprietary and the vendor no longer supported it. L-3 Comm-Sonoma EO therefore developed their own in-house platform-control software that is robust and can be modified if needed. The control software for the STRAPs was upgraded to this new, more reliable software:

Implementation of the new stabilized platform geo-pointing software was incorporated into both units.

2.2.5 Replacement of the Operating System

The STRAPs originally used a MS Windows-based operating system that was not robust enough for operational use.

The operating system on both units was switched to QNX, a stable, embedded, real-time operating system specifically designed for 24/7 operation. The firmware and operating system have proven themselves capable and reliable over thousands of flight hours on many other L-3 Comm-Sonoma EO platforms.

2.2.6 Performance of Functional Tests of the Upgraded STRAPs

The following functional tests of the two upgraded systems were performed in the laboratory:

- Functional testing consisting of power-up and verification of system operation.
- Testing to validate the two systems in accordance with the system requirements specification.
- Platform stability and orientation was verified via a convergence and error testing.

3.0 Conclusion

The work described above was successfully completed by L-3 Comm-Sonoma EO and the two upgraded and functional STRAP units were returned to NRL in December 2012. Functional tests at the CIRPAS Radiometer Calibration Laboratory were conducted by the PI, confirming that both units were operational and ready for test flights.

3.1 Post-Project Note

This DOE ARM AAF project did not fund any actual test flights of the newly upgraded STRAPs. However, after successful completion of the modifications to the STRAPs (as described above), the PI, Dr. Anthony Bucholtz, and Dr. Haflidi Jonsson (CIRPAS Chief Scientist) obtained other funding from the

Office of Naval Research (ONR) to conduct test flights in April 2013 of the upgraded STRAPs on the CIRPAS Twin Otter aircraft. As a result of those flights the following improvements were made to the STRAPs by L-3 Comm-Sonoma EO (under an extended warranty from this project):

- • The firmware was updated to minimize overheating of electronic components during extended aircraft maneuvers outside the limits of travel of the STRAPs.
- • The firmware was updated to allow both STRAPs to be run on the same network.

4.0 References

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