

# Landing Gear Health & Usage Management System (HUMS) Condition Based Maintenance (CBM)

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## Abstract

This paper provides information on the development of a landing gear Structural Health Monitoring (SHM) system that provides prognostic/diagnostic Health & Usage Management System (HUMS) capabilities through direct load measurement in addition to fluid-level detection algorithms. The system provides advanced monitoring technology via the incorporation of new sensors integrated into the landing gear assembly. The direct load measurement approach is a paradigm shift from current methods of tracking fatigue damage of airframe landing gear systems and fuselage support structures, which depend on aircraft parameters recorded onboard at various low sampling rates by SHM devices<sup>1</sup>. The landing gear SHM provides direct loads measurement, weight/balance calculations, and the ability to perform Condition Based Maintenance (CBM) on the landing gear components.

**Keywords:** landing gear, HUMS, CBM, fatigue, safety, loads, strut, fluid

## Introduction

NAVAIR contracted with ES3 to support the development of the landing gear SHM through the Small Business Innovative Research (SBIR) program, via a Phase II award on the N121-043 topic. Although the primary focus of the development program is for fixed wing aircraft, the proposed solution will be directly transferable to other Navy airborne platforms. This paper will address the following topics in the area of aircraft HUMS and CBM: (1) advanced landing gear sensors for direct load measurement; (2) data fusion of direct loads monitoring data into fatigue life assessments; (3) paradigm shifts in aircraft maintenance utilizing fluid-level detection algorithms; (4) system verification and validation; and (5) safety and maintenance benefits.

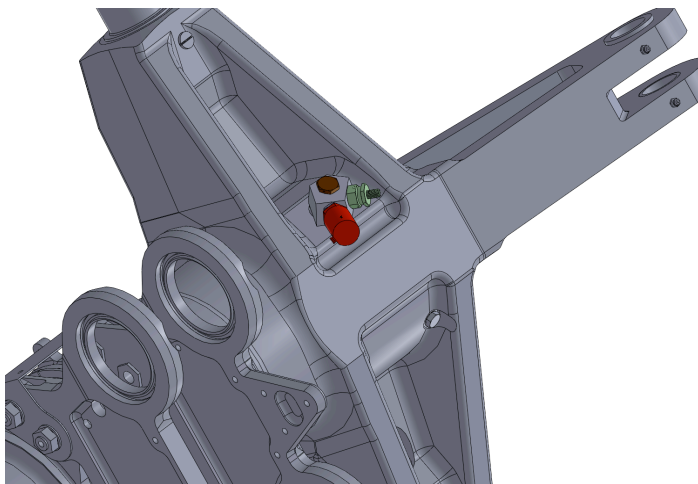


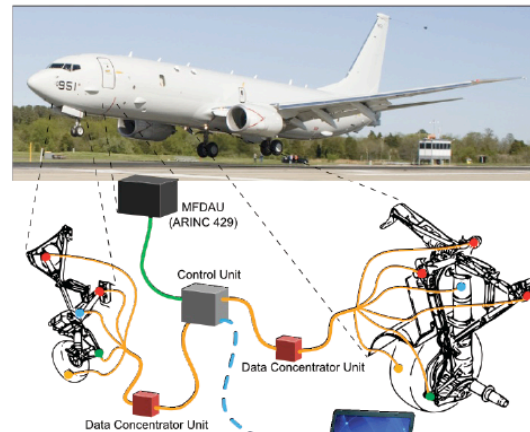
Figure 1: Sensor Assembly on Landing Gear Strut

Prior work in the field of spectrum development and usage monitoring has typically focused on the aircraft structure, with assumptions translated to the landing gear components without any direct measurement. The benefits of usage monitoring on aircraft are demonstrated in DOT/FAA/AR-04/6, *Continued Evaluation of Spectrum Development of a Usage Monitoring Spectrum*<sup>2</sup>. The same benefits can be realized for landing gear.

Direct loads measurement provides the ability to extend service life, remove components based on actual loading conditions, improve safety, increase aircraft availability, and save maintenance costs with incorporation of CBM data into the maintenance practices. This paper advances the state-of-the-art via the miniaturization of sensors rated for the severe landing gear environment at a high Technological Readiness Level (TRL). The models shown in Figure 1 depict the conceptual design of sensors currently flying on aircraft for loads spectrum data collection purposes. This paper varies from prior publications outlined below, in that the prior applications concentrated on fluid level detection for CBM purposes—while this paper enhances the SHM system capability via the addition of direct load monitoring devices throughout the landing gear structural load path.

### Prior Publication

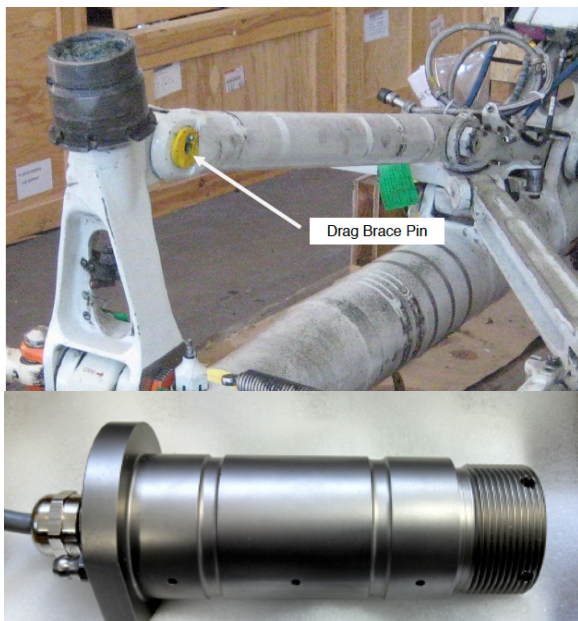
Early development of the landing gear SHM system was presented at the 6<sup>th</sup> European Workshop on Structural Health Monitoring, in a paper regarding *Aircraft Landing Gear Fluid Level and Landing Energy Monitoring System*<sup>3</sup>. The focus of that paper was the detection of improper fluid level and hard landings via the SHM system and sensors. As shown in Figure 2, technological feasibility of the fluid level detection was accomplished in 2013 as part of the N121-043 SBIR effort.



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**Figure 2: N121-043 SHM System Concept**

### Sample Results



**Figure 3: Landing Gear Load Pin**

One example of advanced landing gear sensors is the load pin shown in Figure 3. This advanced sensor replaces a drag brace pin with an instrumented pin for direct load measurement. This landing gear load pin was recently utilized for high-fidelity laboratory testing on a landing gear assembly. The SHM system development includes sensors in the load path for vertical, drag, and side loads. In addition, the system sensors provide the capability to monitor brake torque.

ES3 is leveraging the specialized products and services from Flight Data Systems Pty. Ltd. (FDS) located in Melbourne, Australia. FDS is a company specializing in Flight Data Management, established in 1990. Supplying flight data acquisition units, Flight Data Monitoring (FDM) & readout services to commercial & military customers globally. FDS also manages a complete logistics management service for the Australian Defence Force (ADF).



Figure 4: RDC Prototype from FDS

Using the FDS Remote Data Concentrator (RDC) unit for data acquisition and interface hardware specific to the ES3 SHM systems, the output being fed to a Central Control Unit (CCU). The ES3 SHM CCU is derived from the FDS Modular Acquisition Unit (MAU).



Figure 5: MAU/CCU from FDS

Examples of the derived products are shown in Figure 4 (RDC) and Figure 5 (MAU). The RDC can be installed on the landing gear assembly, with the CCU installed in the landing gear bay area for interface and transmission of landing gear sensor data to control/recording devices located elsewhere in the aircraft.

The landing gear SHM system also allows data fusion of direct loads monitoring data into fatigue life assessments. This feature is provided via utilization of communication to platform HUMS and associated flight records for data assurance purposes. The interface and communication of the SHM control units to the aircraft HUMS equipment provides the ability to synchronize loads data, allowing for elimination/reduction of estimates on landing gear loads usage and service life. A sample of the data collected from the drag brace landing gear load pin during laboratory testing is shown in Figure 6.

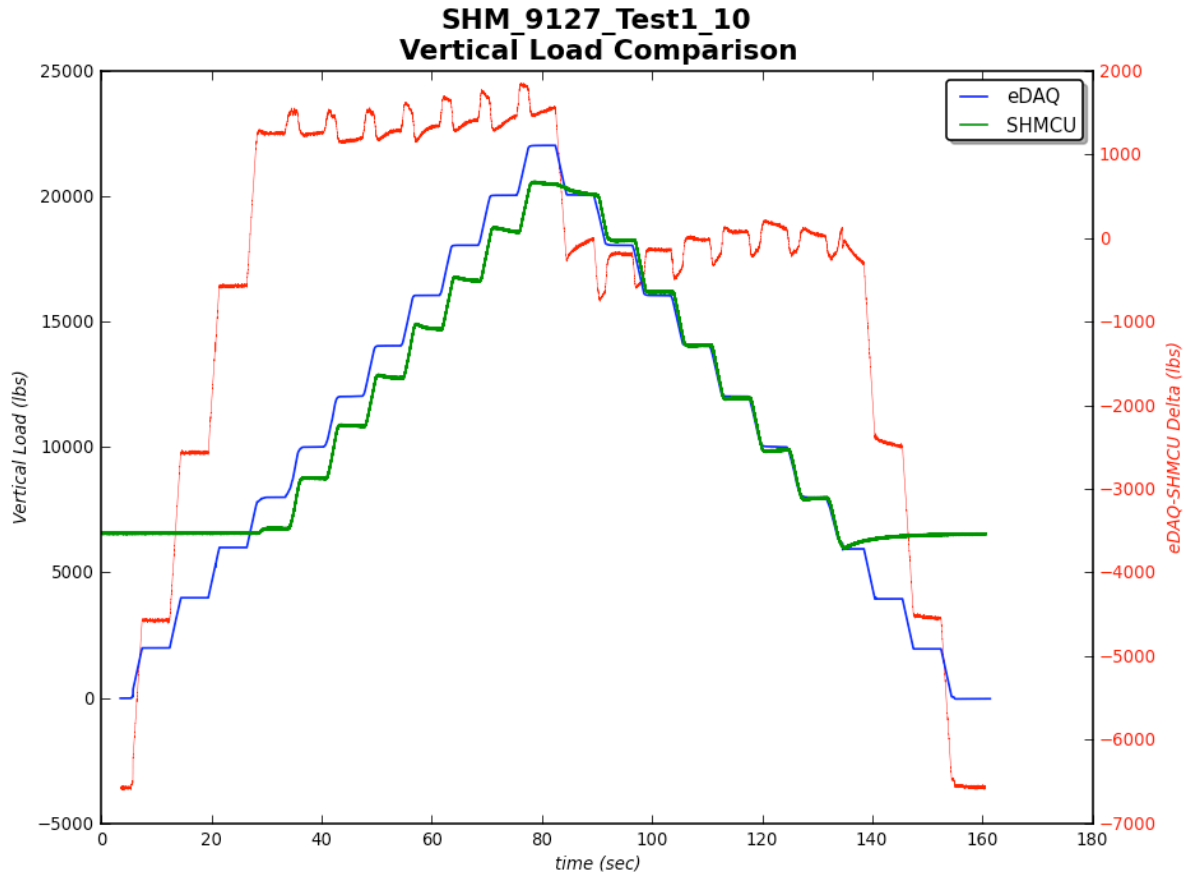


Figure 6: SHM System - Landing Gear Load Pin (Sample Data)

The SHM technology and algorithms also provide the ability for a paradigm shift in aircraft maintenance, utilizing fluid-level detection algorithms. Previously, detection of an improperly serviced strut with weight on aircraft wheels was not possible. The incorporation of the SHM sensors and unique aircraft algorithms changes the maintenance approach, allowing for appropriate CBM based on the actual condition of the landing gear component service condition.

Laboratory testing of the SHM components using early TRL technology has also been completed. The system development is transitioning into form, fit and functional hardware in a high-fidelity laboratory environment. The planned testing includes verification of landing gear multi-body dynamic models and validation of that model with the high fidelity laboratory testing.



The SHM technology also provides a safety benefit with the improvement of weight and balance calculations. The landing gear sensors and associated control/interface units provide the ability to calculate actual weight and balance information. This information can then interface with other platform HUMS systems for use in improving maintenance practices, or enhancing crew safety during operations.

### **Current Status of the Work**

The landing gear SHM system has completed definition of system requirements for proceeding into development activities. The design portion of the development has been initiated, with formal Preliminary Design Review (PDR) scheduled for the end of January 2015. In addition, validation/verification planning has begun for high-fidelity laboratory testing to be executed with actual landing gear components and functional hardware in the first quarter of 2015.

### **Acknowledgments**

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