Marcias Martinez

T: *+1-315-268-3875* Email: mmartine@clarkson.edu

Research Statement

My research has been focused on the implementation of a holistic structural integrity process for the aerospace and mechanical engineering industry.

Primarily, I am interested in the use of smart materials in the development of sensors for Structural Health Monitoring (SHM) systems required to identify and quantify structural damage. This structural damage of both metallic and composite structures can be produced by overloading conditions, environmental factors, impact or fatigue. Since 2005, I have been working on analyzing and understanding the capabilities of the academically and commercially developed "off-the-shelf" systems, which are available to perform SHM and load monitoring in the field. I have gained valuable experience in this area. However, SHM cannot be tackled independently, since it is just one component of a much larger system. The aging of structures requires that the problem be analyzed by taking a holistic approach, which requires an understanding of the loads supported by the structure, the initial structural conditions, environmental effects on the structural performance, and material properties of the components composing the structure. All of these conditions and properties interact and, thus, a multi-physics based model is required, which is a fundamental part of the Holistic Structural Integrity Process (HOLSIP). Clearly, HOLSIP requires multiple inputs to fully provide the required outputs that structural integrity engineers need to assess the remaining useful component life of an aerospace structure. Through my research, I have contributed to the development and execution of a road map that interconnects HOLSIP with other research fields, as shown in Figure 1.

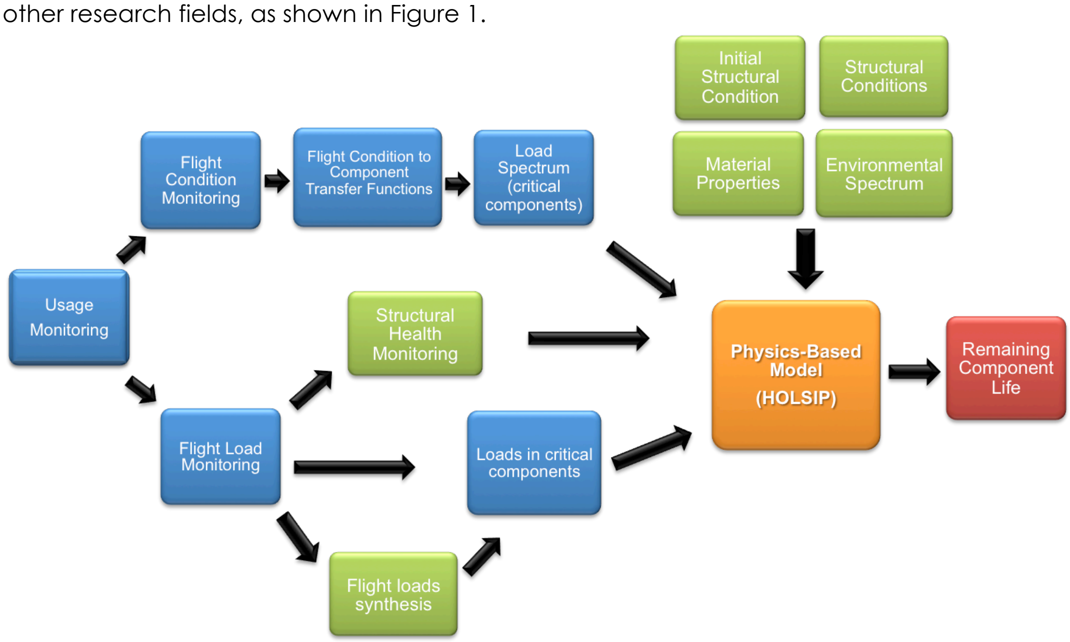

Figure 1: HOLSIP - Usage Monitoring Flow Chart

Although, Fig. 1 shows a roadmap primarily directed to the aerospace industry, it is important to note that HolSIP methodology can be applied to any mechanical and/or civil infrastructure. The usage monitoring flow chart shown in Fig. 1 uses two distinct approaches to estimate loads. The first approach, Flight Conditioning Monitoring, uses machine learning techniques such as Neural Networks Algorithms to estimate the loads on the structure based on the flight state parameters, i.e. altitude, aircraft weight, and aircraft manoeuvre, to name a few. While I have participated in efforts in this direction, my research concentrates on the second approach known as Flight Load Monitoring, which combines the use of sensors to directly measure the health and loads acting on the structure. The aim of HOLSIP is to advise governments and sustainability organizations on useful remaining component life of a structure. My background in materials modeling of solidification processes and micro structures developed during my M. Eng. studies has played a crucial role in obtaining a greater appreciation for the vast problem of ageing structures.

As it relates to the HolSIP methodology, my research has focused on:

1. Integration of fiber optic and piezoelectric sensors in composite structures;
2. Development of SHM facilities to test and validate the capabilities of SHM systems; under realistic operational conditions;
3. Damage monitoring and modeling in both metallic and composite structures;
4. Load monitoring using Micro-Electro-Mechanical Systems (MEMS) and distributed sensing Rayleigh backscattering systems, and
5. Structural Health Monitoring (active and passive methodologies).

One of the many challenges in the SHM field is the need to validate the capabilities of SHM systems with respect to standard Non-Destructive Evaluations (NDE) techniques. Most of the SHM systems I have evaluated have been found to possess Technology Readiness Level (TRL) between 1 and 3, on the scale where a TRL of 9 is considered to be a mature commercially available technology. Many of the SHM systems analyzed to date have been developed and tested on simple coupons, but, particularly in aerospace applications, there is a requirement to move these systems up the TRL ladder. My experimental work attempts to validate the developed computational models and my research in the last 3 years, while working at the National Research Council of Canada, I was in charge of developing a series of well documented platforms that vary from very simple structures to a complex full scale test of an airplane wing. The first SHM platform, shown in Figure 2 (1), consists of an 18 feet simple cantilever aluminum beam that provides a perfect scenario for evaluating Load Monitoring system capabilities to measure bending, torsion and shear loads. A second version of this platform makes use of the complexity of a riveted and adhesively bonded skin on spars, in order to validate the ability of SHM and load monitoring systems. As primary investigator, I have taken the task of documenting and designing the different test procedures while ensuring realistic test conditions encountered during the service life of aerospace structures. The second SHM platform, shown in Figure 2(2), consists of a wing box with aluminum spars and ribs. The wing box is manufactured with interchangeable metallic and composite skins. I have worked on the development of procedures to grow hidden cracks emanating from holes, or sections of the spars and ribs. As part of this procedure, the structure can be fatigue loaded using a realistic aerospace spectrum while the SHM systems are evaluated for their ability to quantify damage locations in this more complex aerospace structure. Finally, the third SHM platform shown in Figure 2(3), examines an actual wing from a CF18 fighter aircraft. This platform contains the most realistic case scenario and requires the SHM and load monitoring systems to be of a higher Technology Readiness Level (TRL) in order to identify the realistic loads and damages that are experienced by this aerospace structure.

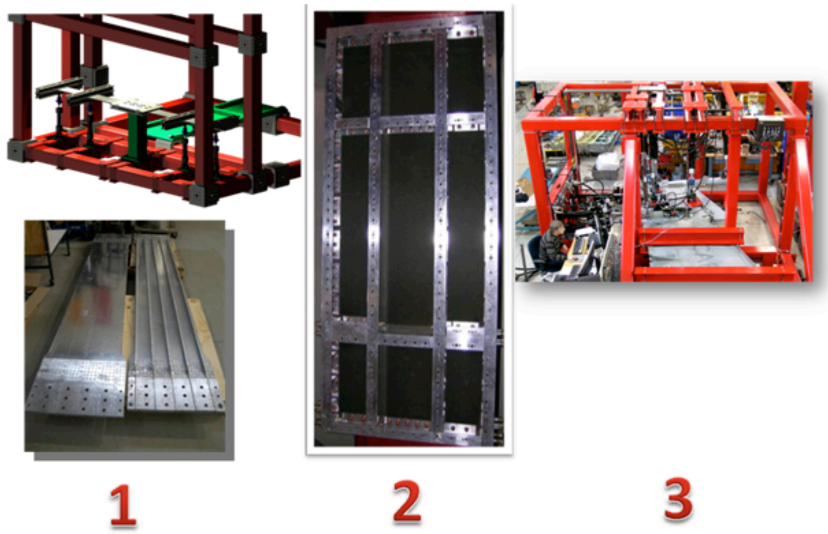

Figure 2: SHM Test Platforms (1) Load Monitoring Platform (2) Damage Detection Platform (3) CF-18 Load and Damage Monitoring SHM Platform.

It is important to add that the development of these platforms has allowed me to build academic relationships with national (Canada) and international (USA, U.K. and Mexico) organizations, which provides a unique opportunity for adding my expertise to that of other researchers in the field.

If given the opportunity to join your university as a professor in engineering, I look forward to working with students and colleagues within the department on extending the use of SHM on different mechanical and aerospace structures. As part of a first phase, I would concentrate on developing structures that mimic real-life conditions in a controlled environment. I would then join forces with SHM and load monitoring equipment manufacturers in order to validate and improve the SHM systems currently available on the market. In the case of aerospace structures, I have been working on the design of an amphibious solar powered Unmanned Air Vehicle (UAV) as shown in Figure 3. The primary intention of the design is to develop a a full scale test of this type of structure that could be used for the development of SHM systems while serving as a unique facility for training graduate and undergraduate students. The test platforms will need to include loads, vibration and environmental factors typically found in the field. The evaluation of these SHM systems should not be limited solely to the sensor but expanded to the entire system as a whole. As the complexity of UAV increases, it is becoming more apparent that these structures are no longer disposable platforms. Their avionics and the level of sophistication have dramatically increased to the extent that their costs are quickly approaching those of regular military and civilian aircrafts. Finally, I would continue my research on the utilization of FEA for the development of a HOLSIP model that may include residual stresses, crack nucleation sites and manufacturing process (i.e., shot peening) on the growth of these flaws.

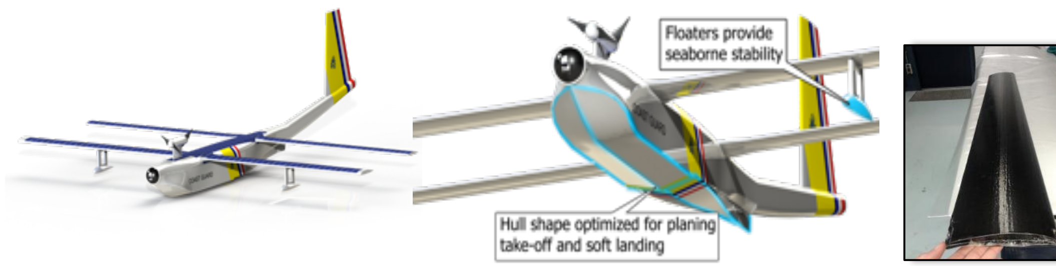

Figure 3: Delft University of Technology, Amphibious, Solar Powered UAV (Dr. Martinez, Lead Engineer). Approximate size of the UAV 2.5 m by 2.5 m by 0.75 m.

Finally, I would like to re-iterate that my research goals are directly linked to solving, from fundamental principles, the real challenges faced by the SHM community. I look forward to developing a multi-cultural research team of students, which can aid in solving some of the challenges that we face in both the aerospace and other structural Industries for the 21st century.