**Purpose**

Non-destructive integrity testing is essential in the maintenance of composite structures such as aircraft wings. Composite structures can sustain damage, often not visible to the human eye, which can lead to catastrophic failure during normal use. Determining if a structure has the integrity to function properly is a time-consuming and inaccurate process to conduct manually. Automated testing allows for precision damage detection and the ability to map that damage onto a 3D model. The computer numeric control (CNC) scanner was designed to automate the measurement and analysis of composite structures.

**Design Features**

The 5-axis design positions a sensor at any location around an object and orients it perpendicular to that surface. Stepper motor rotation is converted into translational motion using ball screw and linear bearing assemblies in the X, Y, and Z directions to achieve a required 40 in. cube scan volume. A two-stage telescoping Z-Axis was designed to maintain the 40 in. axis range while not exceeding a maximum height specification of 8 ft. Structural components were designed to have negligible deflection under anticipated static and dynamic loading. Finite element analysis was performed to verify preliminary analytical deflection calculations. Stepper motor operation is controlled using Mach 4 (Newfangled Solutions, Livermore Falls, ME) CNC driver software. Sensor data is collected and processed using LabVIEW (National Instruments, Austin, TX). A Keyence LK-H157 laser displacement sensor maps surface distance measurements used to generate a 3D model. Surface impedance and ultrasound contact sensors will interchange with laser to detect structural damage.

**Specifications**

**General**
- Max Height: 7 ft. 11.5 in.
- Footprint: 6 ft. [X] x 5 ft. 7.8 in. [Y]
- Weight: 400 - 500 lbs
- Scan Volume: 41.02 in. [X] x 33.62 in. [Y] x 43.98 in. [Z]
- Ball Screw Lead: 0.197 in.
- Translational Precision: 0.0001 in.
- Max Translational Speed: 200 in./min

**Axis Drive**

- **X-Axis:** 2x NEMA 34 - 1841 oz.-in. (Parallel)
- **Y-Axis:** 1x NEMA 34 - 1841 oz.-in.
- **Z-Axis:** 1x NEMA 34 - 1841 oz.-in. / 1x NEMA 23 - 100 oz.-in. (Series)
- **Pan:** 1x NEMA 17 - 64 oz.-in. (360° rotation)
- **Tilt:** 1x NEMA 17 - 115 oz.-in. (Dual Shaft; 180° rotation)

**Sensor**

Keyence LK-H157 Displacement Laser
- Repeatability: 0.25 μm
- Scan Cycle: 10 μs

*T 40 in. range achievable with Tilt-Axis redesign.

**Conclusion**

This is the first phase in the design of an autonomous machine to perform non-destructive integrity testing of composite structures. The 2015-16 design team completed the mechanical design as well as manufactured and assembled many of the major scanner components. The next phase of this project will complete the manufacturing and assembly of the scanner, perform experimental characterization testing, and develop calibration procedures.