The aerospace industry relies on nondestructive evaluation (NDE) to ensure aircraft safety and will benefit from methods that allow for early damage detection. Photoluminescence piezospectroscopy (PS) has demonstrated stress and damage sensing of substrates when coupled with alpha-alumina nanoparticles in a polymer matrix applied as a sensor coating. Alpha phase alumina exhibits photoluminescent spectral emission lines (R-lines) that shift due to changes in the stress state of the alumina. The coatings’ capability for sensing early subsurface damage suggests the potential for implementing stress sensing paint for integrity monitoring of aircraft structures. To achieve a viable stress sensing coating that can be applied as a paint, materials for optimal sensing and processing need to be tailored for aircraft applications. In addition, advances in optics technology for area scanning and faster data collection are needed. In this work, manufacturing of the sensing paint was achieved by introducing alumina nanoparticles into an aircraft grade topcoat using 3 different processing approaches and the paint with the best dispersion was identified using quantitative luminescence intensity results. To maintain the ease of application through spraying, dispersant was added to the paint. Tensile tests on composite and aluminum substrates resulted in spectral shifts with applied loading that reveal non-uniform and non-recoverable stresses within the paint. Scanning electron microscopy showed microcracks verifying that the sensing paint experienced damage during loading. Future iterations of the sensing paint will focus on improvements in polymer mechanical properties and homogeneity on application, particle to polymer bonding and enhanced adhesion. Area scanning was achieved through the development and calibration of a hyperspectral imaging system using a laser with wider aperture. The long-term goal is to establish a standardized paint-based PS coating and optics technology for structural integrity monitoring of aircraft structures.