PROJECT SUMMARY

Identification and Significance of the Problem. To address the NASA need for compact nondestructive evaluation (NDE) systems for *in situ* evaluation of the structural integrity of complex, built-up spacecraft components and structures, Physical Optics Corporation (POC) successfully developed, demonstrated, and delivered to NASA a novel Structural Integrity Inspection and Visualization System (SIRIUS) based on one-sided three-dimensional (3D) structure imaging via collecting the information on density profiles in multiple object cross sections through hard X-ray Compton imaging tomography (CIT). The developed standalone SIRIUS Phase II prototype system, based on a 200 kV X-ray source, flat-panel X-ray detector (FPD), and apodized X-ray imaging optics, demonstrated excellent potential for 3D localization of defects in various aerospace materials and structures, such as thermal protection system (TPS) ceramic and composite materials, micrometeoroid and orbital debris (MMOD) shielding, spacecraft pressure walls, inflatable habitat structures, composite overwrapped pressure vehicles (COPVs), aluminum-rubber composites, and metal honeycomb materials. In Phase II, POC developed a compact, standalone version of the SIRIUS system with improved performance (in terms of resolution and data acquisition speed), as well as an advanced graphical user interface (GUI) for straightforward data acquisition and visualization. At the end of Phase II, POC performed a technology readiness level (TRL)-6 demonstration of SIRIUS at NASA facilities.

Technical Objectives and Work Plan. Phase II objectives were: (1) Development of the overall fully integrated SIRIUS Phase II design; (2) Development of a high-performance X-ray imaging system; (3) Development of the algorithms and software for 3D image quality and resolution enhancement, as well as artifact reduction; (4) Development of a compact, fully integrated SIRIUS Phase II system; (5) Development of an advanced, user-friendly graphical user interface (GUI) for image acquisition, processing, and display; (6) Demonstration to NASA of the Phase II SIRIUS performance and delivery of the prototype system to NASA; and (7) Identification of the commercial potential of the developed SIRIUS technology. The Phase II work plan included the following tasks: (1) Develop the Phase II SIRIUS Design; (2) Develop or Procure Large-Area X-Ray Imaging Detector; (3) Develop Apodized Multiple-Aperture X-ray Optics; (4) Develop Algorithms and Software for Advanced Image Deconvolution; (5) Develop Algorithms and Software for Axial Resolution Enhancement; (6) Develop Algorithms and Software for Artifact Reduction; (7) Develop or Procure a Compact X-Ray Source; (8) Develop or Procure the SIRIUS Hardware Components; (9) Integrate and Test the SIRIUS Phase II System; (10) Develop a GUI for Image Acquisition, Processing, and Display; (11) Demonstrate the Performance of the SIRIUS Phase II System to NASA; (12) Explore the Commercial Potential and Product Viability; and (13) Prepare and Submit Reports.

Technical Accomplishments (Phase I Project Summary). The major Phase II achievements include: (1) Development of the SIRIUS Phase II system architecture; (2) Development of the detailed mechanical design of the Phase II SIRIUS scanning module in SolidWorks; (3) Development of a Large-Area X-Ray Imaging Detector; (4) Development and testing of multiple-aperture X-ray optics for high-speed imaging; (5) Development of algorithms for advanced image processing, including image deconvolution, multiple-order Compton scattering elimination, laminography-based axial resolution enhancement, and attenuation artifact reduction; (6) Development of algorithm and implementation in software of natural-neighbor-based 3D interpolation approach with improved data reconstruction; (7) Development of full mechanical design, assembly, and testing of two generations ("alpha" and "beta") of SIRIUS hardware; (8) Development of graphical user interface for data acquisition, 3D reconstruction, and analysis; (10) Delivery and demonstration of a TRL-6 system to NASA LaRC at the end of the project; and (10) Analysis of the commercial potential of SIRIUS technology.

NASA Application(s). Noncontact, single-sided NDE of spacecraft components during spaceflight, with the capability to provide reliable, high-resolution assessment of the location and extent of damage within thermal protection shield (TPS) materials, micrometeoroid and orbital debris (MMOD) shields, inflatable habitats, extravehicular activity (EVA) suits and vehicles, electronic systems, conductive structures, pressure vessels, and other lightweight materials, with the ability to function in hard-to-access areas within both pressurized habitable compartments and external space environments. SIRIUS technology can also be used for quality control in spacecraft manufacturing and material R&D, in particular for testing the quality of TPS materials.

Non-NASA Commercial Application(s). NDE of multilayer metal/composite structures in aging and modern commercial and military aircraft, spacecraft, and light marine vessels.