Sensors and Systems for Space Applications

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Sensors and Systems for Space Applications

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This special section of Optical Engineering is devoted to recent advances in sensors and systems for space applications.

The popular appreciation of space weather, orbital debris, and commercial space launch increases the demand for contextual understanding for both challenges and possibilities for the future of space. Developments in microsat and picosat systems, coupled with more affordable launch services, such as the pioneering Space X enterprise, may vastly transform space activities for global communication, knowledge discovery, economic prosperity, and national security. Specifically, sustained excellence in communications, position navigation, and timing is vital to the future conduct of space policies and operations. Toward that end, effective research and development ranges from operational concepts to subsystems and component-level innovations that cover all aspects of the design process, including end-user requirements definition and how those requirements impact design and operational decisions. It is anticipated that the range of scientific and commercial-related topics will also foster multidisciplinary discussions that allow stakeholders to gain an understanding of the technological issues being addressed by their counterparts working in different areas such as: (i) methods of robustness testing for space platforms, (ii) sensors and control for space robustness and autonomous operations, (iii) remote sensing for space intelligence and security, (iv) access assurance and security in space, and (v) optical and quantum information sciences and technologies for flexible and resilient timing, navigation, and communications.\(^1\)

Zhang et al. present recent advances in low-velocity impact testing in hybrid composites for space applications. Low-velocity impact testing is a common, pressing issue in material science because the repercussions are not only hidden but occur often. Carbon fiber-reinforced polymer composites (CFRP) are strong, light weight materials used in everyday products. However, basalt carbon has been gaining traction in more applications as a composite polymer manifested by its mechanical tolerance. Out of all the methods of material testing, eddy current-pulsed thermography (ECPT) is a growing nondestructive testing (NDT) procedure for emerging modalities. ECPT can detect and characterize subtle defects of low-velocity impacts of both basalt-carbon composite and CFRP multi-layers through electromagnetic induction. To validate the thermographic effects, x-ray computed tomography and ultrasonic C-scan are utilized. To analyze the thermal data, both ultrasonic C-scan and x-ray tomography were utilized to visualize the topography and temperature profiles. The ECPT was chosen as the ideal sensing method for polymer composite testing to ensure the materials robustness of future space satellites.

Chen et al. review the recent advances in manufacturing for temperature gradients in additive processes for space applications. Laser metal deposition (LMD) projects a laser with powdered metal injected through a gas stream to additively fill a surface. Testing examines any correlations between the microstructure traits and temperature to model the temperature gradients of the grain size of the deposition layer. The results indicate that the sensed asymmetric temperature distributions support the thermal cycle curve models.

Sun, Song, and Liu highlight an ensemble of classifiers to improve classification performance. Object classification includes ground-based space object detection, ground-based multi-modal imaging for space launch,\(^2\) as well as methods for remote sensing. The objects to classify correspond to the nearest cluster based on their traits with the result being discounted by their paired weight for each classifier. Using the weights, errors are reduced modeling hard (e.g., probabilistic) and soft (e.g., fuzzy) decision making.

Čierny and Cahoy calibrate orbital beams in laser communications. Nanosatellite designs equipped with more complex instruments for data collection and processing, so the downlink traffic demand can be overwhelming for RF communications. Therefore, laser beams offer larger data throughput as well as minimizing hardware, processing power, and cost. The paper presents calibration techniques to enhance beam pointing on nanosatellite laser downlink terminal for CubeSat. Results demonstrate tracking errors of 16 \(\mu\)radians root mean square error (RMSE) for the two axes, overcoming the requirement of 0.65 mrdians using higher downlink data throughput.

Tang, Ye, and Xiao address recent advances for solar cells operating in extreme environments for space applications. While solar cells flourish in everyday environments, they do not thrive in harsh conditions in space, such as ionizing UV irradiation from the sun or any high-energy particles. To solve this, two materials are coupled together to endure harsher conditions along with superior performance: titania.
communications network through the dynamic data-driven holistically assesses the space domain data, manages robust decentralized, capability-based access control (BlendCAC), nonuniform SSA systems. Xu et al. introduce a secure and limited in performance especially in decentralized and information analysis, shedding light on cutting-edge technologies of interdisciplinary research in nondestructive evaluation, image processing, optical engineering, composite materials, additive manufacturing, information fusion, data analytics, sensor design, renewable energy, signal processing, satellite communications (SATCOM), blockchain, and SSA. The prominence of space in supporting daily activities will continue to drive research in sensors and systems for space.

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References

Genshe Chen received the BS and MS in electrical engineering, and a PhD in aerospace engineering, in 1989, 1991, and 1994, respectively, all from Northwestern Polytechnical University, Xian, China. He did postdoctoral work at the Beijing University of Aeronautics and Astronautics and Wright State University from 1994 to 1997. He worked at the Institute of Flight Guidance and Control of the Technical University of Braunschweig (Germany) as an Alexander von Humboldt research fellow and at the Flight Division of National Aerospace Laboratory of Japan as a STA fellow from 1997 to 2001. He was a postdoctoral research scientist in the Department of ECE of the Ohio State University from 2002 to 2004. He was with Intelligent Automation, Inc., Rockville, MD, as the program manager in Networks, Systems, and Control from 2004 to 2007, and was with DCM Research Resources LLC, Germantown, MD, as CTO from 2008 to 2010. Currently, he is the CEO/CTO of IFT.

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