NASA Sensors and Instrumentation: Driving Technologies to Enable an Innovative and Prosperous Future

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Abstract: The NASA Engineering and Safety Center (NESC) stems from the NASA Office of the Chief Engineer and is dedicated to conducting discipline specific gap analyses to identify areas for strategic investment; leading in-depth investigations of the state of the discipline and providing recommendations to senior NASA management on investment, divestment, and consolidation; and providing input to strategic planning and roadmap activities for 20 distinct disciplines, including Sensors and Instrumentation. The Sensors and Instrumentation discipline, which includes optics and photonics, is critical to ensuring the health and safety of NASA's missions, as well as providing innovative solutions that enable future discovery.

Key Word—*Sensors, Instrumentation, Optics, Photonics, NASA Engineering and Safety Center*

1. Introduction

The success of every technology development and its implementation, on Earth and in space, relies on our ability to accurately and precisely sense, measure, and monitor physical parameters and phenomena. Sensors and instrumentation (S&I) provide us the ability to gauge the health and status of a particular system and the means to explore the Universe. At NASA, S&I is essential to all mission directorates related to engineering, science, and exploration, and so preserving its health across the Agency and community is a priority. As such, the NASA Engineering and Safety Center (NESC) has established a Technical Discipline Team (TDT) to ensure that the discipline remains healthy and is forward looking.

The NESC's mission is "to perform value-added independent testing, analysis, and assessments of NASA's high-risk projects to ensure safety and mission success. The NESC engages proactively to help NASA avoid future problems." As a direct offspring of the Office of the Chief Engineer, the NESC acts as a Program and Mission independent organization and is comprised of the Agency's leading experts across multiple disciplines that includes: Aerosciences; Avionics; Cryogenics; Electrical Power; Environmental Control & Life Support; Flight Mechanics; Guidance, Navigation & Control; Human Factors; Loads & Dynamics; Materials; Mechanical Systems; Nondestructive Evaluation; Nuclear Power & Propulsion; Propulsion; *Sensors & Instrumentation*; Space Environments; Software; Structures; Systems Engineering; and Thermal Control & Protection. The NESC conducts discipline-specific gap analyses to identify areas for strategic investment; leads in-depth investigation of the state of the discipline, and provides recommendations to senior NASA management on investment, divestment, and consolidation, and contributes to Agency level strategic planning and roadmap activities.

The S&I discipline includes four primary areas based on the 2024 NASA Technology Taxonomy for TX08 [1]. These areas are Remote Sensing Instruments and Sensors Elements, Observatories, In-Situ and Proximity Sensors, and Other Sensors and Instruments. Remote sensing instruments includes detectors and focal planes, optical components, and lasers, for example. Observatories includes technologies related to telescopes and antennae (receive and transmit photons). In-situ and Proximity sensors contains technologies such as those used for vehicle and habitat monitoring and for characterizing Earth and other planetary atmospheres. The last area for "other" is meant to be a catch-all for those sensors and instruments not covered under the other areas. While there is overlap between these areas, it is clear that the S&I discipline spans a broad range of technologies that are applicable to multiple programs and mission types.

Looking towards NASA's future needs, there are several emerging areas that are of particular interest. These include AI and machine learning algorithms for improved sensing, enhanced autonomy of sensors and systems of sensors, quantum sensors, meta-materials and other advanced materials, additive manufacturing, improved Size-Weight and Power (SWaP) for flight systems, and sensors for harsh environments. Many of these technologies and concepts are useful not just for NASA, but for terrestrial-based applications as well. To this end, the NESC welcomes industry, academia, and international government agency collaborations through the request of assessments, participation in the S&I TDT's Communities of Practice (CoPs), and workshop attendance.

2. Assessments and Subject Matter Expert (SME) Support

A primary goal of the NESC is to act as a technical resource for the S&I community in support of NASA projects and Programs. NESC assessment "tiger" teams include technical experts from NASA, industry, academia,

Federally Funded Research and Development Centers (FFRDCs), and Other Government Agencies, to develop approaches to identify, solve, and prevent issues relevant to NASA. These Agency-critical assessments, which can be requested by any organization, provide an independent and expert view of a critical technology development, active mission element, or as risk mitigation action. Assessments are reported to the requestor and the NESC Review Board. Assessment recommendations and findings are typically documented in a report or presentation and provided to the assessment requestor. Assessment reports are only made public if approved by the requesting organization and do not include sensitive materials. The S&I TDT has supported numerous assessments over the years on a wide range of exploration, engineering, and science missions and topics.

3. Discipline Enhancing Activities

NESC discipline enhancing activities are primarily driven by the CoPs. The S&I TDT CoPs include In-Situ and Proximity (ISP) Sensors, Quantum Sensing (QS), Optics and Photonics (O&P), and Infrared (IR) Detectors. Each comprises members of the community who have a mutual interest in ensuring the success of S&I technologies and want to share their ideas. The CoPs host guest speakers, organize community workshops and Technical Exchange Meetings (TIMs), and hold discussions on the state of the workforce. CoP goals and example activities are summarized in the following paragraphs.

In-Situ and Proximity Sensors CoP: Since its formulation, this CoP has assisted the S&I TDT in assessing and providing recommendations regarding these technologies. A NASA-internal searchable ISP technology database was developed, and continues to be populated, to track all ISP sensors and instrumentation systems used in industry and at all NASA centers for member awareness and utilization. This database, combined with monthly discussions allows the CoP to continually evaluate ISP sensor needs and determine Gaps for the NASA Agency. CoP presentations highlight developing technologies and provide a foundation for the database.

Quantum Sensing CoP: The QS CoP was formed to promote an understanding across NASA Centers of quantum sensing research and to develop use-cases for NASA applications. The CoP has over 40 active members across NASA and JPL and meets monthly to provide regular, timely technical interchange between NASA QS practitioners and outside experts and industry leaders. A QS speaker series was established to focus on use cases and technologies being applied for sensing applications. This CoP also provided SMEs and speakers in support of a QS workshop, held in 2022, that had the goal of identifying NASA-internal and -external capabilities and Agency future needs. By bringing together technical experts and end-users, an appropriate strategy was established to develop and maintain the state-of-the-art sensing competence and capabilities to meet the NASA's future needs for science and exploration [2,3].

Optics and Photonics CoP: This CoP is the most recent CoP and is still in the formulation stage. Its formulation is driven by the need to identify critical optics and photonics technology gaps for NASA and to provide detailed descriptions of critical O&P technologies that includes level of maturity, performance, and potential applications. This CoP will provide a forum for O&P experts to discuss current technologies, make recommendations that support emerging technologies, and prioritize those that may significantly enhance performance over the state-of-the-art. Also discussed is the state of the workforce. Identifying future NASA and community needs and barriers to training the next generation in these areas is a priority.

Infrared Detector CoP: The IR Detector CoP was formed to promote knowledge sharing among science and engineering practitioners to identify and assess critical IR detector technologies for NASA applications. The CoP actively solicits participation from individuals across the community to represent the breadth of development activities across industry, FFRDCs, academia, and Other Government Agencies. They create assessments for IR detector topics related to NASA's Critical At-Risk Industrial Technology List and are working to establish a searchable database for IR Detectors with space flight heritage and under for those still under development. This CoP recently held an IR Detector TIM at JPL with the goal of evaluating NASA-needed technologies, identifying opportunities for investments and collaboration, and to formulate agency-level strategies to meet its near- and far-term needs.

4. Areas of Collaboration

NASA welcomes partnerships and open exchange of information through participation in S&I TDT and CoP speaker series and via the public-facing TechPort web-portal [4]. NESC frequently sponsors TIMs and workshops to facilitate discussion across platforms and institutions, especially in emerging technology areas that will ensure our collective future.

5. References

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[4] https://techport.nasa.gov