Overview of the NESC Sensors & Instrumentation Discipline

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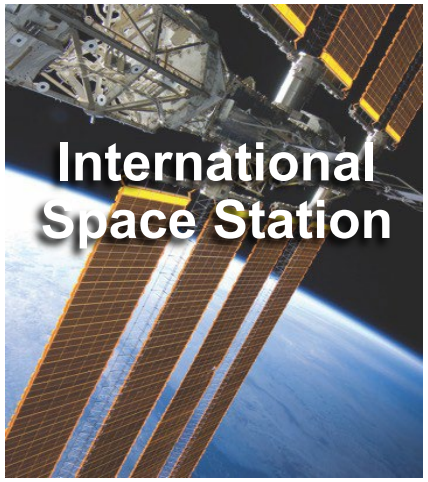
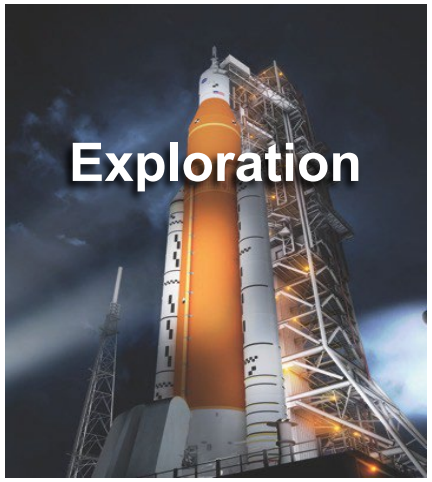
Presentation to Quantum Sensing Group
Stanford University
382 Via Pueblo Mall, Stanford, CA 94305

NESC Background

- NESC was established in July 2003 in response to the Columbia accident.
- NESC provides independent assessment of and solutions to technical issues for NASA programs and projects.
- NESC highlights NASA's traditional safety philosophy:
  - ✓ **Strong In-Line Checks and Balances**
  - ✓ **Value-Added Independent Assessments**
  - ✓ **Healthy Tension Between Organizational Elements**





NESC is cultivating a safety culture focused on **engineering and technical excellence**, while fostering an **open environment** and attacking challenges with **unequalled tenacity**.

What Do We Do for NASA

Bring in independent, diverse team of technical experts from NASA Centers, industry, academia, and other government agencies to perform:

Assessments include independent testing, and analyses, the results of which are peer reviewed by the NESC Review Board and documented in comprehensive reports to the project or customer.

Range of Support activities include providing technical expertise for consulting on program/project issues, problem investigation and solution recommendation, supporting/leading design reviews, and other technical activities. Connect Center personnel across the Agency, industry, academia, and other government agencies.

The NESC typically funds assessments and support activities

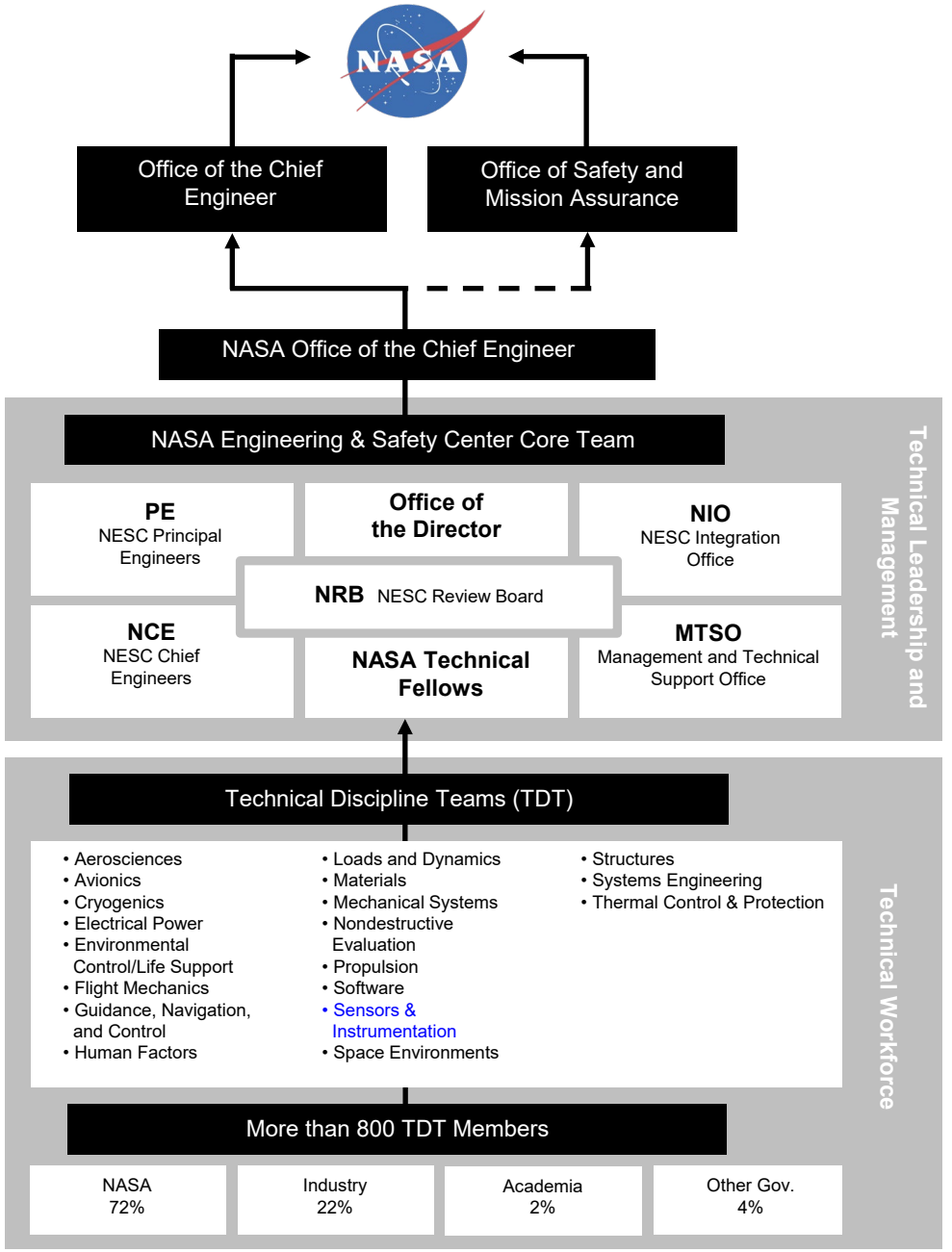
Photos: NESC Testing 2004-2021

NESC Leadership & Technical Fellows

- **Senior-level engineers and scientists with distinguished and sustained records of technical achievement**
  - Agency's leading technical experts
  - Build and maintain the health of the discipline
- **Lead NESC Technical Discipline Teams and provide expertise from NASA, other federal agencies, academia, and private industry**
  - Conduct workshops to enhance discipline awareness
  - Sponsor/support Agency-level standards and specifications
  - Ensure lessons learned are identified and incorporated in processes
- **Discipline Capability Leadership**
  - Conduct discipline specific gap analyses to identify areas for strategic investment
  - Lead in-depth investigation of the state of the discipline and provide recommendations to senior NASA management on investment, divestment, and consolidation
  - Provide input to Agency level strategic planning and roadmap activities

NESC Organization & Resources

- NESC has 69 full-time employees selected from across the Agency as well as from outside the Agency.
- NESC Chief Engineers at each Center provide technical insight and liaison roles.
- 20 NASA Technical Fellows are recognized experts in their respective fields.
- 20 Technical Discipline Teams create a network of **more than 800 engineers available for matrix support**.
- More than 225 TDT members are intentionally drawn from industry, academia and other government agencies to prevent insularity.
- Participation on NESC teams provides value to home organizations.
  - Valuable problem-solving experience
  - Broad Agency-wide perspective
  - **Engage next generation of scientists and engineers**



Sensors & Instrumentation Discipline

- NASA's Sensors & Instrumentation (S&I) discipline area is one of twenty specializations within the NASA Engineering & Safety Center (NESC).
- The S&I TDT focuses on the evaluation and development of technologies for instrumentation and sensing, including remote observation capabilities.
- The S&I TDT team provides technical expertise to the Agency on the sensors and instrumentation crucial to the missions of the:
  - Science Mission Directorate (SMD)
  - Human Exploration and Operations Mission Directorate (HEOMD)
  - Aeronautics Mission Directorate (ARMD)

Sensors & Instrumentation TDT

Singh	**Upendra**	**LaRC - Team Lead**
Gaskin	**Jessica**	**MSFC - TDT Deputy**
NASA		
Biagi	Chris	KSC
Edwards	William (Chris)	LaRC
Haw	Magnus	ARC
Humphreys	William (Tony)	LaRC
Hunter	Gary	GRC
Li	Jing	ARC
Conaty	Carmel	GSFC
Santos	Jose	ARC
Refaat	Tamer	LaRC
Stahl	H (Phil)	MSFC
Tonn	Synthia	GSFC
Wells	Nathan	JSC
Wollack	Edward	GSFC
Yu	Anthony	GSFC
Ericsson	Aprille	GSFC
Reynolds	Renee	GSFC
Gunapala	Sarath	JPL
Industry/FFRDC Support		
Fan	Tso Yee (T.Y.)	MIT Lincoln Laboratory
Youngquist	Robert	Q Physics, inc.
Rupavatharam	Krishna	Montana State University
Nosho	Brett	Aerospace

Sensors & Instruments Scope and Decomposition

Remote Sensing Instruments and Sensors Elements

Sub-area	
Detectors and Focal Planes	
Electronics	
Optical Components	
Microwave, Millimeter, and Submillimeter Waves	
Lasers	
Cryogenic/Thermal	

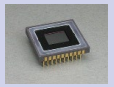
These instruments and sensors can be either active or passive devices in practice, depending upon the measurement regime and detection technology.

Observatory Technologies Elements

Sub-area	
Mirror Systems	
Structures and Antennas	
Distributed Aperture	

Observatory technologies enable or enhance large aperture monolithic and segmented single apertures as well as structurally connected or free-flying sparse and interferometric apertures.

In-situ Instruments and Sensors Elements

Sub-area	
Field and Particle Detectors	
Atomic and Molecular Species Assessment	
Sample Handling	
Biological and Environmental Sensors	
Electromagnetic wave-Based Sensors	
Extreme Environments Critical System Health Management	

Perform in-situ characterization of Earth and planetary atmospheres and the space environment, as well as vehicle and habitat monitoring.

Discipline Strengths

SMD Support

- **Instruments and observatories across the EM and particle spectra, including**
  - Gravitational waves, space weather, astrobiology/life detection, and quantum techniques for normal and harsh space environments,
  - Systems engineering and project management, technology and concept development, subject matter expertise for insight and oversight in cryogenics, lasers, telescopes, optics, detectors, coatings, electronics
  - Imaging, and spectral sensors & instruments for ground-based, aircraft, sub-orbital, and space-based platforms, e.g., passive microwave, Radar, Lidar, IR, UVOIR, X-ray, Gamma Ray, atmospheric electric field, current, and conductivity measurement
  - Sensors related to Biological and physical sciences

ARMD

- **Measurement of aerodynamic flow fields (off-body and surface), including**
  - Measuring aero-structural interactions
  - Nondestructive evaluation of materials structures, and material state
  - Vehicle structural and propulsion health monitoring; aircraft flight & ground testing
  - Wind tunnel instrumentation
  - Battery health monitoring
  - Instrumentation for next-generation vehicle technologies

HEOMD Support

- **Design, implementation and operation of ground and flight instrumentation, including**
  - EDL and GN&C sensors and instruments: active optical systems for landing and hazard avoidance; T, P, friction, stress sensors
  - Structures and systems health management; propulsion and power system monitoring
  - Human health life support; bioscience instruments & payloads
  - Neutron and charged particle instruments
  - Safety and prospecting sensors and instruments; regolith interrogation instrumentation
  - Laser optical systems and components for laser comm

Cross-Cutting Technology Development

- **Development and miniaturization of sensors, sensor fusion, embedded sensors, comms-enabled sensors, imaging systems and optical communication sensors and systems including**
  - Electronic and optical instruments for UAS, smallsats, & landers
  - Additive manufacturing systems
  - Orbital debris tracking sensors
  - Vehicle systems and fuels safety state-of-health sensors for launch operations
  - Measurement of electromagnetic environmental effects on avionics
  - Harsh environment technologies for ocean worlds
  - Plume impingement dust monitoring instrumentation

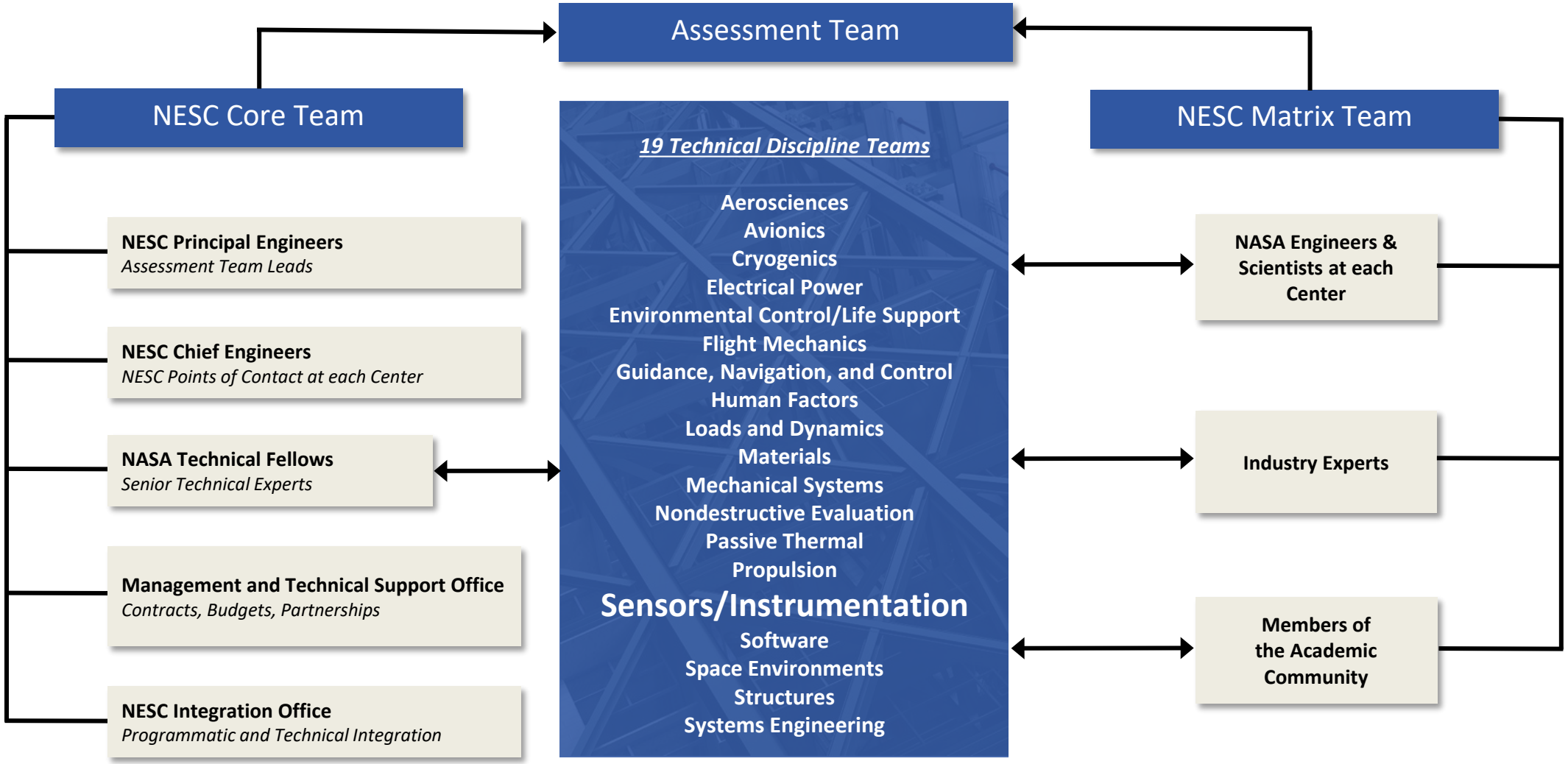
General S&I TDT Activities

- Act as an independent technical resource for the discipline in support of NASA projects/programs
- Develop approaches to identify, solve and prevent sensors and instrumentation related problems
- Develop strategies, plans, and priorities for maintaining and advancing the discipline.
- Develop and assimilate lessons learned, best practices, and/or knowledge capture products for NESC Academy.
- Participate as sensors and instrumentation experts in multi-discipline independent investigations and other activities:
  - Conduct assessments (formal investigations with documented final reports)
  - Provide technical support (informal program support without final report)
  - Identify experts for staffing NESC assessment and technical support teams, reviews or reviewers
  - Participate in Community of Practice activities (may include organizing workshops)

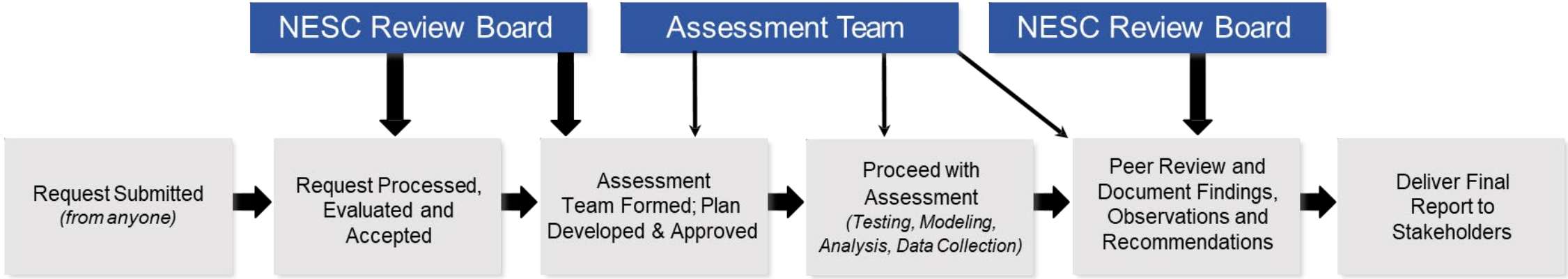
While an out brief is provided to the NRB, any products generated by the NESC in support of a Project are delivered to the Project!

It is up to the Project to disseminate the products outside of the Project as they deem fit.

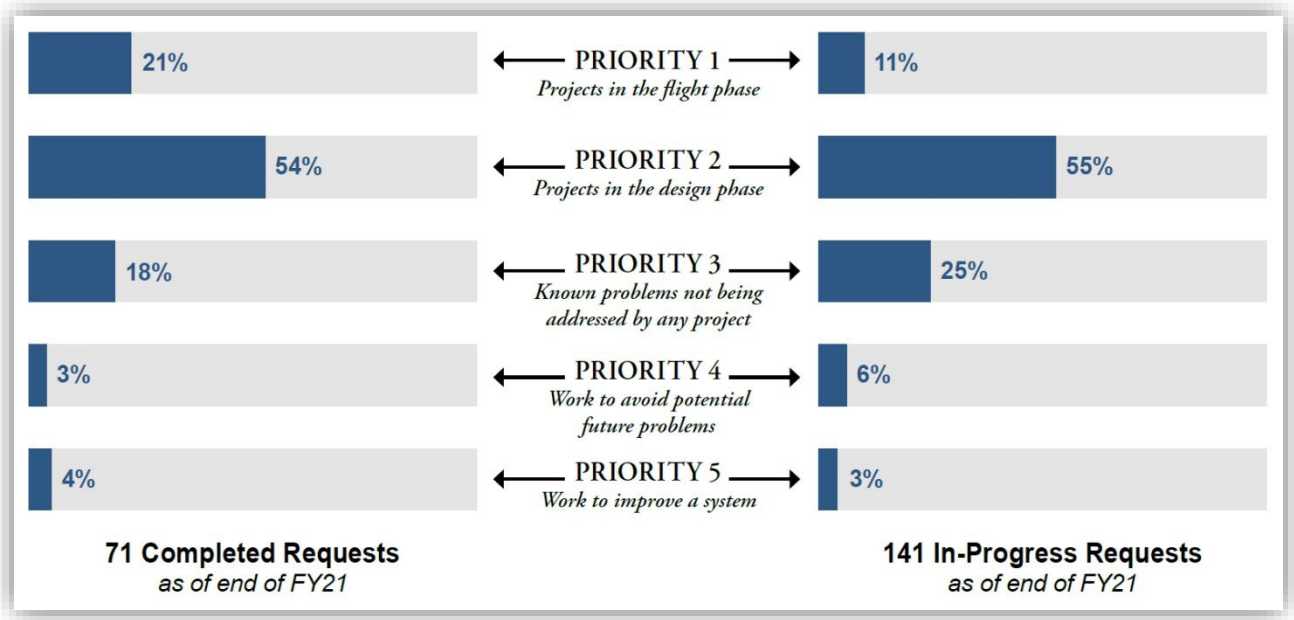
The NESC Assessment Team



Performing NESC Assessments



NESC requests evaluated on risk to the Agency and NESC task priorities:



Institutionalized “Tiger Team” approach to solving problems!

S&I Assessments and Support Activities

EXAMPLES

- Agency level Independent Technical Assessment: Assessment of NASA and External Quantum Sensing Capability. The outcomes will help the agency in establishing appropriate strategies and investments to develop and maintain the state-of-the-art sensing competence and capabilities required to meet the agency's future needs – Agency Level - NESC
- Agency level Strategy and Discipline Enhancing: Agency Program Management Council assigned task to assess the state of active optical technology capability and to provide agency-level strategy and solutions to advance high-risk active optical technologies to meet future NASA SMD and HEOMD mission critical needs – Agency Program Mission Council, NASA HQ
- NESC Assessment: "Technology Readiness Assessment (TRA) of the candidate lidar instruments for ACCP" for Earth Science, Science Mission Directorate
- NESC Assessment: "Independent Reliability Assessment of the NASA GSFC Laser Transmitter for the LISA Program" – for Astrophysics, Science Mission Directorate
- NESC Assessment: "Thermocouple Interference during High-Speed Entry Assessment" - Investigation of the correlation between the anomalies observed in thermocouple temperature measurement and roll angles maneuvers for the orbiter and EFT-1 during landing
- NESC Assessment: "Instrument Ultraviolet (UV) Coating Review to solve the coating problem associated with JPL Mars 2020 Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals (SHERLOC) mission
- Problem Solving: "Super-pressure Balloon Engineering Mishap Assessment" at WFF to understand the issues associated with the failure of the super-pressure balloon envelopes over several flights

Sensors & Instrumentation Communities of Practice

- In-situ and Proximity Sensors
  - Interact with ARMD, HEOMD, SMD, and STMD
  - Covers both engineering sensors and science sensors
- Quantum Sensors
  - New CoP in formulation
  - Working closely with HQ SMD in defining the Agency approach to QS to support SMD and other areas
- IR Sensors
  - New CoP in formulation
  - Primary focus is to support instrumentation for the SMD
- Cross-Discipline CoP with Avionics
  - Working with the Tech Fellow for Avionics to establish a cross-disciplinary team to leverage the overlap between science sensors and avionics sensors

Independent Technical Assessment of NASA and External Quantum Sensing Capability

Background:

- Quantum information and Technology have become of national importance
- Grassroot efforts in NASA centers have been growing
- An agency-wide study is prudent and requested by NESC Sensors and Instrumentation Quantum Sensing Community of Practice (QS CoP)
- Assessment is being sponsored, funded and managed by NASA Engineering and Safety Center (NESC)
- Assessment period is Oct -2021 – Sept 2023

Objectives:

- Understand NASA's internal needs, activities and competences of Quantum Sensing (QS) capability for future missions
- Survey external capabilities for NASA to collaborate with and/or leverage
- Identify gaps and priorities in both short-term and long-term development and infusion within the agency

Organization:

- Independent and non-commercial technical assessment
- **The external assessment panel consists members from academia, national labs and other government agencies**
- Assessment task led by the CoP lead and supported by NASA QS CoP
- **HQ TIGER team forms core NASA stakeholder and PoC at HQ**
- Interactions between Panel and NASA HQ and Centers will be coordinated jointly by the NESC and Assessment Task lead

Approach:

- Assessment panel collects data, perform analysis and synthesizes report
- Send survey questionnaire to NASA Centers via Center Chief Technologist Offices
- Seeks information and feedbacks from NASA HQ via QS TIGER team
- Organizes a Technical Interchange Meeting with NASA and external QS community for broad exchanges and discussions for assessment
- Logistic support being provided by NESC staff
- A final report and presentation by the external panel to NESC, NASA Centers and NASA HQ stakeholders

What Do We Do for Centers

- Problem Investigation and Solution Recommendation
- Bring in external experts from other Centers, industry, and academia to study a problem and recommend a solution
- Usually, the NESC pays for this and not the project
- Technology Assessment
- Bring in external experts from other Centers, industry, and academia on an NDA basis to peer review a new approach determine if it is ready for use
- This may be valuable for helping a new researcher build out a program
- Communities of Practice
- Help Center personnel obtain peer connections across the Agency, industry, academia, and OGAs

Quantum Sensing Capability Panel & Support

Name	Organization	Role	Expertise and notes
Core Team			
Dr. Upendra Singh	**NESC LaRC**	NESC Lead	NASA Technical Fellow for Sensors and Instrumentation
Dr. Nan Yu	**JPL**	QSCA Task Lead	Group Lead, CoP lead, Quantum clocks and sensors
Prof Prem Kumar	**Northwestern Univ**	**Panel Co-chair**	Prof., Quantum and optical communications and sensors
Dr. John Kitching	**NIST**	**Panel Co-chair**	Group lead, Chip-scale clocks and sensors
Prof Ronald Walsworth	**Univ. of Maryland**	Panel Member	Prof., Clocks, magnetometers, precision measurements
Prof Saikat Guha	**Univ. of Arizona**	Panel Member	Prof. Quantum communication, imaging, and measurements
Dr. Andrew 'AJ' Metcalf	**US Space Force**	Panel Member	Program lead, Photonics and clocks
Dr. Dana Berkeland	**US Government**	Panel Member, ex officio	Atomic devices, clocks, intel community
Dr. Danielle Braje	**MIT Lincoln Lab**	Panel Member, ex officio	Group lead, Quantum sensors, clocks, and integrated photonics
Dr. John Burke	**DARPA**	Panel Member, ex officio	Former AFRL, Clocks and Sensors, navigation devices
Consultants			
Cornelius (Neil) Dennehy	NESC Technical Fellow Office	NASA Technical Fellow Representative and Liaison	
Dr. Azita Valinia	NESC	NESC Chief Scientist	
Business Management			
Theresa Bardusch	LaRC/MTSO	Program/Financial Analyst	
Assessment Support			
Betty Trebaol	LaRC/AMA	Project Coordinator	
Linda Burgess	LaRC/AMA	Planning and Control Analyst	
Guy Kimmberly	LaRC/AMA	Technical Writer	
Leanna S. Bullock	LaRC/AMA	Technical Editor	

Quantum Sensing Capability Tiger Team

1. Dr. Mario Perez, Science Mission Directorate, NASA HQ
2. Dr. Bradley Carpenter, Science Mission Directorate, NASA HQ
3. Mr. Mark McDonald, Chief Architect, NASA Headquarters, Space Technology Mission Directorate, NASA HQ
4. Dr. Jason Mitchell, Capability lead, Space Communication and Navigation (SCaN), NASA HQ
5. Dr. Christopher Moore, Exploration Capability Program Manager, Human Exploration and Operation Mission Directorate, NASA HQ
6. Dr. Louis M Barbier, NASA Office of Chief Scientist, NASA HQ
7. Dr. Erica Rodgers, Science and Technology Partnerships Lead, NASA Office of Chief Technologist, NASA HQ
8. Mr. John Dankanich, Chair, Chief Technology Council, NASA HQ
9. Dr. Nan Yu, Lead, NESC Sensors and Instrumentation Quantum Sensing Community of Practice (QS CoP)
10. Mr. Cornelius (Neil) Dennehy, NESC Technical Fellow GN&C
11. Dr. Azita Valinia, NESC Chief Scientist
12. Dr. Upendra Singh, NESC Sensors and Instrumentation Technical Fellow

Active Optical Assessment and Recommendation on NASA Technology Development, Maturation, and Infusion into Future Missions – APMC

Requested Scope

Agency Program Management Council – Formal Action Item: 09-13-2017 Action #7:

Charter an Active Optical (Laser/Lidar) tiger team, which includes representation from SMD, STMD and HEOMD to address an increased emphasis on Active Optical technology which is critical for future NASA Earth, Planetary Science and Mars Exploration. Team to provide agency-level strategy and solutions for advancing high-risk Laser/Lidar technologies that are not currently being sufficiently planned or developed or risk reduced to meet NASA missions requirements.

Assigned to: Sensors/Instruments Capability Lead/Upendra Singh, NASA Tech Fellow S&I

September 2017 (Start); September 2019 (completion)

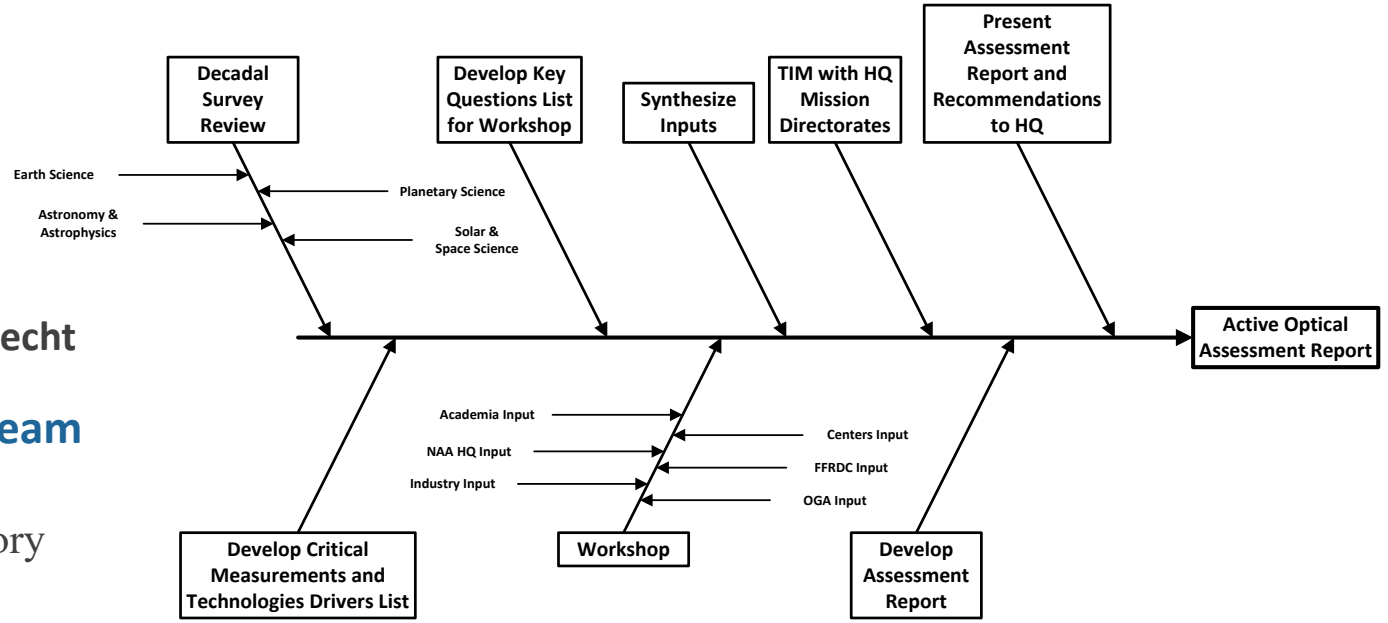
NASA/CP-2019-220422 - Proceedings of the NASA Technical Interchange Meeting on Active Optical Systems for Supporting Science, Exploration, and Aeronautics Measurements Needs

Assessment Approach

- Active Optical is a multi-directorate teaming of SMD, HEOMD, ARMD and Space Technology Mission representatives to provide the guidance and list of priority measurements requirements to meet their critical future needs.
- Created an Active Optical Tiger team consisting of MD's representatives, CLT/TDT leads/co-leads and an external assessment team to work together to seek community inputs to formulate an integrated Agency level strategy.
- Engaged with US Government entities, industry, and academia, to leverage common Active Optical interests and complementary skills/expertise resident in those sectors.
- Developed a cross-cutting strategy based on "Lead, Leverage and Collaborate" approach with NASA and external entities, national and international, to meet NASA Science, Aeronautics, and Exploration needs.
- Developed an integrated technology development and investment plan to address each directorate requirements in a cross-cutting, synergistic and cost-effective manner, to meet the Agency-level, priority Active Optical space-based measurements/missions.

Active Optical Tiger Team

- **S&I Tech Fellow Team** –
  - **Upendra Singh**, S&I Tech Fellow,
  - **Steve Horan**, Deputy, TDT and
  - **Terence Doiron**, Deputy, CLT
- **Active Optical Advisory Tiger Team**
  - SMD: **Michael Seablom**
  - STMD: **Prasun Desai**
  - HEOMD: **Jason Crusan, Christopher Moore, Phil Liebrecht**
- **Active Optical Assessment and Recommendation Team (S&I TDT Members)**
  - **Dr. Robert T. Menzies**, Retired Jet Propulsion Laboratory (JPL), Chair
  - **Dr. T. Y. Fan**, Massachusetts Institute of Technology (MIT) Lincoln Lab
  - **Dr. Michael Hardesty**, Boulder Lidar Associates
  - **Dr. David Tratt**, Aerospace Corporation
  - **Dr. Dennis Killinger**, SenOptics LLC



Technology Readiness Assessment of the candidate LIDAR instruments for Aerosols and Clouds-Convection-Precipitation (ACCP) – Earth Science

Requested Scope

- The ACCP Systems Engineering Team requested NESC and the S&I TDT to assist with the performing a Technology Readiness Assessment of 9 candidate LIDAR instruments. During the study, the original 9 were down-selected to 3 viable candidates for the study.

Assessment Plan

- The NESC provided at team of SMEs to serve on the ACCP Lidar TRA Panel.
- Over the course of approximately one year, the panel reviewed information supplied by the 3 instrument candidates. This information included:
  - self-assessed technology readiness reports
  - instrument narratives
  - instrument heritage claims
  - instrument functional block diagrams
  - electrical and optical circuit schematics
  - technology maturation plans
- To accomplish their charter, the Panel met directly (mostly remotely) with the instrument candidate teams in technical interchange meetings.

LIDAR Technical Readiness Assessment Team

Name	Organization
Upendra Singh	NESC Lead
Bill Luck	LaRC, Engineering Directorate Chief Engineer
Mark Stephen	GSFC, Code 5500
Robert Menzies	JPL retired
Dave Tratt	Aerospace Corp.
Keith Murray	LaRC, ESTO
Dave Rosenbaum	LaRC, D211
James Barrie	Aerospace Corp
John Cavanaugh	GSFC
Luis Ramos-Izquierdo	GSFC, Code 5500
Ed Eloranta	University of Wisconsin-Madison
Joe Gasbarre (TRA coordination)	LaRC/ACCP SET
Justin Yoshida (TRA coordination)	Aerospace Corp/ACCP SET
Alan Little (TRA coordination)	LaRC/ACCP SET

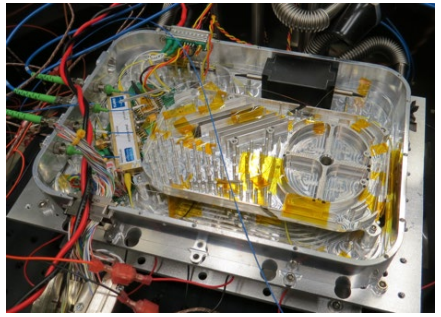
Independent Reliability Assessment of the NASA GSFC Laser Transmitter for the LISA Program - Astrophysics

Assessment Scope

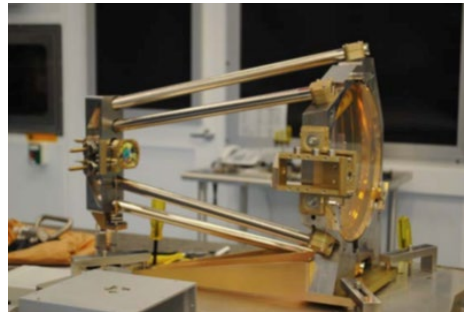
- GSFC requests that the NESC assess the TRL 6 design of the Laser System for the LISA.
- This reliability assessment will, at a minimum, produce an evaluation of:
  - LISA Laser Transmitter reliability
  - Physics-of-failure analysis
  - Identification of failure modes
  - Screening opportunities for laser components
- The effort shall include the following tasks:
  - Assess the design for weaknesses and suggest improvements to mitigate risks
  - Assess the laser reliability plan for weaknesses and suggest improvements to mitigate risks and improve effectiveness
  - Assess the current redundancy plan on laser subsystems for weaknesses and suggest improvements to mitigate risks and improve effectiveness.

LISA Laser Study Assessment Team

Name	Discipline	Organization
Core Team		
Upendra Singh	NESC Lead	LaRC
Stephen Horan	S&I Deputy	LaRC
Neal Spellmeyer	Laser/Fiber Comp./Fiber Amp	MIT-Lincoln Laboratory
Erik Zucker	Laser Diodes	Erik Zucker Consulting
Malcolm Wright	Power Amplifiers (PAs)	JPL
Mulugeta Petros	Laser Electronics	LaRC
Charles Antill	Laser Electronics	LaRC
Matthew Joplin	Radiation Effects	GSFC
Joseph Minow	Radiation Effects	MSFC
Azita Valinia	Astrophysics	GSFC
Business Management		
Theresa Barduch	Program Analyst	LaRC/MTSO
Assessment Support		
Betty Trebaol	Project Coordinator	LaRC/AMA
Linda Burgess	Planning and Control Analyst	LaRC/AMA
Leanna S. Bullock	Technical Editor	LaRC/AMA



Laser



Telescope

Summary & Final Thoughts

A primary Goal of the S&I TDT is to increase support for across all NASA directorates

Emphasis is on:

- Solving problems related to science-based instrumentation and telescope systems
- Independent technical assessment and review
- Technical roadmap development support

NESC Provides:

Independence & Objectivity - performs technical assessments and provides recommendations based on independent testing and analysis. An independent reporting path and funding from the OCE help ensure objective technical results.

Engineering Excellence - draws on the knowledge base of technical experts from across NASA, industry, academia, and other government agencies. Collaborating with leading engineers allows the NESC to optimize processes, strengthen technical capabilities, and broaden perspectives.

A Unique Resource - The NESC is an Agency-wide resource that provides a forum for reporting technical issues and contributing alternative viewpoints to resolve NASA's highest-risk challenges. Multidisciplinary teams of ready experts provide distinctively unbiased technical assessments to enable informed decisions.

Questions?

Upendra N. Singh, Tech Fellow for S&I

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Jessica A. Gaskin, Deputy Tech Fellow for S&I

jessica.gaskin@nasa.gov