

LADAR Optical Innovative Technology Research (LOITeR)

Task Order 1

Statement of Objectives (SOO)

29 March 2019

1.0 Objective

The objective of the Laser Detection And Ranging (LADAR) Optical Innovative Technology Research (LOITeR) Task Order 0001 is to continue electro-optical research and development (R&D) focused on maturation of the Identification at Range Integrated Sensor (IRIS), Sensor for Image Recognition and Exploitation (SIREN), and 3 Dimension Target Operations (3DTO) systems toward completing successful flight test, developing successful Aided Target Recognition (AiTR) computer software and systems, and providing the foundations of a Multi-Mode LADAR (M2L) system for demonstration to the Combat Air Force. Further, this task order will continue research in foundational technologies necessary to underpin systems being developed under the IRIS, SIREN, 3DTO, M2L, and other LADAR technologies enhancing combat identification and high resolution wide area three-dimensional imaging (WATI).

2.0 SCOPE

The scope of this task order is intended to include the widest breadth of potential research, (6.1, Basic, 6.2 Applied, 6.3, Advanced Technology Development) advancing the state of the art in active electro-optical sensing, either alone or in conjunction with other sensing technologies. This task order seeks to continue research in the five primary technology areas, but may evolve to include others. Those five areas are:

- 2.1 Synthetic Aperture Laser Radar (LADAR)
- 2.2 Vibration Sensing
- 2.3 Direct Detection 3 Dimensional (3D) LADAR
- 2.4 Multiple modalities in a single LADAR sensor
- 2.5 Active Advanced Concept Exploration

Research in these areas will mainly focus on underpinning technology reinforcing maturation of these systems toward successful flight test or flight demonstration. Other research efforts, for example 3D holographic imaging, non-mechanical beam steering, and Active Advanced Concept Exploration, to name a few, will also be conducted. Research objectives under this task order may be accomplished through methods including without limitation: component fabrication and analysis, system integration, modeling and simulation (M&S), signal analysis, software development, laboratory experimentation, target fabrication, field and flight testing, and data analysis. As new technologies, concepts, and/or synergies with passive EO/IR or active and passive RF present themselves, these opportunities will be evaluated and potentially pursued.

3.0 Background

The Air Force Research Laboratory (AFRL) LADAR Technology Branch (AFRL/Rymm) conducts wide breadth research to enhance Air Force and DOD capabilities for targeting and identification by advancing sensor technology throughout the visible to IR regions of the electromagnetic spectrum. Our mission is focused on research and development of active systems technology addressing enduring Air Force applications for which EO/IR sensor technology provides unique mission capabilities. Research is mission oriented, but includes efforts associated with exploratory research including: multidimensional, multifunctional technologies for active sensing; EO component and material technologies; EO phenomenologies; optical aperture technologies; modeling, simulation, and signal processing techniques; and algorithm development. Current research is focused on maturing synthetic and holographic aperture LADAR, LADAR vibrometry, direct detection 3D LADAR, multiple modalities in a single LADAR sensor, and continuing to discover and conduct basic development of advanced LADAR concepts.

Synthetic Aperture LADAR (SAL) research addresses high confidence target identification (ID) at standoff ranges for both reconnaissance and targeting platforms. SAL offers enhanced spatial resolution beyond the diffraction limit of conventional optics through coherent collection and processing of laser-illuminated scenes. To date, the SAL research area has begun demonstrating SAL at ranges of interest to ACC with SWAP traceable to a large POD. Flight testing is being performed on the first bench level SAL system under contract to The Raytheon Company. Work is also ongoing to demonstrate holographic aperture synthesis and is currently performing testbed research.

LADAR Vibrometry is maturing airborne vibration and micro-doppler measurement systems using laser radar. The objective is to provide a non-imaging modality for combat identification of ground targets at tactical ranges. Research has focused on phenomenology, signature collection, sensor product visualization, and pilot-aiding target recognition algorithms. Currently the vibrometry program has demonstrated an airborne vibrometer, gathered data and is preparing demonstrate the system in a line-of-the-Air Force jet. Research is also on-going into automatic and aided target recognition algorithms for in-cockpit pilot cueing.

The objective of 3D LADAR research area is the application of 3D for enhanced combat identification. Ongoing research areas include the 3 dimension Target Operations (3DTO) program, Geiger mode, and linear array technology exploration. Currently the 3DTO program is performing field demonstrations of the 3D sensor and will begin flight demonstrations soon. Demonstrations will include both contractor (Northrop Grumman) test aircraft flight experiments and podded flights on a tactical military aircraft. The tactical fighter flights are likely to be in a LITENING pod on an F-16. Geiger mode and linear array technology exploration are being conducted at the laboratory level.

Multi-mode LADAR is developing sensors incorporating the three main LADAR detection modes: SAL, LADAR vibrometry, and direct detection 3D LADAR. SAL provides improved along-track and range resolution for ID of unobscured or concealed stationary targets at long standoffs. Vibrometry provides ID of unresolved vibrating targets, even when obscured. And the direct detection mode enables day/night ID at longer ranges vs 2D images, as well as high area coverage rates to quickly prosecute target queues. Multi-mode LADAR sensor will be able to synergistically switch between all three modes with minimal SWaP-C and performance impacts vs single mode sensors. The overall goal of the multi-mode LADAR project is to build and

demonstrate a sensor capable of high speed switching between modes using a single detector array and agile laser transmitter.

Active Advanced Concept Exploration (AACE) has provided much foundational research for RYMM through the years. Most recently digital holographic imaging techniques were explored and led to the Synthetic Holographic Apertures with Diverse Optical Wavelengths (SHADOW) In-house program, which was further leveraged into the DARPA Fine Detail Optical Sensor and Military Imaging Sensor Technology programs. Additionally, imaging cameras were developed and used to construct an imaging multi-static bi-directional reflectivity distribution function sensor, which is helping benchmark LADAR tests and support phenomenology investigations. Finally, today's 3D imaging programs were leveraged by early AACE 3D in-house research.

4.0 TASKS/TECHNICAL REQUIREMENTS:

4.1 Computational Research for Advanced Optical Systems (CRAOS)

4.1.1 Modeling, Simulation, Processing, and Exploitation

4.1.1.1 Using computer science based computer software design principles, enhance computational research tools and products for the LADAR mission area focusing on optical waveform concepts, electro-optical focal plane array technology, low SWaP-C technologies, automatic and aided target recognition, and EO/IR LADAR Systems and Components accomplished through modeling and simulation, algorithms, signal processing, and program/project computational research. Modeling and simulation efforts focus on physics based and performance based techniques incorporating component level, system level, and mission application capabilities. Develop advanced tools, processes, and procedures for verification and validation as applied to modeling, simulation, and algorithm development.

4.1.1.2 Research and apply computer science based computer software design principles building upon requirements driven and test driven development principles leading to a computer software architecture utilizing modular and reusable concepts for LADAR research software libraries.

4.1.1.3 Research and apply best practices in database systems and design to deliver a database architecture for multiple sensing modes and sensor data formats supporting enhancing modeling and simulation efforts, supporting algorithm development, and archiving critical LADAR research.

4.1.2 Research Computer Infrastructure

4.1.2.1 Develop and enhance the computational infrastructure enabling LADAR research. The areas to be developed and enhanced include, but are not limited to: model and simulation execution; signal processing efficiency, fidelity, and speed; algorithm development efficiency, fidelity, and speed; archival of experiment and test data and their associated meta-data; processing software selection and maintenance; and user/program data storage architecture(s). Research and apply current best practices and emerging capabilities associated with compute capabilities, networks, software services, and hardware and software resources.

4.2 Active Advanced Concept Exploration (AACE)

4.2.1 Research and mature new and unique techniques necessary to increase the performance and range of LADAR systems. Performance and range increases include: the ability to maintain situational awareness

during combat operations of various sensors having sufficient range, sensitivity, and robustness to jamming to enable formation of the required air order of battle; supporting accurate target tracking and identification capabilities in support of ground and air operations; and the providing multiple modalities in a single LADAR sensor.

4.2.2 Develop and apply new waveforms and processing methods enabling performance improvements in LADAR operations.

4.2.3 AFRL/Rymm seeks the ability to maintain facility and Test, Measurement, and Diagnostic Equipment capability in the face of rapidly changing hardware and computer software technology. Improvements and upgrades to atmospheric metrology characteristic equipment and target characteristic measurement sensors is ongoing and necessary.

4.3 Identification at Range Integrated Sensor (IRIS) (in-house research components)

4.3.1 Enhance and validate existing modeling and simulation capabilities to assess the operational envelope of the various SAL systems. Use simulation efforts that consider platform/target motions, detrimental noise (amplitude and phase) from sources and detectors, and distributed atmospheric effects across the real aperture as well as the synthetic aperture.

4.3.2 Experiment in the laboratory and field to accomplish SAL system design validation, component analysis, and validation and verification of modelling and simulation efforts.

4.3.3 Develop, refine, and apply image formation and analysis algorithms for real and simulated SAL data products including wide-band phase history data and associated narrow-band data.

4.3.4 Enhance database capabilities to access and archive large, diverse data sets from both simulations and live data collections.

4.3.5 AFRL/Rymm seeks innovative new designs in seed lasers, amplifiers, and isolators suitable for deployment with operational SAL systems.

4.3.6 Create revolutionary characterization and measurement techniques suitable for determining atmospheric impacts on coherent sensing modalities during field and flight tests. Characterization efforts should consider impacts to the system under test as well as size, weight, and power (SWaP) requirements for any platform-based instrumentation.

4.3.7 Create revolutionary waveforms capable of enhancing SAL system capabilities allowing operation of other sensing modalities without significantly increasing system SWaP requirements.

4.4 3D Targeting Operations (3DTO) (in-house research components)

4.4.1 Enhance target tracking, detection, classification, and identification through acquisition and exploitation of 3D sensing and preparation of this technology for field and flight demonstration.

4.4.2 Research and characterize emerging 3D coherent-detection and direct-detection LADAR sensing technologies. Though the objective is the best technologies, current research is focused on Geiger-Mode Avalanche Photodiode (GmAPD) focal plane arrays and Linear-Mode Avalanche Photodiode (LmAPD) focal plane arrays, as candidate 3D LADAR sensor systems for respective mission applications.

4.4.3 Research and characterize emerging technologies for data synthesis, fusion, and exploitation including multi-frame stitching, frame-to-frame stacking, image and point-cloud registration, micro-scanning, super-resolution, fusion with other sensor data (visible imagery, Forward Looking Infra-Red (FLIR), vibrometry, etc.) and other data reduction and enhancement methodologies enhancing the ability of target recognition and identification at extended ranges. RYMM seeks design, development, and integration of signal processing techniques, data exploitation algorithms, and modeling and simulation concepts.

4.4.4 Analysis, document, and catalog laboratory and experimental results to predict performance in multiple sensing platforms and environments (such as LITENING pod, AGILE pod, MTS-B turret, etc.).

4.5 Synthetic Holographic Apertures with Diverse Optical Wavelengths (SHADOW) (in-house research components)

4.5.1 Conduct agile-frequency, high frame-rate sensor research for 3D holographic imaging, including research into sensing and correcting distributed volume aberrations due to turbulence.

4.5.2 Research image sharpening algorithms for use with redundant-pupil-sampling, develop algorithms and optimizations, and high fidelity modeling and simulation of atmospheric turbulence and sensors. Image sharpening algorithms should leverage 2D range-resolved slices of 3D holographic data. Study high-speed target and speckle phenomenology and dynamics.

4.5.3 Create multi-plane aberration correction algorithms for the 3D holographic sensor and explore fundamental limitations of the various existing multi-plane algorithms, documenting performance as a function of isoplanatic patch size, coherence diameter, signal to noise ratio (SNR), target contrast, and target-coherence time. Using this data, determine the number of planes required for various atmospheric profiles, as well as the optimal locations for correcting deep-turbulence conditions.

4.5.4 Analyze and validate various approaches to high-fidelity-wave-optics simulations with simulated data products generated for varying system and atmospheric parameters, resulting in multi-plane algorithms capable of calculating 3 plane or more multi-conjugate digital image correction.

4.5.5 Conduct hardware and system design trade studies for 3D holographic sensor systems to include critical components like high frame rate cameras and optical single sideband modulators for agile frequency waveform generation, leading to demonstration hardware assembly and testing.

4.6 Anti-Access Detection and Discrimination (A2D2) (in-house research components)

4.6.1 Research Geiger mode LADAR technology to detect and identify critical mobile targets (CMTs). Research enhanced technology for UAVs with a focus on small UAVs, other unique or innovative aerial platforms, "attributable" sensor assets, and tactical off-board sensing (TOBS).

4.6.2 Develop algorithms and code to process Geiger mode LADAR data for direct detection LADAR applications including combat identification and tracking. Algorithms and code should address processing Geiger mode LADAR data toward localized mapping and near real-time processing aspects to enhance combat identification, targeting and tracking. Obscurants and foliage penetration will be a consideration.

4.6.3 Create scientific models of LADAR system components, LADAR systems, performance models, and simulations of sensor implementations, sufficient to show mission utility. Test and characterize these M&S to

validate, including performance of simulations and sensor hardware to demonstrate technology and capabilities toward mission applications.

4.6.4 Develop hardware for adaptive waveform direct-detection LADAR implementation allowing testing and characterization of 3-D imaging and multi-function modalities. Identify cooling, size, weight, and power (C-SWaP) design needs for current small UAV platforms and generation of C-SWaP design criteria for future designated platforms.

4.7 Multiple Modality LADAR (M2L) (in-house research components)

4.7.1 Create agile 2 micron lasers capable of short direct detect pulse chains and burst modes, high coherence seed development, and high power fiber amplifier research. Coherent capabilities of interest are narrow linewidth and frequency or phase modulation.

4.7.2 Research high speed photon counting receivers coupled with low noise Read-out Integrated Circuits (ROIC) with exquisite sensitivity detectors. Of interest are low cross-talk, MHz frame rates, and sub-nano-second range precision to accomplish rapid switching between amplitude and timing measurements.

4.7.3 Create M&S and signal processing algorithms leading to image formation based on holographic LADAR, linear mode direct detection, and vibration sensor point designs. Research, design, and develop new algorithms to assess sensor design, predict operational performance, and determine transmit/receive link budgets for various mission scenarios.

4.8 Advanced EO Phenomenology, Simulation & Experiments (APSE)

4.8.1 Research, characterize, and demonstrate active phenomenology, simulation, and experiments related to active sensing LADAR technology.

4.8.2 Research, characterize, and demonstrate instrumentation and test procedures to support verification and validation of LADAR systems through detailed characterization of LADAR components, atmospheric channels, and target phenomenology. Incorporate these results into M&S and validate them by experimentation, including correcting, updating, and upgrading current component, atmosphere, and target modeling parameters.

4.8.3 Update previously developed signal processing and data mining research for active LADAR sensing capabilities. Create new algorithms addressing critical weaknesses in previously generated material.

4.9 Non-Mechanical Beam Steering

4.9.1 Develop advanced beam control, including non-mechanical steering methods.

4.9.2 Investigate compatibility with LADAR, advanced modes of operation towards exploiting random access pointing for enhanced Combat ID, simultaneous multiple target engagement, targeting concurrently with Bomb Damage Assessment (BDA), off-boresight targeting, opportunistic mapping, and ISR.

5.0 OTHER OBJECTIVES

5.1 Aircraft Modification and Sensor Integration

Based on the offeror's approach to the above objectives, electro-mechanical interface to aircraft systems, test planning, set-up, and execution may be necessary for sensor demonstration, test, and integration. Comply with AFRLI 17-130, AFRLI 61-601, AFRLMAN 99-103.

5.2 Laboratory, Field and Flight Collections

5.2.1 General

Provide flexible approaches and solutions to execute collection of experimental measurements and field data including atmospheric metrology, outdoor imagery and associated ground, air, and image truth data using breadboard or off the shelf imaging systems. AFRL has a need to advance this area under various conditions and environments, therefore, testing on towers, mountains, and platform- and/or aircraft-mounted sensors may be used.

5.2.2 Test Equipment

Use and maintain all AFRL/Rymm laboratory components and equipment necessary for research under this task order. Use Rymm owned mobile laboratory equipment in accordance with paragraph 5.2.3, Field Test Equipment, in the basic IDIQ contract.

5.2.3 Flight Test(s)

Based on the offeror's approach to the above objectives, electro-mechanical interface to aircraft systems, test planning, set-up, and execution may be necessary for sensor demonstration, test, and integration. Comply with AFRLI 17-130, AFRLI 61-601, AFRLMAN 99-103.

5.3 Fabrication or Upgrade of Systems/Sub-Systems/Components/Test Jigs/Test Targets

Develop innovative and rapid test systems, sub-systems, optical and electronic bread and printed circuit boards, components, enclosures, test jigs, and test targets used during Sensors Directorate research, development, indoor or outdoor laboratory research, investigation, field, flight, or space test data collections. The contractor may have access to a government owned machine shop and electronics benches to accomplish this objective.

5.4 Research Equipment Upgrades

Provide inputs to the Government to assure its laboratory equipment, including both indoor laboratories and mobile laboratory equipment, are modernized and upgraded with the most state-of-the-art equipment available and affordable. Provide inputs to the Government in responds to changing technology, capability, and test demands to minimize the impact on laboratory components due to changing phenomenologies, techniques, and simulations activities. If the use of Rymm owned equipment or mobile laboratory equipment require upgraded equipment or configuration for testing, physically upgrade the equipment where needed and approved by the Government.

6.0 Base Support

Base Support/Network Access/Laboratory/Wright-Patterson AFB test range access is anticipated to be made available under this task order. If contractor determines use of available base support to be in their best interest, it must be included as such in the proposal.

6.1 Compliance

If the contractor is provided base access and support, comply with all Air Force and/or local installation regulations, policies, or applicable programs (including classified research facilities, mobile labs, targets and associated vehicles). Compliance shall include tracking location of equipment, tool control, supplies, and test measurement and diagnostic equipment (TMDE); documenting compliance, supporting paperwork, inventories and calibrations. Correct and report deviations from Government regulations through an appropriate chain-of-command.

7.0 Safety

Comply with all Air Force, Federal, state, and local safety and environmental regulations. Comply with system safety requirements contained in MIL-STD 882E, Section 4 "General Requirements" for any non-Commercial-off-the-Shelf (COTS) deliverable systems or hardware. Identify safety-critical components of those systems or hardware as well as computer software interfaces with those components. Test and verify the safety-critical hardware and computer software for safety acceptance.

Comply with the safety and accident prevention clauses, Air Force Consolidated Occupational Safety Instruction, AFI 91-203.

8.0 SECURITY:

Comply with the security requirements for the LIDR effort which is SECRET/NOFORN with a migration path to Top Secret SCI (note: minimum of 1 contractor staff required to have Top Secret SCI clearance). Ensure government information and computer security requirements are met for contractor staff, test facilities, equipment, data acquisition devices, and all data collected by test and research activities. The following security documents are applicable to this program:

- Electro-Optical Targeting Sensors Security Classification Guide, dated 20 Feb 15;
- DoD 5220.22M, National Industrial Security Operating Manual (NISPOM) dated Feb 06;
- Joint Special Access Program Implementation Guide (JSIG);
- DoDM 5205.07, Volumes 1-4;
- DoD M 5200.01, Volumes 1-4;
- Executive Order 13526

9.0 Operational Security (OPSEC) Procedures:

9.1 General Operations Security (OPSEC) procedures

General OPSEC procedures, policies and awareness are required in an effort to reduce program vulnerability from successful adversary collection and exploitation of critical information. OPSEC will be applied throughout the life cycle of the contract. The Critical Information List (CIL) will be provided upon request by

AFRL/ RYOY Information Protection Office. While working on the government installation, OPSEC guidance will be provided by AFRL/RYOY Information Protection Office.

9.2 Program Protection Plan (PPP)

The Contractor shall participate with the Government in the development of a PPP, to include the identification of Critical Program Information (CPI), and shall also participate with the Government in determining countermeasures needed to safeguard the CPI throughout the acquisition process. The Contractor shall plan for and execute program protection in accordance with the PPP and program guidance.

10.0 DELIVERABLES:

Deliver data in accordance with the CDRLs listed in the basic IDIQ contract SOO. Computer software deliverables are anticipated throughout the TO and will be considered during evaluation of this TO. Include computer software source code and appropriate source code documentation. Hardware deliverables are also anticipated throughout the TO and will be considered during the evaluation of this TO. CAP may be required.

11.0 Non-Data Deliverable (Outputs)

11.1 Hardware

Any hardware developed or purchased during the course of this effort shall be delivered to the Government.

11.2 Computer Software

All computer software databases, pseudo code, interpreter code, source, and associated libraries developed or purchased during the course of this effort shall be delivered to the Government.