STATEMENT OF OBJECTIVES (SOO)
"Multi-Spectral Sensing Technologies Research and Development (MuSTeR)"

RYM BAA Background information

The Multispectral Sensing & Detection Division (RYM), Sensors Directorate (RY), Air Force Research Laboratory (AFRL), conducts research in the following areas:

- **I.** Multiband Multifunction Radio Frequency Sensing (RYMF)
- **II.** Laser Radar Technology (RYMM)
- **III.** Passive Radio Frequency Sensing (RYMP)
- **IV.** Distributed Radio Frequency Sensing (RYMS)
- **V.** EO Target Detection & Surveillance (RYMT)

The goals of the 13 research topics are aligned with the strategic capabilities outlined in the Air Force S&T 2030 document: Global Persistent Awareness, Resilient Information Sharing, Complexity Unpredictability and Mass, and Speed and Reach of Disruption and Lethality. Solutions are required across the electromagnetic spectrum, with significant work in electro-optical/infrared (EO/IR) and radio frequency (RF) sensing.

The technologies outlined below are charged with enhancing the state-of-the-art (SOTA) sensor system research and development, utilizing the entire electromagnetic spectrum to deliver next generation capabilities in global persistent awareness to the Air Force.

I. RYMF – Multiband Multifunction Radio Frequency Sensing

1. **Multiband Multifunction Array Development:** The objective of this research is to advance antenna and electromagnetic technology and phenomenology studies for air, ground and space-based sensing applications including radar, communications, satellite operations, and intelligence, surveillance and reconnaissance systems (ISR) from HF to W-Band frequencies. In particular, the objective of this research is to advance the field of detection, tracking, and fusion of data and modeling and simulation of difficult targets in rapidly varying environments and contested electromagnetic spectrum utilizing broad and agile electromagnetic spectrum, advanced antenna and scattering theory as well as situational awareness methodologies and develop architectures and algorithms for ISR, navigation, communications.

This topic specifically addresses development of new concepts and improvements in the following areas:

a) SOTA of multiband and multifunction, low cost, lightweight, planar and conformal phased array antennas operating at various power densities
b) Antennas having the gain performance of conventional antennas in a significantly smaller physical space to reduce antenna size, weight, and co-site interference, for applications from HF through W-band and beyond

c) Electromagnetic research in radiating, wave guiding, wave transforming, and electromagnetically-responsive structures and materials, with emphasis on integration of antennas and radiating structures with aircraft
d) Advanced computational electromagnetic (CEM) methods including finite element, boundary integral, asymptotic, frequency domain, and time domain algorithms. Develop CEM frameworks including CAD and meshing, usability, and parallel algorithms
e) Space-Based/Cross-Domain RF Sensing Techniques
f) Novel Enabling RF Technology for Disaggregated Systems

2. **Fully Adaptive Radar:** The concept of fully adaptive radar (FAR) seeks to exploit all available degrees-of-freedom on transmit and receive in order to maximize target detection, tracking and classification performance in computationally demanding and training data starved scenarios.

This topic specifically addresses development of new concepts and improvements in the following areas:

(a) Physics and phenomenology-based adaptive signal processing methods for enhanced radar target detection and estimation, tracking and classification involving closed loop radar operation. The onerous challenges of harsh environments, difficult targets, and a rapidly shrinking electromagnetic spectrum necessitate a systematic treatment for developing closed-loop radar operation.

(b) Novel approaches for overcoming large number of degrees of freedom and the number of unknowns. Relevant performance metrics include the tracking error and computational cost.

(c) Exploitation techniques that facilitate co-existence of radar and communications in a given spectral band using a host of diversity mechanisms.

(d) Algorithmic approaches that exploit available diversity mechanisms to permit spectral sharing and enable synergy between radar and communication functions pertaining to both the signal level as well as protocol layers is particularly encouraged.

3. **Advanced Digital Multifunction Arrays:** The next generation of radio frequency sensors will be highly digital systems with a wide frequency band that can perform multiple, simultaneous tasks such as radar, electronic warfare, and communications. This research topic intends to develop sensors capable of performing digital beamforming while exploiting power, polarization, spatial, spectral, and temporal diversity to perform multiple, simultaneous tasks controlled through an intelligent sensor resource manager (ISRM). Intelligent resource management includes, but is not limited to, Passive Radar Illumination Selection Manager (PRISM), multi-mode resource allocation and scheduling coalescence. In addition, we seek to develop modes, such as ESM and MTI, which can be controlled through the ISRM. Models and hardware prototypes of such sensors will be developed to validate and verify performance.

II. RYMM – Laser Radar Technology

4. **Laser Radar Imaging, Systems, Components, and Applications:** This objective of this research is to develop innovative laser radar based approaches for ISR, precision attack and air-to-air engagements. This may include new techniques, phenomenologies, hardware and algorithms to detect, track and especially identify difficult air and ground targets in challenging environments. Included in this area are new ideas for fundamental measurement concepts, design and development of sensors, active FPAs with integrated ROICs as well as flight laser systems and components. Both direct detection and coherent ladar systems are of interest including but not limited to 1-D, 3D, synthetic aperture, holographic aperture and vibration imaging modes.

Specific system areas of interest include:

(a) Low cost, size, weight, and power (SWaP) approaches for all modes
(b) High performance 3-D/1-D arrays for long range sensing
(c) Coherent detector arrays
(d) Agile flight laser sources
(e) High power fiber distribution
(f) Advanced image formation algorithms
(g) Real-time ladar signal processing
(h) AiTR features and algorithms
(i) Data fusion methods for combined ladar/EO operations
(j) Methods for atmospheric turbulence metrology and mitigation over long air-to-air and air-to-ground path
(k) New concepts, implementations, phenomenology or algorithms in laser based sensing
(l) Direct-detect and coherent modeling and simulation aperture synthesis processing
(m) Vibe ATR for on/off and plant classification
(n) Synthetic data generation for ATR development

III. RYMP – Passive Radio Frequency Sensing

5. **Passive Radio Frequency Sensing**: This research investigates evolutionary and revolutionary improvements to passive RF sensing systems for situational awareness, tracking and targeting applications. Active (monostatic) radar is the traditional workhorse for long-range surveillance and all-weather targeting. Signals Intelligence (SIGINT) is central in understanding adversary capabilities, intentions and deployments by measuring their RF emissions. Modern Integrated Air Defense (IAD) systems are forcing blue sensing platforms farther back, leading to the current emphasis on developing strategies to operate in A2/AD environments. The agility of these advanced IADS is one factor driving SIGINT to be done on faster time scales, becoming ever closer to the tactical timescales required by Electronic Support Measures (ESM) receivers.

Areas of interest include, but are not limited to:

a) SIGINT systems
b) Passive radar systems to exploit any/all available RF sources to provide situational awareness through radar functionality without ownship transmission, automatically

configure RF receiver/processor to collect on targets and process into detections/tracks/images

c) Mature Illumination Selection Manager algorithms
Real-time selection of available illuminators based on required radar modes
d) Novel techniques for improved detection, geolocation and identification of fixed and mobile critical targets
e) Novel signal geolocation techniques for individual or multiple ground and airborne targets
f) Novel techniques for ground and airborne passive radar
g) Utilize flexible, upgradable, modeling simulation and assessment (MS&A) to develop future passive sensing capabilities
h) Ground based Passive Multi-mode RF Systems prototype with advanced digital AESA
i) Mitigation of terrain-target coupling effects on automated target recognition (ATR)
j) Rapid discrimination of targets of interest using high range resolution mode
k) Identification of moving ground targets
l) Real-time tasking/reduced PED timeline through increased edge processing

IV. RYMS – Distributed Radio Frequency Sensing

6. **Waveform Phenomenology, Design and Applications:** This topic addresses the development of innovative techniques concentrated on identifying and capitalizing on signal phenomenology that gives rise to new and difficult-to-detect RF waveform. Waveform agility is the foundation of this research which takes advantage of all possible degrees of freedom, and explores noise-like waveforms, interference-tolerant waveforms, and low probability of intercept, low probability of detection, and low-probability of exploitation (LPI/LPD/LPE) waveforms.

Specific areas of interest include:

a) Detection, tracking and imaging multi-mode, multi-function techniques supporting distributed processing
b) Joint radar/ communications waveforms
c) Combined synthetic aperture radar (SAR) and ground moving target indication (GMTI) in challenging clutter environments
d) Adaptive radar and game theoretic decision making for cognitive sensing and transmit pulse optimization
e) Waveform design for distributed sensor platform synchronization
f) Robust multi-static transmit waveforms and receive processing chains to enable multi-domain MTI and SAR
g) Multi-static MTI techniques and hardware implementations for low-SWaP airborne platforms
h) Multi-function waveforms enabling simultaneous radar and communications for HF systems

i) Single-pass multi-static 3D SAR to support combat ID (CID) and automatic target recognition (ATR)
j) Advance existing SOTA imaging methods – decrease runtime, add environmental robustness, fully automate
k) Multi-domain multi-static imaging approaches that provide operational covertness for assisting with target custody in denied environments
l) Evaluate waveforms & algorithms in a distributed/multi-static sensing with modeling, simulation and analysis (MS&A) capability

7. **Sensor Information Processing and Integration:** This topic addresses new approaches to the integration and understanding of massive amounts of data coming from diverse, distributed sensor platforms with the goal of developing actionable intelligence and achieving autonomous or semi-autonomous situation awareness. The fundamental difficulties include modeling and algorithm development for distributed active/passive sensing, computational complexity, massive amounts of disparate information, the need to integrate human and sensory input, cultural backgrounds, and the ability to identify and seek missing information.

Specific areas of interest include:

(a) Robust detection, tracking and imaging using multiple sensor platforms
(b) Cognitively-inspired methods for detection, data integration, and tracking
(c) Integration of human and sensory inputs
(d) Learning abstract concepts from sensor data
(e) Situation modeling and learning
(f) "Big data" methodologies
(g) Adaptive sensing techniques for improved radar detection and tracking
(h) Waveform design, optimization, and selection in contested/congested spectrum.
(i) Distributed active/passive sensing for congested and contested environments
(j) Cross-domain (e.g., ground, air, space), long-range radar and/or multi-spectral sensing

V. RYMT - EO Target Detection & Surveillance

8. **Passive Electro-optic and Infrared Sensor Technology:** The objective of this research is to promote novel sensors, sensor technologies and algorithms for target sensing in general, and in particular, target detection, recognition and tracking. This can be done by any EO/IR waveband, phenomenology permitting.

9. **Novel EO/IR Hardware and Algorithms:** This topic addresses the development of innovative hardware and algorithms to detect low-signal targets in noisy and heavily cluttered environments using EO/IR sensors. Of great importance is leveraging system benefits or information advantages yielded by multispectral/multiband approaches. Included in this area are new ideas for design and development of EO/IR sensors, focal plane arrays (FPA), hybrid

FPAs and infrared cameras for high-resolution, low-power, lightweight, low-cost, portable midwave and longwave infrared sensing.

Specific areas of interest include:

(a) High-temperature operation
(b) Multispectral-sensing
(c) Tunable wavelength devices
(d) Algorithms for target detection/identification/tracking and fusion (with other INTS) with an emphasis but not exclusivity to artificial intelligence and machine learning
(e) Detection performance modeling and mission level engagement modeling
(f) Passive EO/IR technology to support sensing and sense making
(g) Find/fix/track/target critical mobile targets
(h) Passive air-to-air surveillance technologies
(i) Technologies reducing cost and/or size/weight/power of optical components
(j) Model-based system engineering of passive EO/IR sensor systems and exploitation

10. **Hyperspectral Imaging Technology:** The objective of this research is to develop day/night hyperspectral technologies for enhanced material detection and identification with specific emphasis on challenges related to contested environments. Con-ops may include systems designed to operate at significant stand-off range, low cost and SWaP systems to operate on penetrating platforms, or similar technology to operate on cube-sats/small-sats. Interest includes supporting component technologies (e.g., focal planes, cryo-coolers, freeform optics, etc.) and data exploitation algorithms (e.g., atmospheric compensation, target detection, machine learning, etc.) as well.

Specific areas of interest include, but are not limited to:

(a) Low cost-SWaP midwave infrared (MWIR) and longwave infrared (LWIR) HSI systems
(b) Airborne active/passive HSI systems incorporating other sensor modalities
(c) Equipment/methods for full spectral characterization of material bi-directional reflectance distribution function (BRDF)
(d) Concepts, hardware, and software for hyperspectral cube-sats and small-sats
(e) Multi-sensor data fusion/processing (HSI + LIDAR/FMV/Hi-res imagery/3D/RF)
(f) Novel spectrometer concepts
(g) Low-cost focal plane array technology
(h) Machine learning algorithms for detection, identification, dimensionality reduction, false alarm mitigation, etc.
(i) Open architecture and open mission system technologies
(j) Detection performance modeling and mission level modeling

11. **Standoff High Resolution Imaging (SHRI):** The objective of this research is to advance the field of long range multi-band imaging for significantly extending range and improving performance of passive EO/IR ISR/strike systems in highly contested environments. The approach uses high performance components for EO/IR, including large-format high operating

temperature imaging/video arrays, reduced detector size, novel filter arrays and high speed, low noise sampling and readout. Extending SHRI performance to multi-band and multispectral systems is a primary focus. Advanced processing techniques and algorithms utilizing artificial intelligence/machine learning (AI/ML) are desired as well to achieve diffraction limited performance in support of improved single and multi-sensor exploitation. The focus application of SHRI technologies is to support new and improved sensors for both low-cost attritable and traditional ISR platforms.

12. **Infrared Search and Track Technology:** The objective of this research is to develop an advanced long range and wide field of view staring infrared search and track (IRST) system that provides state-of-the-art performance. Currently fielded IRST systems are based on longwave scanning sensors where typical performance is dictated by the scan dwell time and revisit rate. An improved staring system would allow operation at video rates, giving faster track initiation.

This research area potentially leverages the latest technology of large infrared FPAs with High Operating Temperature (HOT) and uncooled thermal detectors to eliminate a large cooler thus reducing system size and weight, small pixel pitch which provide better image resolution, and digital read out integrated circuits (ROICs) versus analog. The challenge is to provide range resolution to aid in a robust, precise weapons quality track.

The objective is to develop an IRST conceptual design that supports the generation of fire control solutions at range along clear atmospheric paths and in cluttered air-to-air and air-to-ground environments with a low false alarm rate while staring over the entire system field of regard. The trade space to be considered includes current and future advancements in large format FPAs, innovative read-out architectures, sensor chip assembly designs, innovative wide field of view optical designs, and advanced processing methods for target detection/tracking at range and in clutter that fully exploit the high frame rate advantages of a staring system. Research should take into account total system life cycle costs and identify alternatives to high cost, high failure rate and high maintenance items such as thermal infrared transparent conformal window materials. Additionally, basic algorithms and supporting processing architecture suitable for performance validation and verification of the system and target detection including tracking and clutter rejection algorithms will be investigated and evaluated. Processing to include range-to-target information and incorporation of other sensor modalities for track formation is also of interest.

13. **Passive EO/IR Space-Based Sensing:** The objective of this research is to develop novel passive EO/IR sensing technologies to reduce cost and SWaP and/or enhance capability of space-based ISR payloads.

Areas of interest include:

(a) Novel optics (large aperture gradient index, waveguide, freeform)
(b) Multi-aperture interferometric imaging technology
(c) FPAs with gain/amplification, and other innovations
(d) Computational imaging/compressive sensing
(e) Event-based sensing technology and algorithm development

(f) Novel data processing techniques for detection and tracking
(g) Technologies supporting reduced C-SWaP high resolution imaging from LEO

OPSEC Requirements for Contracts

The implementation of General Operations Security (OPSEC) procedures, policies, and awareness is crucial to reducing program vulnerability from successful adversary collection and exploitation of critical information. OPSEC will be applied throughout the life cycle of the contract. To support this effort, the Critical Information and Indicators List (CIIL) and the RY OPSEC Plan will be provided by the AFRL/RYSP S&T Protection Office. By identifying and protecting Critical Information and Indicators (CII), the OPSEC process becomes a positive, proactive means by which adversaries are denied advantages. OPSEC is accomplished using a five-step process: 1) identification of CII; 2) threat analysis; 3) vulnerability analysis; 4) risk assessment; and 5) application of appropriate countermeasures. The contractor shall identify CII and develop and apply measures to mitigate risks. OPSEC strategies shall be documented in an OPSEC plan and delivered to AFRL after contract award.

While working on the government installation, the AFRL/RYSP S&T Protection Office will provide OPSEC guidance and training to ensure contractors are familiar with RY's CIIL and OPSEC Plan as it pertains to their contract. This training will be conducted in accordance with Air Force Instruction (AFI) 10-701, Operations Security, and the Wright-Patterson Air Force Base (WPAFB) Supplement to AFI 10-701.

OPSEC Requirements for Assistance Agreements

The implementation of General Operations Security (OPSEC) procedures, policies, and awareness is crucial to reducing program vulnerability from successful adversary collection and exploitation of critical information. OPSEC will be applied throughout the life cycle of the contract. To support this effort, the Critical Information and Indicators List (CIIL) and the RY OPSEC Plan will be provided by the AFRL/RYSP S&T Protection Office. By identifying and protecting Critical Information and Indicators (CII), the OPSEC process becomes a positive, proactive means by which adversaries are denied advantages. OPSEC is accomplished using a five-step process: 1) identification of CII; 2) threat analysis; 3) vulnerability analysis; 4) risk assessment; and 5) application of appropriate countermeasures.

While working on the government installation, the AFRL/RYSP S&T Protection Office will provide OPSEC guidance and training to ensure contractors are familiar with RY's CIIL and OPSEC Plan as it pertains to their contract. This training will be conducted in accordance with Air Force Instruction (AFI) 10-701, Operations Security, and the Wright-Patterson Air Force Base (WPAFB) Supplement to AFI 10-701.

Security Risk Review Guidance

4.1 Security Risk Review – AFRLI 61-113

4.1.1 Contractor employees during the performance of this effort may be required to have access to Critical Technology Elements (CTE), Enabling technologies, Critical Program Information (CPI) or other potential sensitive information. Contractor employees will be required to protect this information from disclosure to unauthorized personnel and companies.

4.1.2 Provide a security plan to comply with the requirements of protection for this sensitive information when requested by the Government COTR/COR. (See CDRL or ADRL, A00X – Security Plan)

4.1.3 Notify the Government immediately within 24 hrs of all security incidents involving loss, compromise, or suspected compromise of CTE/CPI IAW DoDM 5200.01-V3, Enclosure 6. CTE/CPI involved in the incident shall be specifically identified in inquiry and investigation reports.

4.1.4 Covered individuals shall be required to accomplish an updated, "Research and Related Senior/Key Person Profile" on an annual basis and be required to provide an updated list anytime new personnel join. In addition, whenever a new covered individual(s) is to be added or identified as performing under the funded project, a new Research and Related Senior and Key Person Profile will be required prior to continued performance. (See CDRL or ADRL, A00X – R&R Profile)

4.1.5 If, at any time, during performance of this award, the contractor learns that its Senior/Key Research Personnel (including any sub awardee personnel who receive this designation) are or are believed to be participants in a Foreign Government Talent Program or have Foreign Components with a strategic competitor or country with a history of targeting U.S. technology for unauthorized transfer, the contractor will notify the Contracting/Agreements Officer within 5 business days of awareness.

4.1.6 In the event a security risk is identified, and the government has determined the security risk exceeds the acceptable threshold, the contractor will be notified and informed of the termination of award. The Government will be only required to provide a general statement of the reasoning due to government OPSEC measures.

4.1.7 Contractor will be required to flow down this provision to all sub awardees who have personnel designated as Senior/Key Research Personnel as a result of their involvement in the performance of the research.