A13A-T009                          Near Real-Time Quantification of Stochastic Model Parameters

A13A-T015                          Compressed Sensing for Wide Area Chemical and Biological Early Warning

N13A-T003                          Maneuver Prediction and Avoidance Logic For Unmanned Aircraft System (UAS)

Encounters with Non-Cooperative Air Traffic

N13A-T014                          Progressive Model Generation for Adaptive Resilient System Software

N13A-T015                          Airborne Sensing for Ship Airwake Surveys

N13A-T016                          On-Board Data Handling for Longer Duration Autonomous Systems on Expeditionary

N13A-T020                          Proactive Decision Support Tools & Design Schema for Dynamic/Uncertain

Environments

N13A-T024                          Situational Awareness as a Man-Machine Map Reduce Job

AF13-AT01                          Multiphysics-based Sensor Fusion

AF13-AT02                          Decision Making under Uncertainty for Dynamic Spectrum Access

AF13-AT10                          Next Generation Tracking Architectures for Urban Surveillance Areas

N13A-T003                          TITLE: Maneuver Prediction and Avoidance Logic For Unmanned Aircraft System

(UAS) Encounters With Non-Cooperative Air Traffic

TECHNOLOGY AREAS: Air Platform, Sensors

ACQUISITION PROGRAM: PMA 262

OBJECTIVE: Develop an analytic framework and methodology to address unanticipated maneuver encounter modeling, collision risk estimation and ownship maneuver logic to support optimal operation of manned and unmanned aircraft in a complex and congested airspace.

DESCRIPTION: With the widespread introduction of unmanned aircraft, the nature of the airspace will change significantly over the next 10-20 years as they are fully integrated into both segregated and non-segregated airspace.  New procedures and technologies will be required to ensure safe airspace operations while accommodating increasing traffic demands.  Current top level design requirements for sensor systems supporting collision avoidance assume stressing straight-line intruder collision trajectories to establish hardware requirements as a function of maneuver decision latency and own-ship maneuverability.  This is a very reasonable approach to establish the system design.

In practice the current state of the art maneuver logic must be improved to consider unanticipated maneuvers by an intruder occurring after the own-ship collision avoidance maneuver initiation.  Such a situation exists when encountering non-cooperative, maneuvering intruders, such as those operating under Visual Flight Rules (VFR).  These encounters are particularly challenging due to the inherent uncertainties in predicting the future trajectories of these intruders. Understanding the nature of unanticipated maneuvers and their likelihood during encounters in representative actual airspace types is essential for the development of the collision avoidance logic.

Investigators have suggested [1] that one way of meeting this challenge is to treat "well clear" as a separation standard that is quantified using the risk (i.e. probability) of Near Mid-Air Collision (NMAC) at some future time, and to alert pilots when action is required to avoid violating this separation.  A maneuver decision approach which matches suitable encounter models with sensor, air vehicle and level of decision autonomy is needed. This likely involves (explicitly or implicitly) a stochastic model to quantify likely intruder trajectories. A number of candidate approaches exist for computing such risks including the use of continuous-time, maneuver-based stochastic models and diffusion-based methods. A key element in such an approach is the ability to capture variations in maneuvering aircraft trajectories over representative encounter time scales, that it be viable for a real-time collision avoidance and provide a quantifiable performance improvement in terms of the traditional detection-theoretic metrics of probability of detection (Pd) and probability of false alarm (Pfa). Such an approach could then be utilized in the assessment of the overall system level of safety and support administrative certification.

PHASE I: Develop the overall analytic framework and methodology for collision avoidance maneuver logic in the presence of unanticipated intruder maneuvers occurring after the ownship (UAS) collision avoidance maneuver initiation .  Identify the key elements in a maneuver decision approach which matches suitable encounter models with sensor capabilities, air vehicle dynamics and level of decision autonomy.

PHASE II: Develop a maneuver decision approach to account for unanticipated maneuvers as a function of class of airspace and varying levels of knowledge about the type of intruder aircraft. Demonstrate the approach on representative encounter scenarios.  Develop models to validate the approach relative to the risk metrics.

PHASE III: Transition the approach and supporting algorithms into general use for airborne collision avoidance systems in service or under development.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: The research directly supports civil integration of UAS into the NAS. Commercial market for UAS including police departments is a huge private sector growth area.

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KEYWORDS: Radar; Unmanned Aircraft; Collision Avoidance; Encounter Modeling; National Airspace; Due Regard Flight

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Questions may also be submitted through DoD SBIR/STTR SITIS website.

N13A-T014                          TITLE: Progressive Model Generation for Adaptive Resilient System Software

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop a tool for automated and progressive model extraction for supporting automated system reasoning.

DESCRIPTION: This STTR topic solicits the development of a tool which progressively and interactively extracts abstracted model for the program and program components, of programs (software) as it is being developed. The extracted model is targeted toward supporting system reasoning.

Large and complex systems of software, such as the ones used by DoD, are difficult to completely verify and secure. These systems are vulnerable to compromises which take advantage of its weaknesses and flaws. As breaches and compromises have become a fact of computing life, it is important that our computing systems can adapt and operate effectively under such conditions. There is a need for a system which can continuously assess its own state/health, capabilities and limitations, and adapt to the situation, at cyber speed, toward maximizing the potential success of the missions. In the heart of such system there is a comprehensive and timely system reasoning infrastructure. A comprehensive system reasoning requires knowledge/model as a reference for observing system behavior. Ideally, each of the system components has a knowledge/model associated with it, and the aggregate of these component models constitutes the overall system knowledge/model. An effective way for acquiring these models is to progressively and interactively extract it during program development process (coding).

The objective to this solicitation is to design and develop a tool which extracts the abstract knowledge/model of the program as it is being developed (coded).  This software development tool should be applicable to one or more widely used programming languages, within common software development frameworks. The interactive process for in-progress extraction of knowledge/model of a program also enhances software developers’ understanding and awareness of their works, and hence improving the correctness, security and robustness of the resulting code.

PHASE I: Architectural analysis and design for a tool which provides automated and progressive capture of program abstraction/model for an open-source software development environment of choice. Develop a proof of concept prototype for the tool.

PHASE II: Develop a full functioning prototype of a tool which performs automated and progressive capture of program abstraction/model for an open-source software development environment of choice. Demonstrate the efficacy for the tool.

PHASE III: Besides supporting progressive and interactive model extraction for system reasoning, the interactive process for the in-progress extraction of knowledge/model of a program also enhances software developers’ understanding and awareness of their works, and hence improving the correctness and robustness of the resulting code. For the above reason alone, this tool will be valuable for the general software developing public. It should find its role in, and can be ported into, various open-source and proprietary software development environments for enhancing the programmers’ awareness of their work (code), and hence the correctness, security and robustness of the resulting software. This tool should also be applicable and portable to development environments of many different programming languages for many different application spaces, such as high performance computing, mobile devices, embedded systems, finance applications, cloud computing, the web and service oriented applications, etc.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: Besides supporting progressive and interactive model extraction for system reasoning, the interactive process for the in-progress extraction of knowledge/model of a program also enhances software developers’ understanding and awareness of their works, and hence improving the correctness and robustness of the resulting code. For the above reason alone, this tool will be valuable for the general software developing public. It should find its role in, and can be ported into, various open-source and proprietary software development environments for enhancing the programmers’ awareness of their work (code), and hence the correctness, security and robustness of the resulting software. This tool should also be applicable and portable to development environments of many different programming languages for many different application spaces, such as high performance computing, mobile devices, embedded systems, finance applications, cloud computing, the web and service oriented applications, etc.

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5. SBIR OSD12-IA2 Multi-Abstractions System Reasoning Infrastructure toward Achieving Adaptive Computing Systems

KEYWORDS: Software development environment, code quality, automated model extraction, on-the-fly code analysis, model for system reasoning.

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N13A-T016                          TITLE: On-Board Data Handling for Longer Duration Autonomous Systems on

Expeditionary Missions

TECHNOLOGY AREAS: Air Platform, Ground/Sea Vehicles

ACQUISITION PROGRAM: Robotic Systems Joint Program Office

OBJECTIVE: Develop autonomous systems with flexible mechanisms to organize and manage data in a way that the systems can make better use of the large volumes of data encountered over the course of missions of moderate length and coverage area, such as support of small Marine units or similarly sized maritime operations. The types of data handled will include both local sensor data, and data communicated by friendly systems that may involve temporal and spatial relationships. The goal would be to be able to use this capability to support improved planning, decision making, control, and system-level situational awareness on-board the vehicle.  Note that the development of new hardware or platforms is outside the scope of this topic.

DESCRIPTION: Many current autonomous systems have on-board sensors that can collect a great deal of data over the course of a mission, particularly as autonomous systems are increasingly being used in more complex environments over larger areas and longer time durations. However, the volume of that data can be so large that it may not be feasible to store it all locally on the systems. At the same time, the communications and security constraints of the military environment may preclude using any form of remote storage such as cloud computing.  If increased hardware cost, size, weight, and power can be accommodated in the design of an autonomous system, it may be possible to store large amounts of data on-board, at least for part of the mission. However, even when massive local storage of data is possible, using that data effectively remains a very difficult problem. Such massive sets of raw data are at present typically used primarily for post-mission analysis, rather than to guide system plans, decisions, and actions during the course of the mission. Too often, the real-time use of the data in is limited to very narrow slices of the total flow of data. This could in turn lead to poor planning and decision making such as failing to recognize the same or similar situations and attempting to repeat the same unsuccessful actions over and over.

For the future, it is important that autonomous systems begin to take advantage of the broad range of data available to them over the course of an entire mission to the greatest extent possible and identify and utilize what is relevant to support planning, decision-making, and control in particular mission and environmental circumstances.  This should involve sensed and communicated data that has temporal and spatial relationships as opposed to just factual data coded in a world model.  Biological systems are very adept at this kind of high-efficiency, low-cost scanning and summarization of massive amounts of data, so one promising approach might be to utilize mechanisms and models derived from recent practical insights from cognitive and neuro science.  This may include methods for processing incoming streams of data at different time-scales, utilizing longer-term memories in helping to determine what is important, and shorter-term memories for providing real-time analysis of important incoming data, and anticipating and focusing as early as possible on which parts of the data are most likely to be relevant and important.

PHASE I: Phase I will focus on limited-scope development and implementation and feasibility of initial mechanisms to organize and manage data in a way that the systems can make better use of the large volumes of data encountered over the course of missions of moderate length and coverage area. Its outcome will be the results of a feasibility study in which a simplified version of the overall approach will be demonstrated against some combination of stored data, simulation, and/or laboratory experiments as appropriate to the particular methods being explored.  Also, important will be to identify metrics.

PHASE II: In Phase II, the simplified approach demonstrated in Phase I must be broadened and generalized to the point where it can be demonstrated and assessed for viability against the metrics defined in Phase I within more complicated laboratory settings and/or in limited field experiments. The experiments must include real-world perception, action decisions based on situation, and demonstrating whether continued operations without performance degradation are feasible over a long period of time. The results of Phase II must also include a realistic assessment of whether the overall approach is working and can be scaled up for larger tests.

PHASE III: In Phase III, the objective will be to demonstrate that a finalized and field-hardened version of a system with the capabilities shown at the end of Phase II can be transitioned into a specific naval autonomous system and used to support field experiments. Marine Corps autonomy systems designed to support autonomy experiments may provide good candidates for this phase of the STTR.

PRIVATE SECTOR COMMERCIAL POTENTIAL/DUAL-USE APPLICATIONS: A successful demonstration of long-term memory structures that can directly support rapid selection and attention to the most relevant data would have impacts well beyond Navy systems, since these same capabilities would also enable lower cost and more cost-effective autonomy for a variety of industrial robotics and consumer products. Commercial/industrial robotic systems would be obvious beneficiaries in the private sector, but other and unexpected sectors such as service robotics or even the toy industry could also benefit from affordable systems that exhibit fast decision making at low energy and computational cost.

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\*Note that the above list is meant as useful background reading, but is neither comprehensive nor meant to endorse a particular approach.

KEYWORDS: Autonomy; robotics; cognitive architecture; neuroscience; unmanned system; cognitive science

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AF13-AT01 TITLE: Multiphysics-based Sensor Fusion

TECHNOLOGY AREAS: Sensors

OBJECTIVE: To develop new multiphysics-based sensor fusion algorithms which map disparate sensor fields into a single common multiphysics-based representation. This model can then be used to produce higher quality sensor fusion data products.

DESCRIPTION: The proliferation of sensor systems has created a large volume of multi-sensor data across a number of physical fields (e.g., optical, EO/IR, hyperspectral, polarimetric, acoustic/seismic, RF, electromagnetic, mechanical, thermal, electrical, radiation). Classical methods of combining disparate data normally involve highly nonlinear mapping between actual measurements and underlying parameterized target model [1]. Furthermore, each sensor source needs to be statistically characterized for a good joint estimation (fusion) to be performed. Unfortunately, the fields (and consequently the resulting measurements) can be so dissimilar that traditional combining methods (e.g., extended Kalman filtering) [2] may perform suboptimally due to approximations/assumptions required to map into conventional algorithms.

Recent advances in physics modeling and efficient software simulations have given rise to the emerging field of multiphysics modeling [3], wherein a single unified physics representation of objects of interest is developed. In multiphysics-based sensor fusion, all sensor measurements are first mapped into a unified multi-field physics model, which is then used to generate estimates of parameters of interest. For example, an IR/RF/polarimetric sensor suite (maybe employed in an urban warfare setting by law enforcement) could be used to develop a multiphysics model for a set of objects (e.g., targets of concern and clutter (non-targets)), potentially producing more accurate parameters of interest. Additionally, advances in high performance embedded computing (HPEC) [4] make it possible to execute a number of multiphysics models in real-time, an enabler for tactical multiphysics-based sensor fusion.

PHASE I: Identify relevant technological applications (e.g., biomedical, automotive, aerospace, acoustical, geo-mechanical, RF, robotics, machinery monitoring). Develop baseline multiphysics simulation models encompassing selected measurement observables. Derive multiphysics-based sensor fusion algorithms and demonstrate effectiveness using synthetic data sets.

PHASE II: Further refinement and development of the multiphysics models and companion multiphysics-based sensor fusion algorithms. Conduct high fidelity demonstration/validation of algorithm performance, based on finer grained simulations. Develop baseline embedded computing approach for meeting tactical timeline requirements for chosen applications. Quantify performance gains relative to conventional fusion algorithms.

PHASE III: This research is applicable across the entire DOD ISR enterprise.

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KEYWORDS: Multiphysics modeling, multi-sensor data fusion

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AF13-AT10 TITLE: Next Generation Tracking Architectures for Urban Surveillance Areas

TECHNOLOGY AREAS: Information Systems

OBJECTIVE: Develop and implement next generation tracking architectures which exploit wide area motion imagery and leverage projected High Performance Computing capacities.

DESCRIPTION: Wide area motion imagery (WAMI) systems, such as the Autonomous Real-time Ground Ubiquitous Surveillance– Imaging System (ARGUS-IS), produce tens of thousands of moving target indicator (MTI) detections from city- size urban areas (over 40 square kilometers) at video rates of greater than 12 Hz. On-board processing currently provides a limited number of operator-nominated real-time Stationary Video Windows (SVW) and Tracking Video Windows (TVW) for target monitoring and engagement. Off-board processing currently provides a much greater number of automated tracks for forensic analysis but only for a partial portion of the urban surveillance area (Reference 1).

To improve mission effectiveness, the on-board number of real-time targets monitored and engaged needs to be significantly increased and the off-board forensic analysis portion of the urban surveillance area needs to be dramatically expanded. Thus, innovative next generation track processing architectures are needed to fully exploit the revolutionary advances being achieved by WAMI systems with regard to target detection and surveillance area capabilities.

As the densities of the surveillance areas have increased (from rural, to suburban, and ultimately to urban), it has become especially challenging for current generation track processing architectures to correctly and efficiently associate individual MTI detections with vehicle and dismount targets. For example, Multiple Hypothesis Tracking (MHT) has been deployed to address dense environments by forming and maintaining hypotheses until sufficient confidence is achieved to declare an association. However, current MHT’s are limited by the density of the surveillance areas as the track processing requirements grow exponentially as a function of the total number of targets and their relative proximities. Other current track processing architectures such as Particle Filtering and Joint Probabilistic Data Association are also severely challenged by urban surveillance areas.

A potentially rewarding avenue of investigation is the future relationship of target density and High Performance Computing (HPC) capacities with target density having reached an upper bound (i.e. only so many vehicles can be on a roadway; even in an urban traffic jam) whereas HPC processor developments and associated capacities are projected to be unbounded (i.e. multicore processors and distributed databases; for handling Big Data). While these future HPC capacities may extend current tracking architectures which are based on target trajectory modeling; more importantly, they can potentially enable next generation tracking architectures which may be based on higher level multiple-target activity modeling which focuses on correlations of appearance events at the pixel level identified through various learning methods. These pixel-level approaches can be sensitive to imagery noise, etc. and can be computationally demanding due to the large number of pixel-level events which need to be continuously and simultaneously monitored and detected (Reference 2).

PHASE I: Develop a prototype next generation tracking architecture which exploit wide area motion imagery (WAMI) systems and leverage projected High Performance Computing (HPC) capacities for on-board and off-board processing of vehicle and dismount targets within urban surveillance areas.

PHASE II: Determine feasibility of next generation tracking architectures and demonstrate representative implementations of on-board and off-board processing through utilization of a High Performance Computing Environment which includes interactive computing resources, enhanced data management capabilities, and increased data storage.

PHASE III: Exploitation of WAMI over adversarial urban surveillance areas provides for timely target engagement and more comprehensive forensic analysis. Exploitation of WAMI over domestic urban surveillance areas provides for timely emergency response and more comprehensive disaster monitoring.

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KEYWORDS: Wide Area Motion Imagery (WAMI), track processing, appearance modeling, High Performance Computing (HPC), urban surveillance areas

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