# Broad Agency Announcement

## SIGMA+ Sensors

## Defense Sciences Office

HR001118S0035

April 5, 2018

**Table of Contents**

BAA ATTACHMENTS:
        A. ABSTRACT SUMMARY SLIDE TEMPLATE
        B. ABSTRACT TEMPLATE
        C. PROPOSAL SUMMARY SLIDE TEMPLATE
        D. PROPOSAL TEMPLATE – VOLUME 1 TECHNICAL & MANAGEMENT VOLUME
        E. PROPOSAL TEMPLATE – MILESTONES AND DELIVERABLES TABLE

## PART I: OVERVIEW INFORMATION

- **Federal Agency Name:** Defense Advanced Research Projects Agency (DARPA), Defense Sciences Office (DSO)

- **Funding Opportunity Title:** SIGMA+ Sensors

- **Announcement Type:** Initial Announcement

- **Funding Opportunity Number:** HR001118S0035

- **Catalog of Federal Domestic Assistance (CFDA) Number(s):** 12.910 Research and Technology Development

- **Dates** (All times listed herein are Eastern Time.)
  - Posting Date: April 5, 2018
  - Teaming Profile Deadline: April 11, 2018, 4:00 p.m.
  - Abstract Due Date: April 18, 2018, 4:00 p.m.
  - FAQ Submission Deadline: May 24, 2018, 4:00 p.m. See Section VIII.A.
  - Full Proposal Due Date: May 31, 2018, 4:00 p.m.

- **Anticipated Individual Awards:** DARPA anticipates multiple awards

- **Types of Instruments that May be Awarded:** Procurement contracts, cooperative agreements or other transactions

- **Agency contacts**

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    http://www.darpa.mil/work-with-us/opportunities

- **Teaming Information:** See Section VIII.B for information on teaming opportunities.

- **Frequently Asked Questions (FAQ):** FAQs for this solicitation may be viewed on the DARPA/DSO Opportunities Website. See Section VIII.A for further information.

**PART II: FULL TEXT OF ANNOUNCEMENT**

## I. Funding Opportunity Description

This Broad Agency Announcement (BAA) constitutes a public notice of a competitive funding opportunity as described in Federal Acquisition Regulation (FAR) 6.102(d)(2) and 35.016 as well as 2 CFR § 200.203. Any resultant negotiations and/or awards will follow all laws and regulations applicable to the specific award instrument(s) available under this BAA, e.g., FAR 15.4 for procurement contracts.

### A. Introduction

The Defense Sciences Office at the Defense Advanced Research Projects Agency (DARPA) is soliciting innovative research proposals in the area of advanced chemical and biological detector technologies to support a networked system of sensors for the detection, interdiction, and deterrence of clandestine weapons of mass destruction (WMD). Proposed research should investigate innovative approaches that enable revolutionary advances in science, devices, or systems. Specifically excluded is research that primarily results in evolutionary improvements to the existing state of practice.

### B. Background

The United States faces challenges from increased adversarial access to low-cost enabling technologies for the production and deployment of weapons of mass destruction. Additive manufacturing and small-scale chemical reactors, for example, reduce the infrastructure and economic investment required to develop and manufacture weapons with destructive power disproportionate to their size and weight. These developments increase the probability of covert WMD manufacture and deployment, either for terrorist or rogue state purposes, and reduce the observable signatures required to detect their presence.

The SIGMA program began in 2014 as an effort to significantly advance scalable detection capabilities against radiological and nuclear (RN) WMD threats from these non-traditional, clandestine attack vectors. SIGMA developed thousands of high-capability, low-cost detectors and networked them to demonstrate large-scale, continuously-streaming physical sensor networks for the RN interdiction mission. SIGMA capabilities have been tested and operationalized with federal, state, and international partners. Further information about the SIGMA program can be found at the following links:

https://www.darpa.mil/program/sigma
https://www.darpa.mil/news-events/2017-03-01
https://www.darpa.mil/news-events/2016-10-11
https://www.darpa.mil/news-events/2016-08-23

Additionally, the SIGMA network technical capabilities are described in Appendix A.

The SIGMA+ initiative will build on SIGMA's successes by developing a persistent, real-time, early detection system for the full spectrum of chemical, biological, radiological, nuclear, and explosive (CBRNE) WMD threats at the city-to-region scale. Specific targeted capabilities for

each threat mode will focus the envisioned sensor network, advanced intelligence analytics, and adversary modeling developments under one shared network backbone infrastructure and a ubiquitous mobile, adaptive sensing strategy.

**This BAA focuses on research, development, and scale-up of chemical and biological sensors as well as their associated algorithms for the SIGMA+ system. Responses outside of this focus will be deemed non-responsive.** Current plans include a subsequent BAA, anticipated to be released in the first half of the 2019 Government Fiscal Year, to address the developments for automated intelligence analytics and advanced adversary modeling, as well as further developments for the SIGMA network backbone that are expected to be required to perform full fusion of these data and methods.

### C. Program Description/Scope

SIGMA+ will advance, integrate, and scale emerging sensor and data analytics technologies to demonstrate and transition a detection system that fundamentally changes how we detect, interdict, and deter clandestine WMD. The SIGMA+ initiative will leverage and build on sensor capabilities to enable fully-networked scalable, high-capability detectors in the chemical, biological, and explosive (CBE) threat space, similar to what was accomplished in the RN threat space under the SIGMA program. (Although the SIGMA+ system will address RN threats, new RN sensor capabilities are not solicited in this BAA.) Beyond incorporating these additional sensor modalities, SIGMA+ will fuse CBRNE sensor data with new automated intelligence analysis and other contextual data. Furthermore, advanced social science techniques will be leveraged for adversary modeling and integrated into SIGMA+ to maximize detection and interdiction effectiveness. This holistic development and integration of physical sensing, automated intelligence and contextual data analysis, and advanced adversary modeling will result in a transformative and practical early detection system for the full spectrum of CBRNE WMD threats. Proposers to this BAA should focus **only** on the CBE sensor network domain; other areas mentioned will be incorporated into the complete system through subsequent SIGMA+ solicitations and integration efforts.

For chemical and explosives threats, the existing SIGMA network will be extended to include scalable chemical detection technologies that enable identification of a broad range of species and precursors at the 10 parts-per-billion (ppb) (or better) level to identify illicit production of harmful threats in complex urban environments. The focus on detecting threat production will help enable interdiction prior to an attack.

For biological threats, SIGMA+ will develop novel methods, either environmental or human-sensing based, for improved real-time detection of attacks. This effort aims to provide days earlier attack detection and geolocation of a much wider range of attacks, enabling more effective countermeasures and mitigation strategies.

For radiological and nuclear threats, the incorporation of large-scale automated intelligence analytics into SIGMA+ will allow prioritization of detections near statistical limits to enable interdiction of heavily shielded threats, increasing effective system sensitivity by up to an order of magnitude.

Federal and state partnerships will be established for joint testing and large-scale field trials of SIGMA+ capabilities to enable interagency and operational transition.

One example concept of operations (CONOP) for the final SIGMA+ system, for the case of detecting an illicit lab, is as follows: A system of mobile, automated chemical sensors (potentially leveraging existing vehicle fleets as carriers) will continuously scan the streets and buildings of a wide urban area, reporting results in real time via the SIGMA+ network. The incoming data stream will be continuously assessed against, and will help to build, high-resolution spatiotemporal backgrounds to maximize sensitivity for species of interest (e.g., threat and volatile precursors). Automated intelligence analytics, guided by adversary models and contextual data to help extract the most relevant and actionable intelligence, may also be used to cue and direct the sensor network. In that example case, the chemical sensors could be automatically reconfigured for increased detection sensitivity of a particular set of precursor chemicals and/or re-directed to a prioritized search area for further scanning. Similar scenarios can be imagined for the detection of a biological attack. While these examples represent some of the most challenging of applications, the technical advances of the SIGMA+ program will have broad applicability throughout the DoD.

SIGMA+ will consist of three integrated thrusts: sensors, network, and test and evaluation. The program will be conducted in two 2.5-year (30-month) phases. The initial phase (Phase 1) will focus primarily on sensor, network architecture, and automated analytics development, while in the subsequent phase (Phase 2), the emphasis will shift towards full integration into a holistic detection network. System modeling, test and evaluation, and field trials will occur throughout the program.

The simplified timeline below (Figure 1) summarizes the three thrust and two phases involved, as well as the key program milestones.
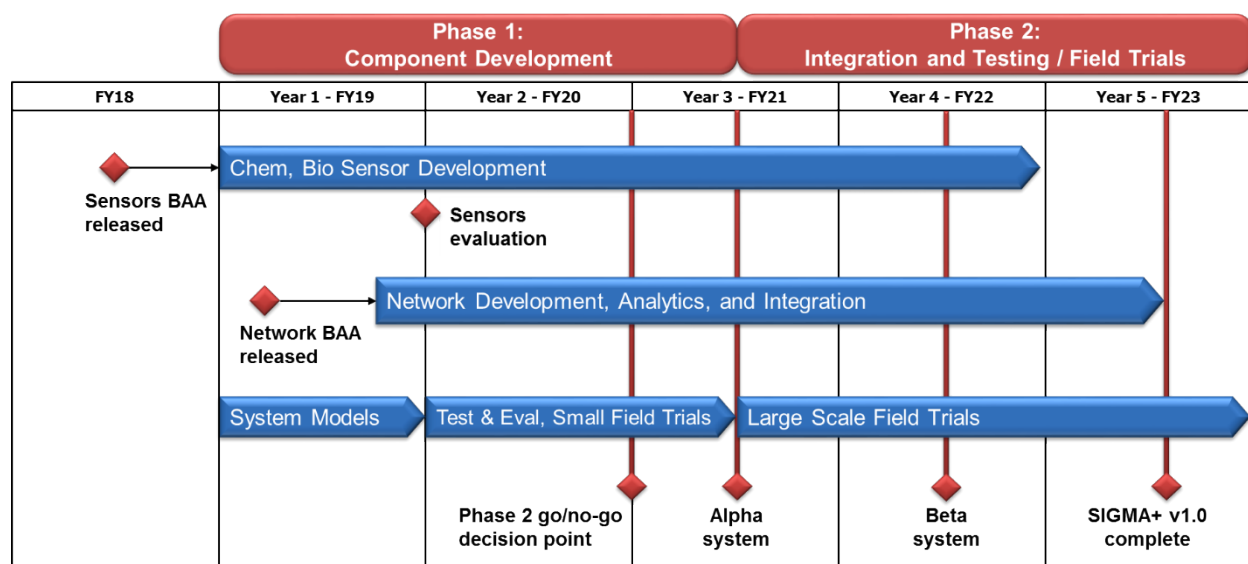


**Figure 1:** *Simplified timeline and key milestones of the SIGMA+ initiative.*

**This BAA covers only the sensors thrust**, described fully in Sections D and E.  There exist, however, dependencies between each of the three thrusts for the construction of the SIGMA+ system.  The current SIGMA network backbone capabilities and proposed SIGMA+ network developments are described in sufficient detail below for proposers to understand the system into which their sensors and associated algorithms will be integrated.  Appropriate application programming interfaces (APIs) and other interface documentation will be provided to selected performers.

Planned tests and evaluation are also discussed below to provide proposers with sufficient context for the delineated goals.  DARPA expects sensors BAA performers and their teams to work with other performers to conduct system-level integration, experiments, and tests with their newly developed detectors.  DARPA will work with individual performers to coordinate this in-development testing cycle.  **Performers should not expect this testing to replace their own internal device testing, and should be prepared to share the results of their internal tests with DARPA-designated performers on the SIGMA+ team.**

*Summary of Network Thrust*
This thrust will develop the SIGMA+ network architecture and incorporate the individual sensor, multi-sensor, and system-level algorithms.  Beginning in the second year, physical sensors will be integrated into the network, and system algorithms will be developed by the third year.  Additionally, adversary characterization will be combined with automated intelligence analytics algorithms.  Further refinement of algorithms and adversary modeling will occur in the remaining years.

Algorithms, network architecture, and user interfaces will be continuously refined throughout the program.  The first integrated version of the system (alpha system) will occur at the end of Phase 1, the beta version of the system will be in Year 4, and SIGMA+ version 1.0 will be completed near the end of Phase 2 in Year 5.

**The network thrust will be covered by a separate BAA at a later time.  Information provided here is purely for guiding sensor proposals covered under this BAA.**

The SIGMA+ network backbone is intended to retain capabilities of the SIGMA network backbone while incorporating new features to achieve SIGMA+ objectives.  An overview of the baseline SIGMA network backbone capabilities can be found in Appendix A.  **Proposers are strongly encouraged to review this information in order to understand the capabilities of the current network and how their sensor might integrate into it, and also to clearly state what new network backbone capabilities might be required to fully support their proposed sensor as well as the proposed CONOP.**

*Summary of the System Modeling, Test and Evaluation, and Field Trials Thrust*
Work in this thrust will combine extensive government-led testing, red teaming, and integrated system modeling to validate capabilities and provide optimal deployment plans for transition.  System models will be developed and tested in Years 1 and 2, with sensor testing, red team experiments, and small field trials providing validation data.  These data sets, along with system model analyses, will be used to evaluate program progress at the end of Year 2.

Additionally, this thrust will focus on field trials of the SIGMA+ system and engagement with transition and operational partners. Transition partners will be identified early such that the system hardware, algorithms, and network can be tailored with these partners as exemplar cases throughout the program. As the system scales up in Years 3-5, larger, iterative system field trials will be conducted with federal and local/state operational partners to test, demonstrate, and further refine system capabilities. Field trial data will be combined with red-team experiments and model simulations to produce validated system receiver operating characteristic (ROC) curves for each version of the system. Transition partners will be engaged throughout the program, maximizing the potential for transition and operational deployment of the SIGMA+ system.

**This work is not being solicited under this BAA. Information provided here is purely for guiding sensor proposals covered under this BAA.**

### D. Program Structure – Sensors Thrust

This BAA solicits proposals to the sensors thrust, which focuses on developing and incorporating chemical and biological sensors, as well as sensor algorithms, into the SIGMA+ architecture.

**Proposers are required to address both the sensor hardware and data processing algorithms that will be needed to meet program metrics.**

The first 30 months (Phase 1) of the sensors thrust will focus on the development, optimization and validation of sensors, as well as building and integrating corresponding sensor-level algorithms into a sensor system.

"Sensor system" is defined here as a collection of sensors with algorithms, and its performance within a proposer-defined CONOP should satisfy the system metrics and constraints as described in Section E and the high-level objectives described in Section C. It is anticipated that the advanced sensors developed will require two types of algorithms to meet the system metrics and to maximize the desired CBRNE early detection capabilities discussed in this BAA: algorithms that operate at the individual sensor level, and higher-level algorithms that operate across multiple sensors in order to, for example, localize the emission of detected precursor effluents.

**Proposers should make clear if additional contextual data is required for, or would greatly benefit, their detection, identification and tracking algorithms (e.g. real-time weather information, available public health reports of infection rates, etc.); if and how that information will be collected by the proposer's sensor system or via an external feed; and what nominal requirements might be imposed on the SIGMA+ network to incorporate and process that contextual data.** Algorithms for automated intelligence analysis as described earlier are outside the scope of this BAA; proposers should, however, ensure that their sensor algorithm and analysis framework can easily incorporate cues and output stemming from such external analyses. For example, intelligence analysis could indicate that a particular type of chemical threat might be in a particular operating area, and this would result in a desired, automated tuning of the sensor algorithms to be more responsive to that type of threat for any detectors entering that operating area.

Proposals must demonstrate that the development of the proposed new detection concepts and technologies can meet the aggressive program timeline for technology maturity for deployment. Full-scale production and integration of custom chemical and biological sensors will begin in Phase 2, along with development of any additional advanced sensor concepts that are identified to close a capability gap. Unit-level testing of sensors and algorithms will be performed continuously throughout the program in both Phase 1 and Phase 2. **The government will conduct independent performance tests, but performers should not expect this testing to replace their own internal testing. Performers should document their internal testing and be prepared to share these results with DARPA-designated performers on the SIGMA+ team.**

Proposals must describe the projected ability of the proposed sensors, algorithms, and manufacturing R&D plan to meet Phase 2 program goals and metrics, described in Section E, for each technical area. A treatment of Phase 2 program plans, including projected costs, is thus required in response to this BAA. Proposals that do not address Phase 2 goals may be deemed non-responsive.

The Government will use a phased acquisition approach for the SIGMA+ program under this Broad Agency Announcement. At this time, DARPA is soliciting detailed proposals for the Phase 1 effort only, consisting of a 30-month base period. Proposers are also required to submit a rough order of magnitude (ROM) proposal for Phase 2, which must include Phase 2 ROM costs, a Phase 2 draft statement of work, and any additional information on anticipated Phase 2 program plans.

DARPA intends to request updated technical and cost proposals for Phase 2 approximately six months prior to the completion of Phase 1. Competition for Phase 2 will be limited to only Phase 1 performers. Participation for Phase 2 will be optional and proposal guidance for Phase 2 will be provided towards the end of Phase 1 to Phase 1 performers. Associated proposal preparation costs for Phase 2 will not be reimbursed under Phase 1 awards.

Evaluation of Phase 2 proposals will be based on evaluation criteria to be specified in the Phase 2 proposal requests, and Phase 2 proposal evaluations will be conducted through a scientific and technical review process. The Phase 2 evaluation criteria will be consistent with the evaluation criteria in this solicitation, and may be tailored to the Phase 2 requests for updated proposals. The Government reserves the right to change the award instrument or issue a new solicitation for Phases 2 if programmatic circumstances dictate.

Program continuation beyond Phase 1 will depend on funding availability and promising Phase 1 results.

An initial assessment of progress will take place at the end of the first year, when all sensors will be assessed against agreed-upon Year 1 metrics. A more rigorous assessment will take place at the end of the second year. Performance will also be assessed against agreed-upon Year 2 metrics.

The first demonstration of SIGMA+ system capabilities will take place at the end of Phase 1 with the alpha version of the system.  At this point, chosen sensors types and sensor algorithms will be fully integrated into the network along with baseline intelligence analytics.  The beta version of the system will be completed in the following year, with refined and further scaled sensors and algorithms.  In the final year of the program, SIGMA+ version 1.0 will be completed, including fully scaled sensors and operationalized algorithms.  Capabilities of this system will be iteratively demonstrated through large field deployments with operational partners.

### E.  Technical Area Descriptions – Sensors Thrust

The sensors thrust consists of two technical areas (TAs).  TA1 encompasses environmental chemical sensing.  TA2 involves biological sensors and is further divided into new detectors for environmental sensing of aerosolized biological threats (TA2.1), and new human-based sensors that may indicate illness before the onset of significant symptoms (TA2.2).

The following subsections provide more information on the sensors of interest along with performance metrics, cost goals, and the requested performance period.  While performers may propose to one or all technical areas, separate proposals must be submitted for each technical area proposed.  It is strongly recommended that proposers review Section E in its entirety even if they are only proposing to one technical area.

In each subsection, the overall objectives for each TA and its detection system are described quantitatively, with both threshold and objective metrics.  The threshold metrics are expected to be reached in Year 2, and the objective metrics are expected to be reached in Year 4.  A nominal timeline for field testing and demonstration is also provided.  Proposers should note that the number of sensors they project to meet the proposed sensor network configuration will be required for full-scale field trials.  For example, if a sensor network of 10 sensors is projected to meet SIGMA+ goals, 10 sensors must be available for field trials.  If 1000 sensors are projected, 1000 sensors must be available for field trials.  Proposals should provide technical rationale for the proposed size of the sensor network, ensuring the projected final sensor count will be capable of providing enough relevant information to demonstrate the desired capabilities at scale.

Lastly, a nominal system and CONOP, with derived requirements for the sensors that make up the system, are provided as a baseline and example.  Performers may propose a different technical approach and CONOP to satisfy the overall system goals and objectives.

Proposed sensor technologies and scanning concepts that can most effectively use existing infrastructure, people, and vehicle fleets with minimum procurement, operational burden, and operations and maintenance costs to meet SIGMA+'s wide-area monitoring objectives are strongly encouraged.  For example, existing vehicle fleets were leveraged under the SIGMA program to carry completely automated and networked RN detectors to continuously monitor the region for RN materials.

Additionally, proposed technologies that can provide additional daily operational or commercial value to help sustain the capability are encouraged.  For example, chemical sensors may also

provide drug production detection capability for daily operational value beyond the CBRNE mission.

Further, local processing and display of information is desirable to maintain capability for the local user during disconnected operations.

In each proposal, performers must clearly describe, as **quantitatively** as possible:
- proposed detector technology and associated algorithms, at the individual sensor and multi-sensor fusion levels, and the nominal CONOP for satisfying the defined system requirements and testing and field trials cycle for each technical area
- expected system detection, identification, tracking, and interdiction capabilities within and beyond the system metrics, and any other auxiliary capabilities that can provide daily operational value
- network and local computational requirements as well as network data streaming requirements for proposed sensors and algorithms
- treatment of disconnected operational scenarios including data management, local display capability as well as a clear description of the differences and limitations between local and network algorithm capabilities
- any required contextual data and sources of those data, as well as requirements for the network to ingest and process these data for sensor algorithms
- proposed detector and algorithm performance/metrics as a function of program year in terms of the DARPA-provided metrics described in the subsections below, and any other additional metrics appropriate to the proposed sensor concept (or propose expected performance as a function of program year in terms of proposed alternate metrics that can still achieve system goals); describe highest priority and highest risk metrics
- risks in the proposed concept, and the proposed R&D path and intermediate milestones to retire the highest risks as soon as possible
- expected system design trades to be studied
- how sensors and sensor algorithms will be internally tested and validated, and how results will be presented
- expected device characterization, stability, and device-to-device variability requirements given defined performance metrics and expected algorithm performance
- given sufficient investment, the scaling path to approach the proposed price levels
- prior and ongoing efforts that will be leveraged for the proposed work.
- available ROC curves and confusion matrixes from prior work on proposed sensors and sensor system
- expected overall size, weight, and power of sensors that make up the sensor system
- prior experience in developing and deploying large scale sensor systems

In addition, performers should justify and break down the prototype and final system costs, and how the proposed R&D will result in achieving the cost goals.

**Raw and processed detector data (i.e., spectra and associated information) must be shared to a DARPA-maintained database beginning at month six and throughout the remainder of the program. Control documents for data formats and required metadata will be established with input from both network IT and sensor performers. The government**

**shall have unlimited rights to all raw and processed sensor data, and unlimited rights to the developed algorithms are strongly preferred. Note that fielded detector systems and associated hardware are program deliverables and therefore will become government property.**

Teaming is encouraged to leverage different capabilities that may allow a detector concept that meets or exceeds the desired metrics, and/or provide a realistic path for scale-up for manufacturing the advanced concept.

Considering the objectives of the SIGMA+ program, selected performers must comply, as applicable, with International Traffic in Arms Regulations (ITAR). Proposers must state in their proposal if the work proposed is expected to be ITAR-controlled, and, if so, if their organization has ITAR certification. It is the responsibility of the proposer to make all determinations about what is and is not ITAR-controlled regarding their work. All selected SIGMA+ performers shall comply with all applicable laws and regulations regarding export-controlled items, including, but not limited to, the requirement for contractors to register with the Department of State in accordance with the ITAR. Proposers may consult with the Department of State regarding any questions relating to compliance with the ITAR and may consult with the Department of Commerce regarding any questions relating to compliance with the Export Adminstration Regulations.

## Technical Area 1: Chemical Detection

DARPA seeks to develop a chemical detection system that enables persistent stand-off monitoring of large urban areas (~10 $km^2$) with multi-story structures to detect and identify production of chemical threats (e.g., explosives, chemical warfare agents, narcotics, toxic industrial chemicals, etc.). This will require simultaneous detection and identification of multiple trace species of interest, such as precursors for specific threats.

DARPA seeks to demonstrate these capabilities in an iterative and agile approach, with the following nominal timeline and accomplishments. Proposers must address their proposed development and deliverable cycles relative to this nominal timeline:

By end of Year 1: Lab tests, initial deployment of prototypes outdoors for background collection
By end of Year 2: Outdoor testing covering > 0.3 $km^2$ with threshold metrics and integration into SIGMA+ network
By end of Year 3: Field trials covering > 1 $km^2$ with better-than-threshold metrics
By end of Year 4: Field trials covering 10 $km^2$ with objective metrics
By end of Year 5: Large-scale field trials > 10 $km^2$ with objective metrics or better

Proposers are required to propose an integrated system that, in addition to hardware, includes algorithms for real-time data analysis and network integration of the individual sensors to improve detection and identification capabilities, reduce false alarms, and provide spatial and temporal localization of production dynamics and potential plume tracking. These algorithms will be scaled for deployment in a cloud environment, and successful performers will be expected to work with the SIGMA+ network backbone team for integration. The system must be

capable of automated, real-time and streaming network operation, but individual sensors should also have stand-alone analysis capabilities in the event of a communications outage or a communications denied environment.

Given the urban environments in which the system will be operating, the ability to detect and determine the concentrations of trace amounts of molecules of interest in the presence of dynamic and chemically complex backgrounds will be essential. Backgrounds will not only include interferences, but may also include background concentrations of precursor chemicals of interest (e.g., acetone) that swamp trace signals attributable to nefarious activity. Approaches that include methods of, for example, deconvolution, signal separation, pattern recognition, machine learning, or non-negative matrix factorization that are able to dynamically assess changes in concentration that might be indicative of a pattern of interest are encouraged.

### *Chemical Sensor System Goals*
The chemical detection system goals are shown below in Table 1, Table 2, and Table 3. Proposers should review these metrics in detail, including the notes.

*Table 1: Chemical detection system-level goals*

| SENSOR NETWORK SYSTEM GOALS | | |
|---|---|---|
| **Parameter** | **Threshold** | **Objective** |
| **Scan rate, long-range\*** | 0.5 km² in 1 hour, 3 story structures | 1 km² in 1 hour, 3 story structures |
| **Scan rate, point-sampler mounted in vehicle\*** | 0.5 km² in 1 hour: equivalent to ~10 km/hour. < 50 m resolution | 1 km² in 1 hour: equivalent to ~20 km/hour. < 30 m resolution |
| \*Nominal urban city block: 100m x 100m, standard sidewalk and 2 vehicle lanes in each block *Proposers should state clearly what spatial resolution and localization capability their system can provide when sensors are operated in long range scanning mode | | |
| **Chemical sensitivity and identification capability\*\*** | > 5 agents plus precursors (e.g., sulfur mustard, TATP, fentanyl) | Adaptable without hardware modification > 20 agents plus precursors (e.g., sulfur mustard, TATP, fentanyl) |
| **Identification sensitivity\*\*** | **Long range, absolute levels:** < 1.25 ppm-m, < 60 s integration **Long range, change in level:** < 0.1 ppm-m **Point sampling mode:** < 5 ppb, < 60 s integration | **Long range, absolute levels:** < 0.25 ppm-m, < 30 s max integration **Long range, change in level:** < 0.05 ppm-m **Point sampling mode:** < 1 ppb, < 30 s integration |
| \*\*Clearly list expected sensitivity and identification capability, including targeted chemical species, expected common confusers, and provide any prior ROC curves and/or confusion matrixes | | |
| **Probability of ID** | 85% | 95% |
| **Probability of false alarm** | $10^{-5}$ | $10^{-6}$ |

*Table 2: Chemical detection system computational goals*

| SYSTEM COMPUTATIONAL GOALS | | |
|---|---|---|
| **Parameter** | **Threshold** | **Objective** |
| **Lag time to identify event after signal integration, detector level (i.e. individual sensor)** | < 5 seconds | < 2 seconds |
| **Lag time to identify/track event after signal integration, system level (i.e. requiring analysis of multiple sensors and integration of contextual data on network)** | < 20 seconds | < 10 seconds |
| **Network computational processing requirements (outside of any on-board processing local to sensor)** | < 1 core per sensor | < 0.1 core, (max 10 per $km^2$) per sensor |
| **Network update interval** | > 1 Hz with GPS location | |
| **Data transfer rate** | < 10 kb/s per sensor | |

*Table 3: Chemical detection system cost goals*

| SYSTEM COST GOALS | | |
|---|---|---|
| **Parameter** | **Threshold** | **Objective** |
| **System cost** | < $600k per $km^2$ of coverage | < $300k per $km^2$ of coverage |
| **Operations cost per year** | < 5% of initial procurement cost | < 2.5% of initial procurement cost |

These system and scanning goals could be met, for example, by a system of versatile, mobile (vehicle-mounted) detectors that can operate as both long-range detectors as well as highly sensitive point detectors. These detectors might be mounted in the cargo spaces of existing vehicle fleets, and normally operated in highly-sensitive point-sensor mode to continuously scan a region for threats and to learn the background. When triggered either by an anomalous detection or by other means, a subset of the detectors might then be converted to long-range scanning mode to further identify the precursor chemicals of interest and spatially isolate the building emitting the effluent. A set of about five such long-range, mobile detectors capable of 300 m sightlines could achieve the desired clearing rate of 1 $km^2$ in one hour of an area with buildings averaging 3 stories high, assuming each detector satisfies the other objective metrics above.

Such a system could be made of sensors described by the additional sensor-level goals in Table 4 below; however, proposers may suggest alternate sensors types and CONOPs that meet the overall system goals. Proposers must fully describe the CONOPs and provide appropriate derived goals.

*Table 4: Additional chemical detection system goals for example CONOPS*

| SENSOR GOALS FOR EXAMPLE CONOPS | | |
|---|---|---|
| **Parameter** | **Threshold** | **Objective** |
| **Type** | semi-mobile, point or long-range | vehicle-transportable, long range, convertible to point sensor |
| **Standoff distance** | > 200 m | > 300 m |
| **Size, weight, power** | < 400 L, 50 kg, 1 kW | < 200 L, 25 kg, 0.5 kW |
| **Environmental tolerance** | -20 to +55 deg C, 20-80% RH | -30 to +65 deg C, 0-100% RH |

DARPA is seeking systems with specified sensitivities and identification capabilities for the broadest number of species, which may be updated for expanded target databases without hardware modification, and that may be converted to point detection operation with equivalent or better detection sensitivities than when in standoff configuration. Proposers may assume detection of a single species for the purposes of detection limits in this context. However, selected performers must demonstrate the same detection limits in complex backgrounds/mixtures.

The government will administer iterative trace species detection challenges that may include specified or unknown target species, detection sensitivities, and environments/backgrounds. Continued participation is contingent on successfully completing each challenge and meeting agreed-upon metrics for each year.

**Technical Area 2: Biological Detection**
The biological detection TA is divided into two separate focus areas: TA2.1 focuses on environmental monitoring solutions for aerosolized bio threats, and TA2.2 focuses on human-based sensors. TA2 proposers may propose to either TA2.1, TA2.2, or both. If both areas are proposed, each must be submitted as a separate proposal.

### a. Technical Area 2.1: Environmental Sensors
For TA2.1, DARPA seeks to develop a system of scalable, versatile, and mobile (ex: vehicle-mounted) air monitoring detectors for continuous surveying of cities for early detection of biological attacks, as well as for monitoring and characterizing benign backgrounds for a wide variety of species. The mobile and real-time network nature of the system could additionally allow external contextual data, such as local weather data, to be taken into account to provide maximum system sensitivity while minimizing false alarms, and to provide rapid secondary screening and adjudication.

DARPA seeks to demonstrate these capabilities in an iterative and agile approach, with the following nominal timeline and accomplishments. Proposers must address their proposed development and deliverable cycles relative to this nominal timeline:

By end of Year 1:  Lab tests, initial deployment of prototypes outdoors for background collection
By end of Year 2:  Outdoor testing covering > 3 km$^2$ with threshold metrics and integration into SIGMA+ network
By end of Year 3:  Field trials covering > 10 km$^2$ with better than threshold metrics
By end of Year 4:  Field trials covering 100 km$^2$ with objective metrics
By end of Year 5:  Large-scale field trials > 100 km$^2$ with objective metrics or better

Proposers are required to propose an integrated system that, in addition to hardware, includes algorithms for real-time data analysis and network integration of the individual sensors to improve detection and identification capabilities, reduce false alarms, and provide spatial and temporal localization of an attack. These algorithms will be scaled for deployment in a cloud environment, and successful performers will be expected to work with the SIGMA+ network backbone team for integration. The system must be capable of automated, real-time and

streaming network operation, but individual sensors should also have stand-alone analysis capabilities in the event of a communications outage or a communications denied environment.

The biological detection system goals for environmental sensing are shown below in Table 5, Table 6, and Table 7.

**Table 5:** *Biological environmental detection system-level goals*

| SENSOR NETWORK SYSTEM GOALS | | |
|---|---|---|
| **Parameter** | **Threshold** | **Objective** |
| **System scan rate*** | 1 km$^2$ in 4 hours<br>100 m & 0.5 PPL resolution<br>< 30 s per scan, with ability to localize signal peak to 5 s | 1 km$^2$ in 4 hours<br>100 m & 0.1 PPL resolution<br>< 30 per scan, with ability to localize signal peak to 5 s |
| **Agent sensitivity**** | Adaptable w/out hardware modification | Adaptable w/out hardware modification |
| | ID > 40 pathogens w/Cat A threats | ID > 40 pathogens w/Cat A threats |
| | < 1500 CFU or PFU sensitivity | < 300 CFU or PFU sensitivity |
| **Probability of ID** | 85% | 95% |
| **False positive rate** | < 10$^{-6}$ | < 10$^{-7}$ |
| *1 km$^2$ is assumed to contain ~20 km of roadway that must be scanned at ~100 m resolution, assuming a vehicle mounted detector. A 5-second localization time provides ~100 m resolution for a vehicle at 20 m/s.<br>**Clearly list expected sensitivity and identification capability, including targeted species, expected common confusers, and provide any prior ROC curves and/or confusion matrixes.<br>**For air sampling approaches, concentrators might be used; clearly define expected flow rates and required size, weight, and power. | | |

**Table 6:** *Biological environmental detection system computational goals*

| SYSTEM COMPUTATIONAL GOALS | | |
|---|---|---|
| **Parameter** | **Threshold** | **Objective** |
| **Lag time to identify event after signal integration, detector level (i.e. individual sensor)** | < 5 seconds | < 2 seconds |
| **Lag time to identify/track event after signal integration, system level (i.e. requiring analysis of multiple sensors and integration of contextual data on network)** | < 20 seconds | < 10 seconds |
| **Network computational processing requirements (outside of any on-board processing)** | < 1 core per sensor | < 0.1 core, (max 10 per km$^2$) per sensor |
| **Network update interval** | 1 Hz with GPS location | |
| **Data transfer rate** | < 10 kb/s per sensor | |

**Table 7:** *Biological environmental detection system cost goals*

| SYSTEM COST GOALS | | |
|---|---|---|
| **Parameter** | **Threshold** | **Objective** |
| **System cost** | < $60k per km$^2$ of coverage | < $30k per km$^2$ of coverage |
| **Operations cost per year** | < 5% of initial procurement cost | < 2.5% of initial procurement cost |

These goals are geared towards a system made of versatile, mobile and continuous air-monitoring detectors for a wide urban area. Such a system could be made of vehicle mounted sensors described by the additional sensor-level goals in Table 8 below; however, proposers may suggest alternate CONOPs that meet the overall system metrics and desire for an adaptable and mobile system.

*Table 8: Additional biological environmental detection system goals for example CONOPS*

| SENSOR GOALS | | |
|---|---|---|
| Size, weight, power* | < 50L, 30 kg, 200 W<br>Vehicle mounted | < 25L, 15 kg, 100 W<br>Vehicle mounted |
| Environmental tolerance | -20 to +55 deg C, 0-100% RH | -30 to +65 deg C, 0-100% RH |
| System cost | < $60k/sensor | < $30k/sensor |
| * Not including concentrators | | |

In all cases, the proposers must fully describe the CONOPs and suggest appropriate derived goals. Proposers should also state if their sensors could be adapted for or have capabilities beyond air monitoring, e.g., for liquids.

The government will administer iterative trace species detection challenges that may include specified or unknown target species, detection sensitivities, and environments/backgrounds. Continued participation in the program is contingent on successfully completing each challenge.

**b. Technical Area 2.2: Human-Based Sensors**

For TA2.2, DARPA seeks to develop a two-tier biological detection system that identifies respiratory pandemics up to three weeks earlier than the state of the art, and provide days earlier detection of large-scale biological attacks. DARPA will field and test this system at scale in order to demonstrate these early warning capabilities. The goal is a system that will measure physiological attributes and biomarkers (defined by the proposer) of an individual, identify deviations from normal to determine if an individual is getting sick, and provide an accurate prediction of the severity of illness before or at the onset of symptoms (tier 1). Suspicion of illness, coupled with predicted severity, will then trigger routing of the individual to obtain accurate point-of-care testing for pathogen identification and reporting (tier 2). Portable point-of-care technology is encouraged, as ultimately diagnostic testing ideally occurs in the home / at the bedside, instead of expecting the patient to travel to a fixed location.

The government will conduct a series of field trials for system capability demonstration. These trials will take an iterative approach as in TA1 and TA2.1; proposers should describe a proposed development and test schedule. As a validation of biological sensing capabilities, the proposed human-based sensor systems should demonstrate detection of a natural influenza outbreak three weeks earlier than the current state of the art in Year 4 of the program. This is envisioned to require deployment of more than 1,000 sensors in Phase 2.

Proposers are required to propose an integrated system that, in addition to hardware, includes algorithms for real-time data analysis and network integration of the individual sensors to improve detection and identification capabilities, and to reduce false alarms. These algorithms will be scaled for deployment in a cloud environment, and successful performers will be

expected to work with the SIGMA+ network backbone team for integration. The system must be capable of automated, real-time and streaming network operation, but individual sensors should also have stand-alone analysis capabilities in the event of a communications outage or a communications denied environment. The proposal must describe and justify the physiological attributes and biomarkers being sensed, as well as the frequency of sensing required to detect aberrations from a healthy state.

Such a system consists of multiple subsystems for tier 1 and tier 2 as follows. First, real-time monitoring of relevant biochemical analytes, such as oxygen, are measured to correspond with tissue-level effects, and deviations from homeostasis are accurately detected. This information can be integrated with measurements of vital signs and activity level, to augment the sensing accuracy of biomarkers. The readout subsystem might consist of a small wearable device that reads out the biomarker assay results, plus a smartphone that performs some level of local data processing and transmits to the network; alternatively, both of these functions could be contained in a single device similar to a smart watch. A suite of data analysis algorithms processes the data (locally, on the network, or a combination of both) to assess whether the wearer is getting sick. Early signs of illness, sensed in real-time as deviations from normal patterns by these advanced algorithms, lead to notifications to the person and encouragement to proceed to a point of care location for further assessment. All these data are collected by the readout subsystem and transmitted to the network backbone for early detection of a potential outbreak or attack.

At the point of care location screening for relevant pathogens and appropriate treatment are conducted. Pathogen information from the point-of-care subsystem is then also transmitted in real time to the network to identify the potential outbreak. It is expected that the point-of-care subsystem is largely based on a COTS platform that may require additional development for additional pathogens and integration into the network.

Proposers must describe how all data will be secured and anonymized, so that there is no risk that potential health information is unprotected.

The goals for this system are shown in Table 9 below, and the derived subsystem goals shown in Table 10, Table 11, and Table 12 below.

Proposers may suggest alternate CONOPs that meet the overall system objectives described above, but must explain how their alternate CONOPs would quantitatively achieve equivalent or better early detection capability within the context of the system metrics and goals provided below. In all cases, proposers must fully provide appropriate derived goals and metrics at the same or greater level of detail as provided below.

*Table 9: Biological human-based detection system goals*

| INTEGRATED SENSOR SYSTEM GOALS | | |
|---|---|---|
| **Parameter** | **Threshold** | **Objective** |
| **Sensor types** | Biomarker sensor + readout system + point-of-care platform | |
| **Pathogen sensitivity, selectivity** | 95% for Influenza A and B, RSV, MERS-CoV, one additional relevant respiratory pathogen* (minimum set) | 95% for Influenza A and B, RSV, MERS-CoV, plus 4 additional relevant respiratory pathogens* |
| **Probability of detection, days prior to onset of symptoms** | 80%, 0 days prior | 95%, 3 days prior |
| **False alarm rate\*\*** | $<10^{-2}$ | |
| **Severity prediction accuracy, days after onset of symptoms\*\*\*** | 80%, 3 days after | 95%, 1 day after |
| **Cost, biomarker sensor plus readout** | < $1k/system (1000 units) | < $500/system (1000 units) |
| **Cost, point-of-care platform** | < $10k/system, $50 per test | < $4k/system, $10 per test |
| *pathogens transmitted by the respiratory route that is contagious and responsible for acute pulmonary pathology<br>**this rate is likely dominated by the false alarm rate of the biomarker sensor and readout system to detect and predict severity of illness | | |

***Levels of severity are defined as follows:

| Level | Oxygen level | Clinical evidence of pneumonia | Care required |
|---|---|---|---|
| Mild | > 90% | No | None |
| Moderate | 85-90% | No | Emergency room visit |
| Severe | < 85% | Yes | Hospitalization |

*Table 10: Biomarker sensor subsystem goals*

| BIOMARKER SENSOR SUBSYSTEM GOALS | | |
|---|---|---|
| **Parameter** | **Threshold** | **Objective** |
| **Size and weight** | minimally invasive | |
| **Power** | self-contained, no power or maintenance required | |

*Additional biomarker sensor subsystem goals:*
- The sensor technology shall be of sufficient maturity to be ready for clinical evaluation (in the context of a clinical research protocol) within 3 months of contract award for initial data collection in humans.
- The sensor shall be scalable to thousands within 4 years.
- The sensor shall have already been demonstrated to function in vivo for at least three months' duration.

*Table 11: External readout sensor subsystem goals*

| EXTERNAL SENSOR SUBSYSTEM GOALS | | |
|---|---|---|
| **Parameter** | **Threshold** | **Objective** |
| **Operating system** | Android or iOS | |
| **Battery life** | > 2 days | |
| **Size** | similar to COTS smart watch or wearable activity tracker | |
| **Weight** | < 100 g | |
| **Data caching** | Required | |
| **Network computational processing requirements** | < 0.05 cores per sensor | < 0.01 cores per sensor |

*Additional external sensor/readout subsystem goals:*
- The proposer shall describe all biometric or environmental data collected by the external sensor and describe how these data streams feed into algorithms for predicting illness.
- The external subsystem shall report averaged biomarker data to the network at a minimum rate of once per minute.
- The external subsystem shall collect and report, at a minimum, averaged biometric information at a minimum frequency of once per minute.

If the external subsystem is composed of a wearable readout sensor plus a smartphone, the following additional goals shall apply:

- The readout sensor shall be capable of continuous wear. Ideally, the device will perform additional functions that are valuable to the wearer.
- The readout sensor shall leverage commercial devices if possible, such as a personal activity tracker or smart watch.

The system goals for the point-of-care platform for infection sensing and pathogen diagnostics are shown below in Table 12.

*Table 12: Pathogen point-of-care subsystem goals*

| PATHOGEN POINT-OF-CARE SUBSYSTEM GOALS | | |
|---|---|---|
| **Parameter** | **Threshold** | **Objective** |
| **Pathogen sensitivity, selectivity** | 95% for Influenza A and B, RSV, MERS-CoV, plus one additional relevant respiratory pathogen* | 95% for Influenza A and B, RSV, MERS-CoV, plus 4 additional relevant respiratory pathogens* |
| **Time to result** | 70 minutes | 30 minutes |
| **Sample type** | Nasal swab | Nasal swab, nasal wash, saliva |
| **Sample preparation** | Internal to the platform | |
| **CLIA status** | Waived / simple | |
| **Size and weight** | < 5 L, < 3 kg | < 2 L, < 1.5 kg |
| **Power** | Both battery and external power operation | |
| *pathogens transmitted by the respiratory route that is contagious and responsible for acute pulmonary pathology. Please provide any prior data on identification and false alarm performance, for example ROC curves and related confusion matrixes. | | |

Proposals must describe the following details about their proposed point-of-care platform:

1. Multiplexing: the ability to evaluate for multiple pathogens, and potentially resistance markers within those pathogens, makes the technology much more widely applicable. Organization of assays around clinical syndromes, with evaluation of multiple pathogens that could cause the syndrome, is preferred.

2. Accuracy: stating performance characteristics of the technology is critical for a successful proposal. Evaluation data from clinical trials, with clinical samples, and with the limits of detection with known quantities of pathogen into appropriate sample types must be included.

3. Ease of use: Technology with ease of use that promotes application in settings outside of the traditional health care system is strongly preferred, including the ability for personnel with minimal training to conduct testing.

4. Ease of integration into population health reporting systems: proposers must describe how the proposed technology easily connects into population health reporting, allowing for seamless integration into data analytics and the SIGMA+ network.

Proposers shall ensure that any sensor development or testing involving human subjects shall adhere to U.S. Government and Department of Defense standards for clinical research to include voluntary participation and informed consent.


## F. Schedule/Milestones

Proposers should provide a technical and programmatic strategy that conforms to the schedule described herein and presents an aggressive plan to fully address all sensor goals, metrics, milestones and deliverables. The task structure must be consistent across the proposed schedule, statement of work, and cost volume.

A target start date of early November, 2018 may be assumed for planning purposes. Schedules will be synchronized across performers, as required, and monitored/revised as necessary throughout the program.

A program kickoff meeting will be held, which all key participants will be required to attend. Performers should also anticipate regular program-wide PI meetings and periodic site visits at the program manager's discretion. Regular teleconference meetings will be scheduled with the government team for progress reporting as well as problems identification and mitigation. All proposals must include these meetings and travel in the proposed schedule and costs. Proposers should assume a program update teleconference frequency of at least once per month, and should budget travel costs for a minimal total of two meetings, averaging three days each, for each year of performance. It is expected that most of these meetings will be in the Washington, D.C. area, but performers should assume sufficient budget for each trip to account for a potential west coast meeting. These in-person meetings could consist of in-person program updates and system and field trials coordination activities and would consist of, on average, the PI and two technical leads.

### G. Deliverables

Performers will be expected to provide at a minimum the following deliverables:
- Monthly financial reports, due within ten days following the reporting month
- Comprehensive quarterly technical reports due within ten days of the end of the given quarter, describing progress made on the specific milestones as laid out in the SOW.
- A phase completion report submitted within 30 days of the end of each phase, summarizing the research done.
- Other negotiated deliverables specific to the objectives of the individual efforts. These may include developed detectors and prototypes, registered reports, experimental protocols, publications, intermediate and final versions of software libraries, code, and APIs, including documentation and user manuals, and/or a comprehensive assemblage of design documents, models, modeling data and results, and model validation data.
- Reporting as outlined in Section VI.C.


### H. Other Program Objectives and Considerations

#### 1. Collaboration

All sensors BAA awardees will be required to work collaboratively with the DARPA designated network performer to develop a fully integrated solution. All proposals must clearly describe plans for interfacing and integrating their proposed technologies/approaches with the network, with integration starting in Year 2 at the latest, and full integration of a prototype sensor(s) completed by end of Year 2. Current SIGMA sensor APIs will be provided to awarded performers. Furthermore, all performers will be required to collaborate, as applicable, with Government team members and transition partners/end users. Proposers should accommodate the need for interfacing and integrating with other parties in their proposal development.

To facilitate collaboration, it is expected that performers will enter into an Associate Contractor Agreement (ACA) with the current SIGMA network performer, and will enter into an ACA with any future DARPA designated network performers. The ACA will include the basis for sharing information, data, technical knowledge, expertise and/or resources essential to the integration of the program technical areas and components. This ACA will ensure appropriate coordination and integration of work by program contractors, ensure complete compatibility between data, tools and services, and prevent unnecessary duplication of efforts and maximize commonality. Without exception, the ACAs must be in place within three months of contract award.


#### 2. Intellectual Property

A key goal of the program is to establish an open, standards-based, multi-source, plug-and-play architecture that allows for interoperability and integration. This includes the ability to easily add, remove, substitute, and modify software and hardware components. This will facilitate rapid innovation by providing a base for future users or developers of program technologies and deliverables. Therefore, it is desired that all noncommercial software (including source code), software documentation, hardware designs and documentation, and technical data generated, developed, and/or delivered by the program be provided as deliverables to the Government, with

a minimum of Government Purpose Rights (GPR), as lesser rights may adversely impact the lifecycle costs of affected items, components, or processes.  Unlimited government rights are preferred.

## II.  Award Information

### A.  General Award Information

DARPA anticipates multiple awards.

The level of funding for individual awards made under this BAA will depend on the quality of the proposals received and the availability of funds. Awards will be made to proposers[1] whose proposals are determined to be the most advantageous to the Government, all evaluation factors considered.  See Section V for further information.

The Government reserves the right to:

- select for negotiation all, some, one, or none of the proposals received in response to this solicitation;
- make awards without discussions with proposers;
- conduct discussions with proposers if it is later determined to be necessary;
- segregate portions of resulting awards into pre-priced options;
- accept proposals in their entirety or to select only portions of proposals for award;
- fund awards in increments with options for continued work at the end of one or more phases;
- request additional documentation once the award instrument has been determined (e.g., representations and certifications); and
- remove proposers from award consideration should the parties fail to reach agreement on award terms within a reasonable time or the proposer fails to provide requested additional information in a timely manner.

Proposals identified for negotiation may result in a procurement contract, cooperative agreement, or other transaction (OT), depending upon the nature of the work proposed, the required degree of interaction between parties, and other factors.

Proposers looking for innovative, commercial-like contractual arrangements are encouraged to consider requesting Other Transactions.  To understand the flexibility and options associated with Other Transactions, consult http://www.darpa.mil/work-with-us/contract-management#OtherTransactions.

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[1] As used throughout this BAA, "proposer" refers to the lead organization on a submission to this BAA.  The proposer is responsible for ensuring that all information required by a BAA--from all team members--is submitted in accordance with the BAA.  "Awardee" refers to anyone who might receive a prime award from the Government, including recipients of procurement contracts, cooperative agreements, or Other Transactions.  "Subawardee" refers to anyone who might receive a subaward from a prime awardee (e.g., subawardee, consultant, etc.).

In all cases, the Government contracting officer shall have sole discretion to select award instrument type, regardless of instrument type proposed, and to negotiate all instrument terms and conditions with selectees.  DARPA will apply publication or other restrictions, as necessary, if it determines that the research resulting from the proposed effort will present a high likelihood of disclosing performance characteristics of military systems or manufacturing technologies that are unique and critical to defense.  Any award resulting from such a determination will include a requirement for DARPA permission before publishing any information or results on the program.  For more information on publication restrictions, see the section below on Fundamental Research.

## B.  Fundamental Research

It is DoD policy that the publication of products of fundamental research will remain unrestricted to the maximum extent possible.  National Security Decision Directive (NSDD) 189 defines fundamental research as follows:

> 'Fundamental research' means basic and applied research in science and engineering, the results of which ordinarily are published and shared broadly within the scientific community, as distinguished from proprietary research and from industrial development, design, production, and product utilization, the results of which ordinarily are restricted for proprietary or national security reasons.

As of the date of publication of this BAA, the Government expects that program goals as described herein either cannot be met by proposers intending to perform fundamental research or the proposed research is anticipated to present a high likelihood of disclosing performance characteristics of military systems or manufacturing technologies that are unique and critical to defense.  Therefore, the Government anticipates restrictions on the resultant research that will require the awardee to seek DARPA permission before publishing any information or results relative to the program.

Proposers should indicate in their proposal whether they believe the scope of the research included in their proposal is fundamental or not.  While proposers should clearly explain the intended results of their research, the Government shall have sole discretion to determine whether the proposed research shall be considered fundamental.  Appropriate clauses will be included in resultant awards for non-fundamental research to prescribe publication requirements and other restrictions, as appropriate.  This clause can be found at www.darpa.mil/work-with-us/additional-baa.

For certain research projects, it may be possible that although the research to be performed by a potential awardee is restricted research, their subawardee's effort may be fundamental research.  In those cases, it is the awardee's responsibility to explain in their proposal why its subawardee's effort is fundamental research.

## III.  Eligibility Information

### A.  Eligible Applicants

All responsible sources capable of satisfying the Government's needs may submit a proposal DARPA's consideration.

1. **Federally Funded Research and Development Centers (FFRDCs) and Government Entities**

   a. **FFRDCs**

FFRDCs are subject to applicable direct competition limitations and cannot propose to this BAA in any capacity unless they meet the following conditions:  (1) FFRDCs must clearly demonstrate that the proposed work is not otherwise available from the private sector.  (2) FFRDCs must provide a letter on official letterhead from their sponsoring organization citing the specific authority establishing their eligibility to propose to Government solicitations and compete with industry, and their compliance with the associated FFRDC sponsor agreement's terms and conditions.  This information is required for FFRDCs proposing to be awardees or subawardees.

   b. **Government Entities**

Government Entities (e.g., Government/National laboratories, military educational institutions, etc.) are subject to applicable direct competition limitations.  Government entities must clearly demonstrate that the work is not otherwise available from the private sector and provide written documentation citing the specific statutory authority and contractual authority, if relevant, establishing their ability to propose to Government solicitations. This information is required for Government Entities proposing to be awardees or subawardees.

   c. **Authority and Eligibility**

At the present time, DARPA does not consider 15 U.S.C. § 3710a to be sufficient legal authority to show eligibility.  While 10 U.S.C.§ 2539b may be the appropriate statutory starting point for some entities, specific supporting regulatory guidance, together with evidence of agency approval, will still be required to fully establish eligibility.  DARPA will consider FFRDC and Government entity eligibility submissions on a case-by-case basis; however, the burden to prove eligibility for all team members rests solely with the proposer.

2. **Foreign Participation**

Non-U.S. organizations and/or individuals may participate to the extent that such participants comply with any necessary nondisclosure agreements, security regulations, export control laws, and other governing statutes applicable under the circumstances.  For classified submissions, this includes mitigating any Foreign Ownership Control and Influence (FOCI) issues prior to transmitting the submission to DARPA.  Additional information on these subjects can be found at http://www.dss.mil/isp/foci/foci_faqs.html.

B.  **Organizational Conflicts of Interest**

FAR 9.5 Requirements

In accordance with FAR 9.5, proposers are required to identify and disclose all facts relevant to potential OCIs involving the proposer's organization and *any* proposed team member (subawardee, consultant). Under this Section, the proposer is responsible for providing this disclosure with each proposal submitted to the BAA. The disclosure must include the proposer's, and as applicable, proposed team member's OCI mitigation plan. The OCI mitigation plan must include a description of the actions the proposer has taken, or intends to take, to prevent the existence of conflicting roles that might bias the proposer's judgment and to prevent the proposer from having unfair competitive advantage. The OCI mitigation plan will specifically discuss the disclosed OCI in the context of each of the OCI limitations outlined in FAR 9.505-1 through FAR 9.505-4.

Agency Supplemental OCI Policy

In addition, DARPA has a supplemental OCI policy that prohibits contractors/performers from concurrently providing Scientific Engineering Technical Assistance (SETA), Advisory and Assistance Services (A&AS) or similar support services and being a technical performer. Therefore, as part of the FAR 9.5 disclosure requirement above, a proposer must affirm whether the proposer or *any* proposed team member (subawardee, consultant) is providing SETA, A&AS, or similar support to any DARPA office(s) under: (a) a current award or subaward; or (b) a past award or subaward that ended within one calendar year prior to the proposal's submission date.

If SETA, A&AS, or similar support is being or was provided to any DARPA office(s), the proposal must include:

- The name of the DARPA office receiving the support;
- The prime contract number;
- Identification of proposed team member (subawardee, consultant) providing the support; and
- An OCI mitigation plan in accordance with FAR 9.5.

Government Procedures

In accordance with FAR 9.503, 9.504 and 9.506, the Government will evaluate OCI mitigation plans to avoid, neutralize or mitigate potential OCI issues before award and to determine whether it is in the Government's interest to grant a waiver. The Government will only evaluate OCI mitigation plans for proposals that are determined selectable under the BAA evaluation criteria and funding availability.

The Government may require proposers to provide additional information to assist the Government in evaluating the proposer's OCI mitigation plan.

If the Government determines that a proposer failed to fully disclose an OCI; or failed to provide the affirmation of DARPA support as described above; or failed to reasonably provide additional information requested by the Government to assist in evaluating the proposer's OCI mitigation plan, the Government may reject the proposal and withdraw it from consideration for award.

## C. Cost Sharing/Matching

Cost sharing is not required; however, it will be carefully considered where there is an applicable

statutory condition relating to the selected funding instrument (e.g., OTs under the authority of 10 U.S.C. § 2371). For additional information on DARPA's authority to award OT agreements, please see http://www.darpa.mil/work-with-us/contract-management#OtherTransactions.

## IV. Application and Submission Information

Prior to submitting a full proposal, proposers are *strongly encouraged* to first submit an abstract as described below. This process allows a proposer to ascertain whether the proposed concept is: (1) applicable to the SIGMA+ Sensors BAA and (2) currently of interest. For the purposes of this BAA, applicability is defined as follows:

- The proposed concept is applicable to the technical areas described herein.
- The proposed concept is important to DSO's current investment portfolio.
- The proposed concept investigates an innovative approach that enables revolutionary advances, i.e., will not primarily result in evolutionary improvements to the existing state of practice.
- The proposed work has not already been completed (i.e., the research element is complete but manufacturing/fabrication funds are required).
- The proposer has not already received funding or a positive funding decision for the proposed concept (whether from DARPA or another Government agency).

Abstracts and full proposals that are not found to be applicable to the SIGMA+ Sensors BAA as defined above may be deemed non-conforming[2] and removed from consideration. All abstracts and full proposals must provide sufficient information to assess the validity/feasibility of their claims as well as comply with the requirements outlined herein for submission formatting, content and transmission to DARPA. Abstracts and full proposals that fail to do so may be deemed non-conforming and removed from consideration. Proposers will be notified of non-conforming determinations via letter.

### A. Address to Request Application Package

This document contains all information required to submit a response to this solicitation. No additional forms, kits, or other materials are needed except as referenced herein. No request for proposal or additional solicitation regarding this opportunity will be issued, nor is additional information available except as provided at the Federal Business Opportunities website (http://www.fbo.gov), the Grants.gov website (http://www.grants.gov/), or referenced herein.

### B. Content and Form of Application Submission

#### 1. Abstract Information

As stated above, proposers are strongly encouraged to submit an abstract in advance of a full proposal to minimize effort and reduce the potential expense of preparing an out of scope proposal. The abstract provides a synopsis of the proposed project by briefly answering the following questions:

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[2] "Conforming" is defined as having been submitted in accordance with the requirements outlined herein.

- What is the proposed work attempting to accomplish or do?
- How is it done today, and what are the limitations?
- Who will care and what will the impact be if the work is successful?
- How much will it cost, and how long will it take?

DARPA will respond to abstracts with a statement as to whether DARPA is interested in the idea. If DARPA does not recommend the proposer submit a full proposal, DARPA will provide feedback to the proposer regarding the rationale for this decision. Regardless of DARPA's response to an abstract, proposers may submit a full proposal. DARPA will review all conforming full proposals using the published evaluation criteria and without regard to any comments resulting from the review of an abstract.

Proposers should note that a favorable response to an abstract is not a guarantee that a proposal based on the abstract will ultimately be selected for award negotiation.

While it is DARPA policy to attempt to reply to abstracts within thirty calendar days, proposers to this solicitation may anticipate a response within approximately two weeks. These official notifications will be sent via email to the Technical POC and/or Administrative POC identified on the abstract coversheet.

### a. Abstract Format

All proposers are required to use Attachment A: Abstract Summary Slide Template and Attachment B: Abstract Template provided to this solicitation on http://www.fbo.gov and http://www.grants.gov. Attachment A Abstract Summary Slide Template must be in .ppt or .pptx format and should be attached as a separate file to this document.

Proposers are strongly encouraged to review Sections I.B-E to ensure their abstract addresses SIGMA+ program objectives and technical requirements.

### 2. Full Proposal Information

Proposals consist of Volume 1: Technical and Management Volume, Volume 2: Cost Volume, and Volume 3: Administrative and National Policy Requirements).

To assist in proposal development, various attachments have been provided along with the BAA posted on http://www.fbo.gov (Attachment C: Proposal Summary Slide Template; Attachment D: Proposal Template Volume 1 Technical & Management Volume; Attachment E: Milestones and Deliverables Table; Attachment F: Proposal Template Volume 2 Cost Volume; Attachment G: Proposal Template Volume 2 Cost Summary; and Attachment H: Proposal Template Volume 3 Administrative & National Policy Requirements Volume).

Full proposals requesting a procurement contract or other transaction (OT) must use the following attachments:
- Attachment C
- Attachment D

- Attachment E
- Attachment F
- Attachment G
- Attachment H

Full proposals requesting a cooperative agreement must use the following attachments in addition to the Grants.gov application package:
- Attachment C
- Attachment D
- Attachment E
- Attachment G
- Attachment H
  *Note – Budget Justification should be provided as Section L of the SF 424 Research & Related Budget form provided via Grants.gov. The Budget Justification should include the following information for the recipient and all subawardees: (1) Direct Labor: Detail the total number of persons and their level of commitment for each position listed (in sections A and B), as well as which specific tasks (as described in the SOW) they will support.(2) Equipment (section C) Provide an explanation for listed requested equipment exceeding $5,000, properly justifying their need to meet the objectives of the program. (3) Travel (section D) Provide the purpose of the trip,

Proposers are strongly encouraged to review Sections I.B-E to ensure their proposal, within the template and framework provided below, fully addresses SIGMA+ program objectives and the specified requirements and questions discussed in Sections I.B-E.

Proposals not meeting the format prescribed herein may not be reviewed.

### a. Full Proposal Format

All proposers are required to use the templates provided as attachments to this solicitation on https://www.fbo.gov and https://www.grants.gov.  Formatting instructions are provided therein.

### 3. Proprietary Information

Proposers are responsible for clearly identifying proprietary information.  Submissions containing proprietary information must have the cover page and each page containing such information clearly marked with a label such as "Proprietary" or "Company Proprietary."  NOTE: "Confidential" is a classification marking used to control the dissemination of U.S. Government National Security Information as dictated in Executive Order 13526 and should not be used to identify proprietary business information.  See Section V.B.1 for additional information.

### 4. Security Information

DARPA anticipates that submissions received under this BAA will be unclassified.  However, should a proposer wish to submit classified information, an *unclassified* email must be sent to the BAA mailbox requesting submission instructions from the DARPA/DSO Program Security Officer (PSO).

Security classification guidance and direction via a SCG and/or DD Form 254, "DoD Contract Security Classification Specification," will not be provided at this time, since DARPA is soliciting ideas only.  If a determination is made that the award instrument may result in access to classified information, a SCG and/or DD Form 254 will be issued by DARPA and attached as part of the award.

## C.  Submission Dates and Times

Proposers are warned that submission deadlines as outlined herein are in Eastern Time and will be strictly enforced.  When planning a response to this solicitation, proposers should take into account that some parts of the submission process may take from one business day to one month to complete (e.g., registering for a DUNS number or TIN).

DARPA will acknowledge receipt of *complete* submissions via email and assign identifying numbers that should be used in all further correspondence regarding those submissions.  If no confirmation is received within two business days, please contact the BAA Administrator at SigmaPlus@darpa.mil to verify receipt.

### 1.  Abstracts

Abstracts must be submitted per the instructions outlined herein *and received by DARPA* no later than the due date and time listed in Part One: Overview Information.  Abstracts received after this time and date may not be reviewed.

### 2.  Full Proposals

Full proposal packages--full proposal (Technical and Management Volume, Cost Volume, National and Administrative Requirements) and, as applicable, proprietary subawardee cost proposals, classified appendices to unclassified proposals-- must be submitted per the instructions outlined herein *and received by DARPA* no later than the due date and time listed in Part One: Overview Information.  Proposals received after this time and date may not be reviewed.

## D.  Funding Restrictions

Not applicable.

## E.  Other Submission Requirements

### 1.  Unclassified Submission Instructions

Proposers must submit all parts of their submission package using the same method; submissions cannot be sent in part by one method and in part by another method nor should duplicate submissions be sent by multiple methods.  Email submissions will not be accepted. Failure to comply with the submission procedures outlined herein may result in the submission being deemed non-conforming and withdrawn from consideration.

#### a.  Abstracts

DARPA/DSO will employ an electronic upload submission system (https://baa.darpa.mil/) for all UNCLASSIFIED abstracts sent in response to this solicitation. *Abstracts must not be submitted via Grants.gov.*

First time users of the DARPA BAA Submission website must complete a two-step account creation process. The first step consists of registering for an extranet account by going to the URL listed above and selecting the "Account Request" link. Upon completion of the online form, proposers will receive two separate emails; one will contain a user name and the second will provide a temporary password. Once both emails have been received, the second step requires proposers to go back to the submission website and log in using that user name and password. After accessing the extranet, proposers may then create a user account for the DARPA BAA Submission website by selecting the "Register your Organization" link at the top of the page. Once the user account is created, proposers will be able to see a list of solicitations open for submissions, view submission instructions, and upload/finalize their abstract.

Proposers who already have an account on the DARPA BAA Submission website may simply log in at https://baa.darpa.mil/, select this solicitation from the list of open DARPA solicitations and proceed with their abstract submission. Note: proposers who have created a DARPA BAA Submission website account to submit to another DARPA Technical Office's solicitations do not need to create a new account to submit to this solicitation.

All abstracts submitted electronically through the DARPA BAA Submission website must meet the following requirements: (1) uploaded as a zip file (.zip or .zipx extension); (2) only contain the document(s) requested herein; (3) only contain unclassified information; and (4) must not exceed 100 MB in size. Only one zip file will be accepted per abstract and abstracts not uploaded as zip files will be rejected by DARPA.

Technical support for the DARPA BAA Submission website is available during regular business hours, Monday – Friday, 9:00 a.m. – 5:00 p.m. Requests for technical support must be emailed to BAAT_Support@darpa.mil with a copy to SigmaPlus@darpa.mil. Questions regarding submission contents, format, deadlines, etc. should be emailed to SigmaPlus@darpa.mil. Questions/requests for support sent to any other email address may result in delayed/no response.

*Since proposers may encounter heavy traffic on the web server, DARPA discourages waiting until the day abstracts are due to request an account and/or upload the submission.*
*Note: Proposers submitting an abstract via the DARPA BAA Submission site MUST (1) click the "Finalize" button in order for the submission to upload AND (2) do so with sufficient time for the upload to complete prior to the deadline. Failure to do so will result in a late submission.*

### b. Proposals Requesting a Procurement Contract or Other Transaction

Proposers requesting procurement contracts or other transactions may submit full proposals through ONE of the following methods: (1) electronic upload (DARPA-preferred); or (2) direct mail/hand-carry.

### i. Electronic Upload
DARPA/DSO encourages proposers to submit UNCLASSIFIED proposals via the DARPA BAA

Submission website at https://baa.darpa.mil/.

First time users of the DARPA BAA Submission website must complete a two-step account creation process. The first step consists of registering for an extranet account by going to the URL listed above and selecting the "Account Request" link. Upon completion of the online form, proposers will receive two separate emails; one will contain a user name and the second will provide a temporary password. Once both emails have been received, the second step requires proposers to go back to the submission website and log in using that user name and password. After accessing the extranet, proposers may then create a user account for the DARPA BAA Submission website by selecting the "Register your Organization" link at the top of the page. Once the user account is created, proposers will be able to see a list of solicitations open for submissions, view submission instructions, and upload/finalize their proposal.

Proposers who already have an account on the DARPA BAA Submission website may simply log in at https://baa.darpa.mil/, select this solicitation from the list of open DARPA solicitations and proceed with their proposal submission. *Note: proposers who have created a DARPA BAA Submission website account to submit to another DARPA Technical Office's solicitations do not need to create a new account to submit to this solicitation.*

All full proposals submitted electronically through the DARPA BAA Submission website must meet the following requirements: (1) uploaded as a zip file (.zip or .zipx extension); (2) only contain the document(s) requested herein; (3) only contain unclassified information; and (4) must not exceed 100 MB in size. Only one zip file will be accepted per full proposal and full proposals not uploaded as zip files will be rejected by DARPA.

Technical support for the DARPA BAA Submission website is available during regular business hours, Monday – Friday, 9:00 a.m. – 5:00 p.m. Requests for technical support must be emailed to BAAT_Support@darpa.mil with a copy to SigmaPlus@darpa.mil. Questions regarding submission contents, format, deadlines, etc. should be emailed to SigmaPlus@darpa.mil. Questions/requests for support sent to any other email address may result in delayed/no response.

*Since proposers may encounter heavy traffic on the web server, DARPA discourages waiting until the day proposals are due to request an account and/or upload the submission. Note: Proposers submitting a proposal via the DARPA BAA Submission site MUST (1) click the "Finalize" button in order for the submission to upload AND (2) do so with sufficient time for the upload to complete prior to the deadline. Failure to do so will result in a late submission.*

### ii. Direct Mail/Hand-carry

Proposers electing to submit procurement contract or other transaction proposals via direct mail or hand-carried must provide one paper copy and one electronic copy on CD or DVD of the full proposal package. All parts of the proposal package must be mailed or hand-carried in a single delivery to the address noted in Section VII below.

### c. Proposals Requesting a Cooperative Agreement

Proposers requesting cooperative agreements may only submit proposals through ONE of the following methods: (1) electronic upload at Grants.gov (DARPA-preferred); or (2) direct mail/hand-carry to DARPA

### i. Electronic Upload

DARPA encourages cooperative agreement proposers to submit their proposals via electronic upload at http://www.grants.gov/web/grants/applicants/apply-for-grants.html. Proposers electing to use this method must complete a one-time registration process on Grants.gov before a proposal can be electronically submitted. *If proposers have not previously registered, this process can take up to four weeks so* registration should be done in sufficient time to ensure it does not impact a proposer's ability to meet required submission deadlines. Registration requirements and instructions are outlined at http://www.grants.gov/web/grants/register.html.

Carefully follow the DARPA submission instructions provided with the solicitation application package on Grants.gov. Only the required forms listed therein should be included in the submission. *Note: Grants.gov does not accept zipped or encrypted proposals.*

Once Grants.gov has received an uploaded proposal submission, Grants.gov will send two email messages to notify proposers that: (1) the proposal has been received by Grants.gov; and (2) the proposal has been either validated or rejected by the system. *It may take up to two business days to receive these emails.* If the proposal is validated, then the proposer has successfully submitted their proposal. If the proposal is rejected, the submission must be corrected, resubmitted and revalidated before DARPA can retrieve it. If the solicitation is no longer open, the rejected proposal cannot be resubmitted. Once the proposal is retrieved by DARPA, Grants.gov will send a third email to notify the proposer. DARPA will send a final confirmation email as described in Section IV.C.

*To avoid missing deadlines, Grants.gov recommends that proposers submit their proposals to Grants.gov 24-48 hours in advance of the proposal due date to provide sufficient time to complete the registration and submission process, receive email notifications and correct errors, as applicable.*

Technical support for Grants.gov submissions may be reached at 1-800-518-4726 or support@grants.gov.

### ii. Direct Mail/Hand-carry

Proposers electing to submit cooperative agreement proposals via direct mail or hand-carried must provide one paper copy and one electronic copy on CD or DVD of the full proposal package. Proposers must complete the mandatory forms (e.g., SF 424 R&R) provided at Grants.gov as part of the opportunity application package for this BAA and include them in the proposal submission. All parts of the proposal package must be mailed or hand-carried to the address noted in Section VII below.

## V. Application Review Information

### A. Evaluation Criteria

Proposals will be evaluated using the following criteria listed in descending order of importance: Overall Scientific and Technical Merit; Potential Contribution and Relevance to the DARPA Mission; and Cost Realism.

- **Overall Scientific and Technical Merit**

The proposed technical approach is innovative, feasible, achievable, and complete.

The proposed technical team has the expertise and experience to accomplish the proposed tasks. Task descriptions and associated technical elements provided are complete and in a logical sequence with all proposed deliverables clearly defined such that a final outcome that achieves the goal can be expected as a result of award. The proposal identifies major technical risks and planned mitigation efforts are clearly defined and feasible.

- **Potential Contribution and Relevance to the DARPA Mission**

The potential contributions of the proposed effort are relevant to the national technology base. Specifically, DARPA's mission is to make pivotal early technology investments that create or prevent strategic surprise for U.S. National Security.

The proposed intellectual property restrictions (if any) will not significantly impact the Government's ability to transition the technology and its integration within the SIGMA+ system.

- **Cost Realism**

The proposed costs are realistic for the technical and management approach and accurately reflect the technical goals and objectives of the solicitation. The proposed costs are consistent with the proposer's Statement of Work and reflect a sufficient understanding of the costs and level of effort needed to successfully accomplish the proposed technical approach. The costs for the prime proposer and proposed subawardees are substantiated by the details provided in the proposal (e.g., the type and number of labor hours proposed per task, the types and quantities of materials, equipment and fabrication costs, travel and any other applicable costs and the basis for the estimates).

## B. Review and Selection Process

DARPA will conduct a scientific/technical review of each conforming proposal. Conforming proposals comply with all requirements detailed in this BAA; proposals that fail to do so may be deemed non-conforming and may be removed from consideration. Proposals will not be evaluated against each other since they are not submitted in accordance with a common work statement. DARPA's intent is to review proposals as soon as possible after they arrive; however, proposals may be reviewed periodically for administrative reasons.

The review process identifies proposals that meet the evaluation criteria described above and are, therefore, selectable for negotiation of awards by the Government. DARPA policy is to ensure impartial, equitable, comprehensive proposal evaluations and to select proposals that meet DARPA technical, policy, and programmatic goals. Proposals that are determined selectable will not necessarily receive awards (see Section II). Selections may be made at any time during the period of solicitation. For evaluation purposes, a proposal is defined to be the document and

supporting materials as described in Section IV.

### 1. Handling of Source Selection Information

DARPA policy is to treat all submissions as source selection information (FAR 2.101 and 3.104), and to only disclose their contents to authorized personnel. Restrictive notices notwithstanding, submissions may be handled by support contractors for administrative purposes and/or to assist with technical evaluation. All DARPA support contractors performing this role are expressly prohibited from performing DARPA-sponsored technical research and are bound by appropriate nondisclosure agreements. Subject to the restrictions set forth in FAR 37.203(d), DARPA may also request input on technical aspects of the proposals from other non-Government consultants/experts who are strictly bound by the appropriate non-disclosure requirements.

Submissions will not be returned. The original of each submission received will be retained at DARPA and all other non-required copies destroyed. A certification of destruction may be requested via email to the BAA mailbox, provided the formal request is received within 5 days after being notified of submission status.

### C. Federal Awardee Performance and Integrity Information (FAPIIS)

Following the review and selection process described above, but prior to making an award above the simplified acquisition threshold (FAR 2.101), DARPA is required[3] to review and consider any information available through the designated integrity and performance system (currently FAPIIS). Selectees have the opportunity to comment on any information about themselves entered in the database. DARPA will consider any comments and other information in FAPIIS or other systems prior to making an award.

## VI. Award Administration Information

### A. Selection Notices

After proposal evaluations are complete, proposers will be notified as to whether their proposal was selected for award negotiation as a result of the review process. Notification will be sent by email to the Technical and Administrative POCs identified on the proposal cover sheet. If a proposal has been selected for award negotiation, the Government will initiate those negotiations following the notification.

### B. Administrative and National Policy Requirements

### 1. Solicitation Provisions and Award Clauses, Terms and Conditions

Solicitation provisions relevant to DARPA BAAs are listed on the Additional BAA Content page on DARPA's website at www.darpa.mil/work-with-us/additional-baa. This page also lists award clauses that, depending on their applicability, may be included in the terms and conditions of awards resultant from DARPA solicitations. This list is not exhaustive and the clauses, terms and conditions included in a resultant award will depend on the nature of the research effort, the

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[3] Per 41 U.S.C. 2313, as implemented by FAR 9.103 and 2 CFR § 200.205.

specific award instrument, the type of awardee, and any applicable security or publication restrictions.

For terms and conditions specific to cooperative agreements, see the DoD General Research Terms and Conditions (latest version) at www.onr.navy.mil/Contracts-Grants/submit-proposal/grants-proposal/grants-terms-conditions.aspx and the supplemental DARPA-specific terms and conditions at:
 www.darpa.mil/work-with-us/contract-management#GrantsCooperativeAgreements.

The above information serves to put potential proposers and awardees on notice of proposal requirements and award terms and conditions to which they may have to adhere.

## 2.  System for Award Management (SAM) and Universal Identifier Requirements

All proposers must be registered in SAM unless exempt per FAR 4.1102.  FAR 52.204-7, "System for Award Management" and FAR 52.204-13, "System for Award Management Maintenance" are incorporated into this BAA.  See http://www.darpa.mil/work-with-us/additional-baa for further information.

NOTE: new registrations can take an average of 7-10 business days to process in SAM. SAM registration requires the following information:
- DUNS number
- TIN
- CAGE Code.  If a proposer does not already have a CAGE code, one will be assigned during SAM registration.
- Electronic Funds Transfer information (e.g., proposer's bank account number, routing number, and bank phone or fax number).

## 3.  Representations and Certifications

In accordance with FAR 4.1102 and 4.1201, proposers requesting a procurement contract must complete electronic annual representations and certifications at www.sam.gov/.  In addition, resultant procurement contracts will require supplementary DARPA-specific representations and certifications. See www.darpa.mil/work-with-us/additional-baa for further information.

## 4.  Intellectual Property

Proposers should note that the Government does not own the intellectual property or technical data/computer software developed under Government contracts.  The Government acquires the right to use the technical data/computer software.  Regardless of the scope of the Government's rights, awardees may freely use their same data/software for their own commercial purposes (unless restricted by U.S. export control laws or security classification).  Therefore, technical data and computer software developed under this solicitation will remain the property of the awardees, though DARPA will have, at a minimum, Government Purpose Rights (GPR) to technical data and computer software developed through mixed sponsorship.

If proposers desire to use proprietary computer software or technical data or both as the basis of their proposed approach, in whole or in part, they should: (1) clearly identify such software/data and its proposed particular use(s); (2) explain how the Government will be able to reach its program goals (including transition) within the proprietary model offered; and (3) provide possible nonproprietary alternatives in any area that might present transition difficulties or increased risk or cost to the Government under the proposed proprietary solution. Proposers expecting to use, but not to deliver, commercial open source tools or other materials in implementing their approach may be required to indemnify the Government against legal liability arising from such use.

All references to "Unlimited Rights" or "Government Purpose Rights" are intended to refer to the definitions of those terms as set forth in the Defense Federal Acquisition Regulation Supplement (DFARS) 227.

### a. Intellectual Property Representations

All proposers must provide a good faith representation of either ownership or possession of appropriate licensing rights to all other intellectual property to be used for the proposed project. Proposers must provide a short summary for each item asserted with less than unlimited rights that describes the nature of the restriction and the intended use of the intellectual property in the conduct of the proposed research.

### b. Patents

All proposers must include documentation proving ownership or possession of appropriate licensing rights to all patented inventions to be used for the proposed project. If a patent application has been filed for an invention, but it includes proprietary information and is not publicly available, a proposer must provide documentation that includes: the patent number, inventor name(s), assignee names (if any), filing date, filing date of any related provisional application, and summary of the patent title, with either: (1) a representation of invention ownership; or (2) proof of possession of appropriate licensing rights in the invention (i.e., an agreement from the owner of the patent granting license to the proposer)..

### c. Procurement Contracts

- **Noncommercial Items (Technical Data and Computer Software):** Proposers requesting a procurement contract must list all noncommercial technical data and computer software that it plans to generate, develop, and/or deliver, in which the Government will acquire less than unlimited rights and to assert specific restrictions on those deliverables. In the event a proposer does not submit the list, the Government will assume that it has unlimited rights to all noncommercial technical data and computer software generated, developed, and/or delivered, unless it is substantiated that development of the noncommercial technical data and computer software occurred with mixed funding. If mixed funding is anticipated in the development of noncommercial technical data and computer software generated, developed, and/or delivered, proposers should identify the data and software in question as subject to GPR. In accordance with DFARS 252.227-7013, "Rights in Technical Data - Noncommercial Items," and DFARS 252.227-7014, "Rights in Noncommercial Computer Software and Noncommercial Computer Software Documentation," the Government will

automatically assume that any such GPR restriction is limited to a period of 5 years, at which time the Government will acquire unlimited rights unless the parties agree otherwise. The Government may use the list during the evaluation process to evaluate the impact of any identified restrictions and may request additional information from the proposer, as may be necessary, to evaluate the proposer's assertions. Failure to provide full information may result in a determination that the proposal is non-conforming.

- **Commercial Items (Technical Data and Computer Software):** Proposers requesting a procurement contract must list all commercial technical data and commercial computer software that may be included in any noncommercial deliverables contemplated under the research project, and assert any applicable restrictions on the Government's use of such commercial technical data and/or computer software. In the event a proposer does not submit the list, the Government will assume there are no restrictions on the Government's use of such commercial items. The Government may use the list during the evaluation process to evaluate the impact of any identified restrictions and may request additional information from the proposer to evaluate the proposer's assertions. Failure to provide full information may result in a determination that the proposal is non-conforming.

### d. Other Types of Awards

Proposers requesting an award instrument other than a procurement contract shall follow the applicable rules and regulations governing those award instruments, but in all cases should appropriately identify any potential restrictions on the Government's use of any intellectual property contemplated under those award instruments. This includes both noncommercial items and commercial items. The Government may use the list as part of the evaluation process to assess the impact of any identified restrictions, and may request additional information from the proposer, to evaluate the proposer's assertions. Failure to provide full information may result in a determination that the proposal is non-conforming. A template for complying with this request is provided in Section IV.B.2.c.

### 5. Program-generated Data

Data are increasingly the key product of research and engineering endeavors. To ensure the reproducibility of results and access to source data for future research, awardees will be required to maintain and deliver any data generated during award performance ("program-generated data") that is needed to accomplish these goals. Awardees shall be expected to document both the proprietary and non-proprietary products of their research to ensure the retention and potential reusability of this information. This may include:

- Raw unprocessed data, software source code and executables, build scripts, process sequence, programmatic communication and other collaboration activities;
- Data sets: rarified, experimental, test and measurement data;
- Design of experiments and simulations;
- Models or simulations (computational or mathematical);

- Recordings of various physical phenomena (including images, videos, senor data, etc.);
- Access to and use of institutional, organizational or scientific community repositories and archives

All program-generated data will reside in DARPA's data repository. When possible, DARPA may share some or all of the program-generated data with the broader research community as open data (with permission to access, reuse, and redistribute under appropriate licensing terms where required) to the extent permitted by applicable law and regulations (e.g., privacy, security, rights in data, and export control). DARPA plans to enable reproducibility of results through data sharing and to establish (or contribute to) digital collections that can advance this and other scientific fields.

### 6. Human Subjects Research (HSR)/Animal Use

Proposers that anticipate involving human subjects or animals in the proposed research must comply with the approval procedures detailed at www.darpa.mil/work-with-us/additional-baa, to include providing the information specified therein as required for proposal submission.

### 7. Controlled Unclassified Information (CUI) on Non-DoD Information Systems

All proposers and awardees will be subject to the DARPA requirements related to Controlled Unclassified Information on Non-DoD Information Systems as detailed at www.darpa.mil/work-with-us/additional-baa.

### 8. Electronic Invoicing and Payments

Awardees will be required to submit invoices for payment electronically via Wide Area Work Flow (WAWF) at https://wawf.eb.mil, unless an exception applies. Registration in WAWF is required prior to any award under this BAA.

### 9. Electronic and Information Technology

All electronic and information technology acquired or created through this BAA must satisfy the accessibility requirements of Section 508 of the Rehabilitation Act (29 U.S.C. § 749d) and FAR 39.2.

### 10. Disclosure of Information and Compliance with Safeguarding Covered Defense Information Controls

The following provisions and clause apply to all solicitations and contracts; however, the definition of "controlled technical information" clearly exempts work considered fundamental research and therefore, even though included in the contract, will not apply if the work is fundamental research.

DFARS 252.204-7000, "Disclosure of Information"
DFARS 252.204-7008, "Compliance with Safeguarding Covered Defense Information Controls"

DFARS 252.204-7012, "Safeguarding Covered Defense Information and Cyber Incident Reporting"

The full text of the above solicitation provision and contract clauses can be found at http://www.darpa.mil/work-with-us/additional-baa#NPRPAC.

Compliance with the above requirements includes the mandate for proposers to implement the security requirements specified by National Institute of Standards and Technology (NIST) Special Publication (SP) 800-171, "Protecting Controlled Unclassified Information in Nonfederal Information Systems and Organizations" (see https://doi.org/10.6028/NIST.SP.800-171r1) that are in effect at the time the BAA is issued.

For awards where the work is considered fundamental research, the contractor will not have to implement the aforementioned requirements and safeguards; however, should the nature of the work change during performance of the award, work not considered fundamental research will be subject to these requirements.

### C. Reporting

#### 1. Technical and Financial Reports

The number and types of technical and financial reports required under the contracted project will be specified in the award document, and will include, as a minimum, monthly financial status reports and a yearly status summary. A final report that summarizes the project and tasks will be required at the conclusion of the performance period for the award. The reports shall be prepared and submitted in accordance with the procedures contained in the award document.

#### 2. Patent Reports and Notifications

All resultant awards will contain a mandatory requirement for patent reports and notifications to be submitted electronically through i-Edison (https://public.era.nih.gov/iedison).

## VII. Agency Contacts

DARPA will use email for all technical and administrative correspondence regarding this solicitation.

- **Technical POCs**:
  Dr. Vincent Tang, Program Manager, DARPA/DSO – SIGMA+ program lead
  Dr. Anne Fischer, Program Manager, DARPA/DSO – chemical/explosive sensors lead
  Col. Matt Hepburn, M.D., Program Manager, DARPA/BTO – biological sensors lead

- **BAA Email:** SigmaPlus@darpa.mil

- **BAA Mailing Address:**
  DARPA/DSO

ATTN: HR001118S0035
675 North Randolph Street
Arlington, VA 22203-2114

- **DARPA/DSO Opportunities Website:**
  http://www.darpa.mil/work-with-us/opportunities

For information concerning agency level protests see http://www.darpa.mil/work-with-us/additional-baa#NPRPAC.


## VIII.  Other Information

### A.  Frequently Asked Questions (FAQs)

Administrative, technical, and contractual questions should be emailed to
SigmaPlus@darpa.mil.  All questions must be in English and must include the name, email
address, and the telephone number of a point of contact.

DARPA will attempt to answer questions in a timely manner; however, questions submitted
within 7 days of the proposal due date may not be answered.  DARPA will post an FAQ list at:
http://www.darpa.mil/work-with-us/opportunities?tFilter=&oFilter=2&sort=date.  The list will
be updated on an ongoing basis until the BAA expiration date as stated in Part I.


### B.  Collaborative Efforts/Teaming

DARPA highly encourages teaming before proposal submission and, as such, will facilitate the
formation of teams with the necessary expertise.  Interested parties should submit a one-page
profile (see Attachment I) including the following information:
- Contact information to include name, organization, email, telephone number, mailing
  address, organization website (if applicable).
- A brief description of the proposer's technical competencies.
- Desired expertise from other teams, if applicable.

All profiles must be emailed to SigmaPlus@darpa.mil no later than the time and date stated in
Part I.  Following the deadline, the consolidated teaming profiles will be sent via email to the
proposers who submitted a valid profile.  Specific content, communications, networking, and
team formation are the sole responsibility of the participants.  Neither DARPA nor the DoD
endorses the information and organizations contained in the consolidated teaming profile
document, nor does DARPA or the DoD exercise any responsibility for improper dissemination
of the teaming profiles.


## IX.  Appendix A

The current SIGMA system and network backbone provides:

1. the ability to ingest, analyze, and store data for thousands to ten thousands spectroscopic
   sensors reporting full spectral data (currently up to 4096 channels per spectra), GPS

location, and device status at 1 Hz, via kilobyte-sized compressed and encrypted packages transmitted directly through WiFi, cellular, or other communication means

2. the ability to run multiple computationally-intensive detection, identification, tracking and sensor fusion algorithms in real-time with minimal reporting latency (~seconds)
3. the ability for bidirectional communication with sensors
4. standalone/local analysis capabilities at each sensor during communication outage or for operation in communication denied environments
5. the ability to simulate 10,000 sensors to demonstrate scalability and to replay historical data through the system
6. the ability to incorporate data from other contextual sensors such as video feeds
7. the ability to query recent historical data (~month) with minimal latency (~10-100 ms)
8. storage of multiple years' worth of sensors data (~10TB/year)
9. management of inventory and device status (including sensor health, calibration data and other metadata) for thousands of heterogeneous sensors
10. display and reporting of device status, sensor output, and location in real-time to analysts and commanders through web-based Command and Control (C2) interfaces
11. security and encryption appropriate for national security information systems
12. an extensible framework capable of supporting novel sensor modalities, detection algorithms, and data fusion
13. the ability to deploy on multiple cloud infrastructure (e.g., Amazon Web Services (AWS), Azure) or locally on premise
14. a code base with unlimited government rights

A more detailed discussion of the SIGMA network backbone can be found in the whitepaper below. The SIGMA+ network backbone is intended to retain the above capabilities while incorporating new features to achieve SIGMA+ objectives.
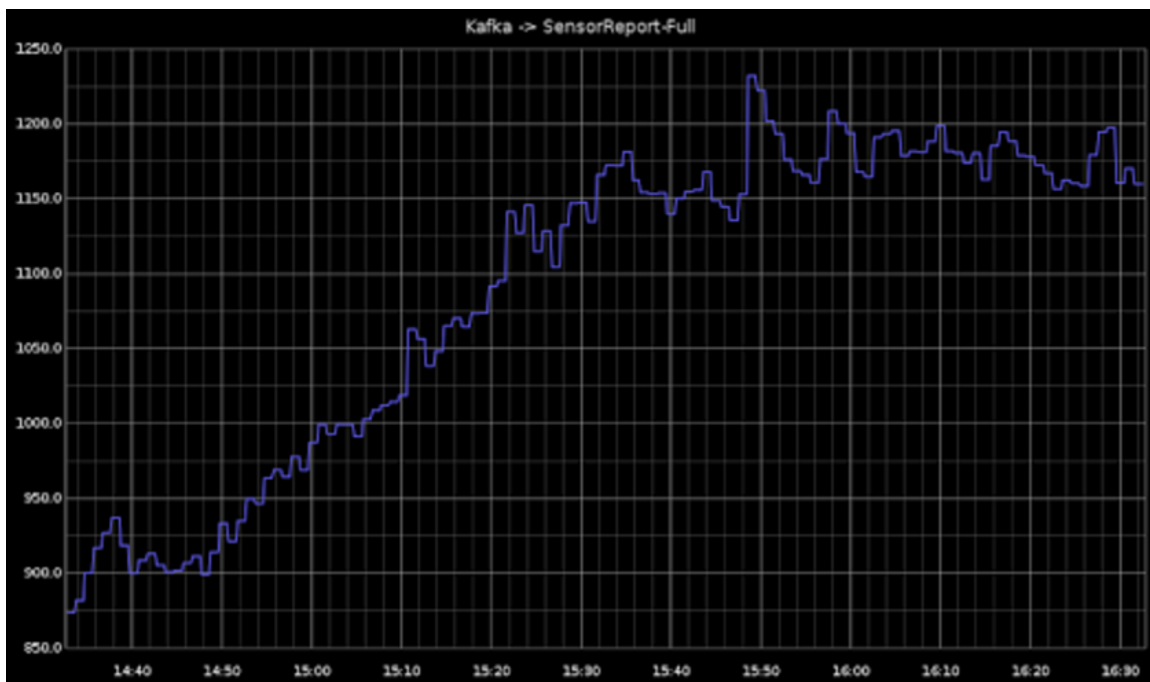
# twosix
### L A B S

# Engineered to Scale
# *A Networked Backbone for Large-Scale Radiation Detection*

Kafka -> SensorReport-Full

**4350 N Fairfax Drive, Suite 410**
**Arlington, VA 22203**
**(703) 543-9662**
info@twosixlabs.com
**www.twosixlabs.com**

### Distribution Statement A
Approved for public release; distribution is unlimited.

# 1. Introduction

Over the past 30 months Two Six Labs along with our teammates at Eucleo have been hard at work proving out a reference architecture for DARPA's SIGMA program (http://www.darpa.mil/program/sigma) that will, when fully realized, be capable of processing radiation data from thousands of portable detectors - deployed in any number of static and mobile configurations - all to increase situational awareness and early warning detection of potential threats. The goal for Sigma is to be able to deliver radiation alerts to a watch officer within seconds from the time a detector passes an unknown threat. For those on the architecture team, there has never been a greater urgency to ensure the availability of a system that is truly fault tolerant, redundant, and by the nature of the volume and velocity of radiation data - roughly 1KB/sec per deployed detector - massively distributed.

This post provides some initial insights into our backbone implementation, an amalgamation of open source web-scale technologies released to the community by the likes of Facebook, LinkedIn, and Twitter that have been engineered into a solution that has proven to be a robust and reliable foundation for our architecture. Currently at 35 AWS compute instances supporting our production system of up to 1000 deployed detectors (http://www.darpa.mil/news-events/2016-10-11), this framework has been tested with simulated loads up to 10,000 detectors simply by dialing up additional compute nodes and rebalancing workloads - processes that can be done without impacting real-time operations.

# 2. Technology Stack

We recognize that the end state of our system could be deployed anywhere and, as such, we need to prepare for any likely installation target. In the interim, we're deploying on AWS, but the option to run on AZURE, GCE, or locally procured hardware remains depending on security restrictions and customer preference. As a result, thus far we've limited the lure of managed services. No doubt they are attractive from a time to deliver mindset, but spending the additional time working directly with open source counterparts has provided great flexibility for future deployments.

At the core, and with a few exceptions, every aspect of the architecture is deployed as a Docker container. This "everything-as-a-container" approach has provided great flexibility by being able to build and test (and even ship) various parts of the framework in isolation. Docker is great for that. We also perform system integration of signal processing algorithms developed by various co-contractors and teammates. Docker is a great enabler for that too. Docker doesn't come without its deployment



**Backbone Execution Environment (Docker)**

| *Bootstrap* | *Core* | *Framework* | |
| --- | --- | --- | --- |
| Zookeeper | Cassandra | Edge | Stream Monitor |
| Ganglia/Graphite | Kafka | Collator | Alert Relay |
| Docker Registry | Postgres | Coordinator | Data Export |
| Mesos DNS | Flash | DB/S3 Writer | Web UI |

**Mesos / Marathon / Chronos**

**Ubuntu 14.04**

**Bare Metal / AWS**

challenges - such as container flight with ephemeral volumes and the need to switch between bridged and host networking, but we've managed to iron out a reasonable approach that overcomes many of these issues.
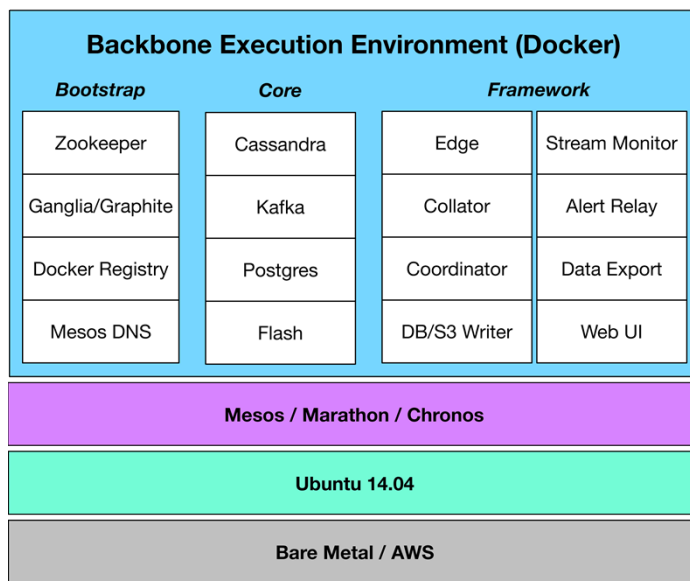
Beyond Docker, we use Apache Mesos (http://mesos.apache.org/) as our cluster manager along with Marathon (https://mesosphere.github.io/marathon/) for orchestrating our Docker containers - currently at 120. Both utilize zookeeper and represent the entirety of what's directly installed on a host - currently running Ubuntu 14.04.

Our data model is defined using Apache Thrift (https://thrift.apache.org/) of which payloads are generated at the point of origin (radiation detectors and phones running Android OS) and transmitted via cellular networks into the backbone and storage. Upon arrival into the backbone, Thrift messages are published via Apache Kafka (https://kafka.apache.org/) using topics based on the names of the Thrift structs and persisted in a three tiered storage architecture (discussed in greater depth in a subsequent section) that consists of a home brew in memory cache, Apache Cassandra (http://cassandra.apache.org/) and Amazon's S3 Block Storage (https://aws.amazon.com/s3/).

Once all of our containers are launched, discovery happens with mesos-dns (https://github.com/mesosphere/mesos-dns). All of our system configurations and deployments are defined using container hostnames (e.g. postgres.marathon.cluster_name). This provides very predictable addressing regardless of the host that eventually executes the container. Most of our clusters run multiple mesos-dns containers and domain forwarders are enabled from the primary dns servers to each of the clusters. This provides the ability to easily address any container running in any cluster.

# 3. Scaling Blueprint
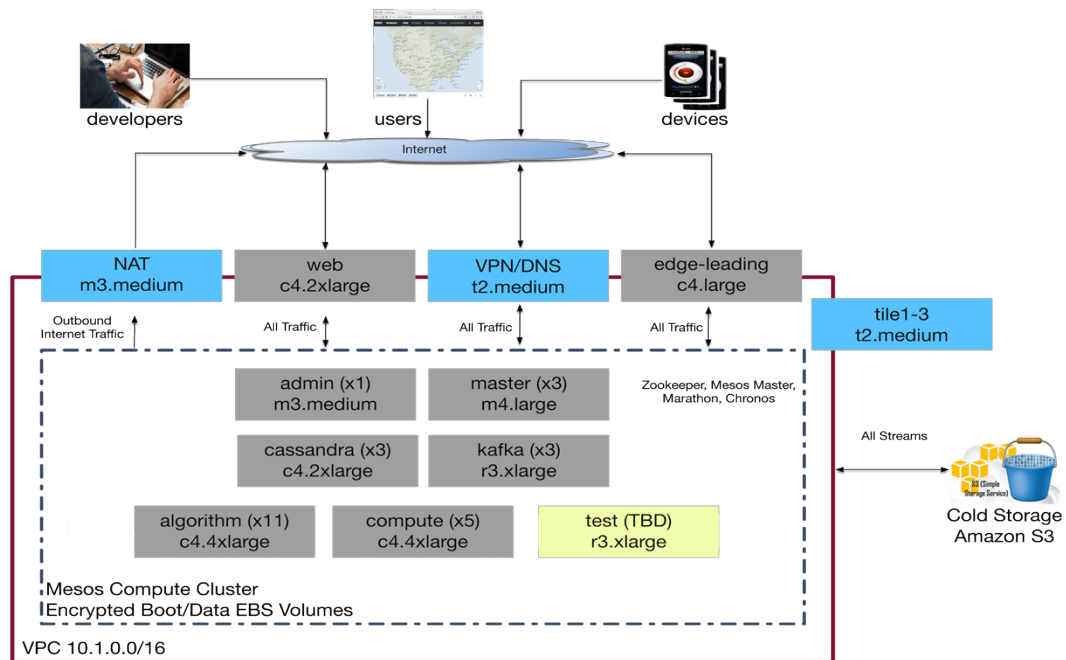


When it comes to AWS instance types, there's nearly something for every task. The challenge for us was finding the right balance of compute power to address our short-term requirements (the minimal cluster reconfiguration after the fact) and doing so at a reasonable cost. We tend to group instance types by RAM/core ratio - that is, gigs of ram per virtual core. Most of our backbone tasks are "core heavy", meaning that ~ 1.875GB of RAM per vCore as provided by the C4 class is generally sufficient for processing.

Our cluster is split by functional area (e.g. algorithms, cassandra, kafka, general compute) allowing us to group similar processing tasks and segregate others. This approach ensures that I/O heaving tasks (e.g. cassandra and kafka) run on separate instances. It also provides the ability to scale different parts of the system based on load - the decision to add more algorithms is different than the need to add another cassandra node. We use a straight 2x redundancy across the board - primarily due to cost, meaning that we can survive one failure per functional area before loss of data.

# 4. Pacing for a Marathon

Marathon has provided a really good way to manage containers and handle redeployments in light of host or service failures. All of our container deployments make use of Marathon constraints to direct the class of machine to run the container (cassandra and kafka are both managed by Marathon but run on separate instance types). To make

this happen, all of our mesos slaves use attributes to define the type of node (as depicted in the scaling blueprint) that are automatically assigned at instance provisioning time.

```
ubuntu@kafka1:~$ cd /etc/mesos-slave/
ubuntu@kafka1:/etc/mesos-slave$ cat attributes
node_type:kafka
```

Attributes map very nicely to Marathon constraints that are honored at container launch time:

```
{
  "id": "kafka-1",
  "instances": 1,
  "cpus": 4.0,
  "mem": 27000,
  "constraints": [
    [
      "node_type",
      "CLUSTER",
      "kafka"
    ]
  ],
  ...
```

Constraints as well as other sizing information are all well and good and Mesos honors these perfectly fine. The challenge, for us, is often tracking down containers that are permanently stuck in a "WAIT" state (received by Marathon but not staged in Mesos). From our experience, this is normally attributed to a constraint violation - lack of port, cpu, memory. Tracking these errors down is a bit of a bear. Unfortunately, nothing is currently presented in the Marathon web UI, rather is logged to /var/log/syslog on the active Marathon master.

```
Dec 30 14:27:29 master1 marathon[12351]: [2016-12-30 14:27:29,224] INFO Offer
[e6606164-e177-4bfd-8b6d-63918702367d-O3981673]. Constraints for run spec
[/export] not satisfied.
Dec 30 14:27:29 master1 marathon[12351]: The conflicting constraints are:
[field: "node_type"
Dec 30 14:27:29 master1 marathon[12351]: operator: CLUSTER
Dec 30 14:27:29 master1 marathon[12351]: value: "fakenode"
Dec 30 14:27:29 master1 marathon[12351]: ]
```

# 5. Container Flight with GlusterFS

Let's face it, while containers and mesos have greatly simplified "run anywhere" deployments, fault tolerance of a single container - a.k.a "container flight" still remains a challenge when ephemeral volumes are at play. Case in point for our architecture, we have a few services that we've elected to not run in HA configurations (e.g. PostgreSQL) as they do not represent mission critical elements and we can survive a few seconds of downtime. Our solution, to date, has been to utilize glusterfs (https://www.gluster.org/) on our compute notes. In order to avoid the split-brain scenario with PostgreSQL, we have marathon constraints to ensure we only ever have a single instance deployed at a time.

# 6. Build Management with Jenkins

We use a pretty vanilla configuration of Jenkins to build our git repos and docker images. Originally, sticking with the docker purest theme, we attempted to run Jenkins master and slaves as containers deployed via mesos (see https://github.com/tehranian/dind-jenkins-slave and https://dantehranian.wordpress.com/2014/10/25/building-docker-images-within-docker-containes-via-jenkins). We've had some early luck with this approach, and we'll admit that we had some docker-in-docker containers running (which sounds a bit crazy), we ultimately had to segment Jenkins into a separate cluster due to some unpredictable performance hits on the host during system builds.

When building docker images, we employ a few container naming conventions that help determine the builds and commits that lead to the container push. This is done by adding labels (https://docs.docker.com/engine/reference/builder/#label) to each image that capture key artifacts like container version, name of git repo, build time, build job #, git branch and commit hash. These artifacts are later dynamically retrieved from the docker registry and stored as Marathon labels in the marathon task json file:

```
"labels": {
  "backbone.version.cinumber": "b158",
  "backbone.version.githash": "2a0b12d",
  "backbone.version.stamp": "4.0.0-SNAPSHOT_20161026-2016_2a0b12d_b158",
  "backbone.version.project": "exporter",
  "backbone.version.time": "20161026-2016",
  "backbone.version.name": "4.0.0-SNAPSHOT"
}
```

Marathon labels are presented in the web UI and are accessible in the REST API, so we have a systematic way to trace down the commit and jenkins build that is responsible for a particular container.

# 7. Private Docker Registry

Our build server pushes new docker images for each git commit to master or a release branch (including commits to upstream dependencies). While it sounds a bit heavy handed, this approach provides the ability to test incremental releases by commit and Jenkins job at the cost of storing extra image layers. We run our own docker registry (built from docker's registry:2 image) with a custom configuration that utilizes a S3 storage backend. After a bit of tweaks to the config.yml, we've had pretty good success running with the following storage configuration block:

```
storage:
  maintenance:
    uploadpurging:
      enabled: true
      age: 168h
      interval: 24h
      dryrun: false
  cache:
    blobdescriptor: inmemory
  s3:
    accesskey: <<AWS_ACCESS_KEY>>
    secretkey: <<AWS_SECRET_KEY>>
    region: us-east-1
    bucket: our-docker-registry
    encrypt: true
    secure: true
    v4auth: true
    chunksize: 5242880
```

All of our clients are authenticated with the docker registry by way of certs installed during host provisioning time.

# 8. Data Access Tiers

We hold 72 hours of data in our kafka topics, just long enough to recover from a system failure, and use partitions as an effective way to distribute processing load across multiple instance of an algorithm (a single algorithm container cannot directly process the full stream). Since our system is expected to grow with new radiation detectors being added over time, expanding and rebalancing partitions is a periodic necessity. Out of the box support for this is a bit manual (see



https://blog.imaginea.com/how-to-rebalance-topics-in-kafka-cluster/), we had to write some tools to help automate the process and are planning to open source those in the near future.
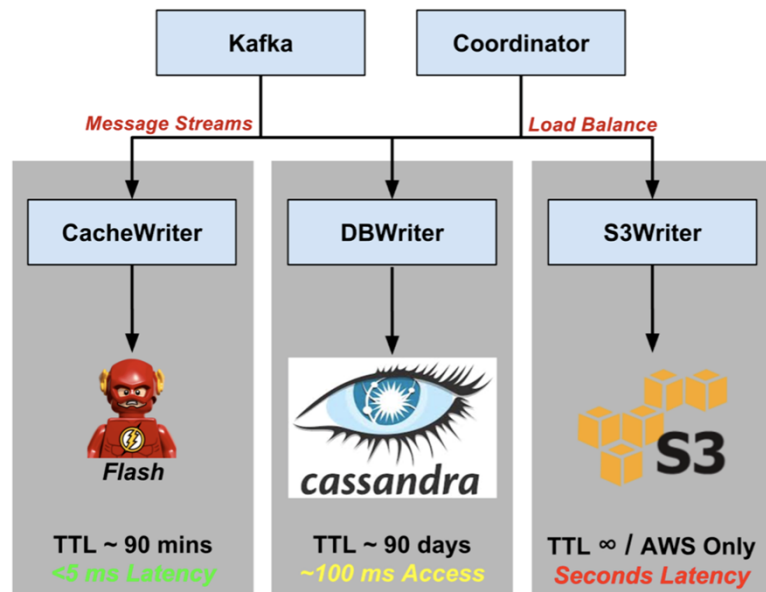
Beyond kafka, we have a data access tiers that service the variety of data use cases required by our system. Some algorithms require additional "nearby" data to perform a more accurate analysis, over what is already provided in the message stream. These queries need low-latency responses (< 5ms) to be able to sustain real-time processing. After some experimenting with a few in-memory (MemSQL, Crate), we opted to roll our own solution to hold 90 minutes of data with geographic indexing.

The remainder of our query use cases are a direct fit for Cassandra and a simple time series data model:

```
CREATE TABLE topic_name (
    payloadid uuid,
    date text,
    time timestamp,
    msgid uuid,
    message blob,
    PRIMARY KEY ((payloadid, date), time, msgid)
);
```

The metadata provides just enough options for query - we frequently pull radiation data - a serialized Thrift blob - for a known detector (payloadid) over a time period. The

composite primary key orders data by payloadid (partition key) and date (clustering key). Records are then ordered by ascending time and leverage the date tiered compaction strategy (DCTS) which was designed specifically for timeseries access patterns. Data lives in Cassandra for about 90 days - a TTL that is assigned at table creation time. While query latencies are largely driven by time period, the average query is serviced in ~ 100ms.

Finally, a copy of every stream is persisted in S3 as a permanent archive. We use a single bucket with per-topic folders. Data is committed every 60 seconds or 32MB, whichever comes first, using a key format yyyyMMddHHmm coupled with an AtomicInteger at the end to catch multiple commits during the same minute. This format allows for time-based range scans and replays with typical queries retrieving a day (20161229) or hour (2016122913) of data. We measure latency from S3 on the order of seconds per query.

# 9. Metrics and Monitoring
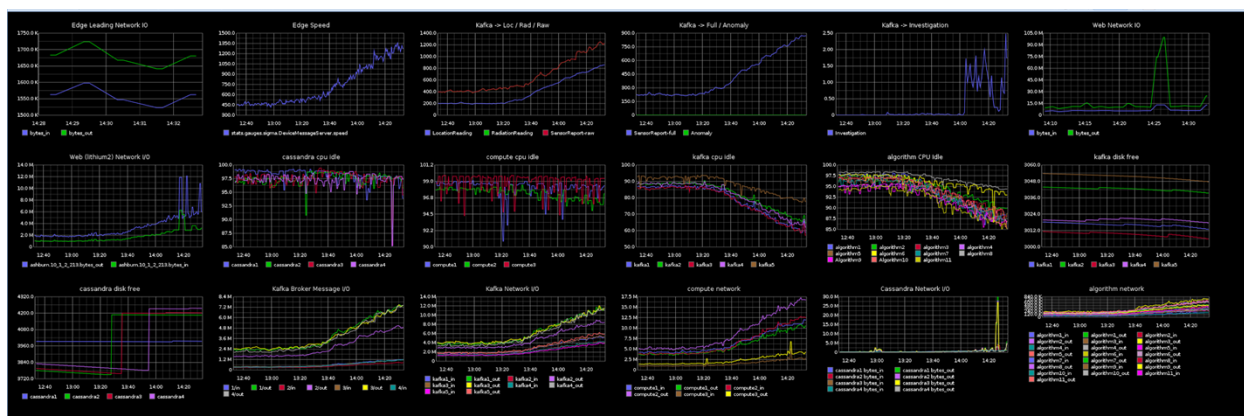


With 35 AWS instances and 120 containers - system monitoring and problem diagnosis starts to get a bit challenging. We've become a big fan of all things metrics: host, core service, framework and make use of graphite dashboards (https://graphiteapp.org/). Almost every dependency we use provides some way of introspection. From REST APIs (Mesos, Marathon), JMX (Kafka, Cassandra), to some custom collection with statsd, dashboards provide the at-a-glance views of aggregated performance across the cluster.

While staring at dashboards are valuable, we also like to know when failures occur, particularly those that happen off-hours and over weekends and holidays - for some reason our system doesn't break during "normal" working hours. We have a number of monitors deployed - each deploy alerting via SMS, email, slack (or all the above).

- AWS Cloudwatch - high CPU, low memory, low disk, accessibility
- Stream Monitor - custom code that watches our ingress streams to ensure that it never drops below a certain threshold - meaning that external devices are having issues communicating to the backbone.
- Burrow (https://github.com/linkedin/Burrow) - checks for offset lags in kafka consumers. Problems often lead to message consumption issues, so burrow has become a swiss army knife for detecting many issues in the system. It even monitors our monitoring systems.