Center for Innovative Technology (CIT)
In conjunction with our partners
Smart City Works, LLC and TechNexus
(the SCITI Program)

Requests Innovators with capabilities
in the following area

Technical Specification:
Indoor UAV Navigation and Sensors
For Responder Search & Rescue missions

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SCITI Labs Specification:
Area 1 – Indoor UAV Navigation and Sensors

Background: The Center for Innovative Technology, in conjunction with our partners Smart City Works and TechNexus is looking for companies with technologies, solutions, and tools to achieve the goals set out in this specification as part of the SCITI program.

Responders undertake search and rescue missions in a variety of adverse conditions. Some disasters such as fire, earthquakes or tunnel collapse can damage buildings or structures, and search and rescue missions must take place in confined or indoor spaces that are significantly deteriorated from their normal state. The success rate in saving the lives of victims depends on the rapidity in which search and rescue operations can be initiated and conducted. The use of UAVs in confined spaces can help improve this success rate in several ways, including:

- autonomous operation earlier in the response cycle while responders are attending to other tasks
- detecting indicators of life that responders are not equipped to detect unaided
- ability to operate in hazardous areas before they have been stabilized and deemed safe

While both UAV platforms and a variety of sensors currently exist in the commercial market, these have not been integrated in a way that fully support these mission sets. This area is focused on integrating and producing a commercial-ready prototype for these types of responder missions.

Scope of Technology: Autonomous navigation for UAVs operating indoors and in confined spaces in support of search and rescue missions in difficult environments such as fire or earthquake damaged structures. Separate prototypes are also sought for two sensors that can operate either hand-carried or mounted on the UAVs: a WiFinder sensor for personal device signals, and a thermal sensor for detecting the heat signatures of people or other living creatures.

General Requirements: The first phase of this effort will consist of two or three separate prototypes: an autonomous navigation capability demonstrated in a vendor-selected UAV platform that meets the general performance requirements; a WiFinder sensor for detecting WiFi and other RF signals from victim phones and other devices; and a thermal sensor for detecting heat signatures of survivors. The eventual goal is that both sensor capabilities will be integrated with the autonomous platform and demonstrated to support the operational use case. A vendor may propose to deliver one, two or all three prototype capabilities. Other requirements are specified below; limited exceptions to these requirements may be considered on a case-by-case basis if the overall set of proposed capabilities is deemed to be of high value to the responder community.

Commercial Availability – The goal is commercial availability of an integrated operational capability by 2020. The target price points are less than $10,000 for an operable UAV platform with autonomous navigation capabilities and fully outfitted with the target sensor set. Target price points for the WiFinder and thermal sensor are on the order of hundreds of dollars or less. Affordability is a critical factor in the ability of responder organizations to adopt new capabilities.

UAV General Performance Specification – The UAV selected to demonstrate autonomous navigation should have a payload capacity in the range of 1-3 pounds, and an operational flight time of 20-30 minutes, minimum. The UAV platform is intended to be used to mount and deploy interchangeable sensor packages including the two specified here. Payload capacity should be adequate to support the weight of both target sensors simultaneously but additional payload capacity beyond that requirement is a secondary concern. Additional flight time is highly desirable.

The UAV must be able to operate in confined spaces such as train or pedestrian tunnels, commercial office buildings including crawl spaces, stairwells and doorways, and collapsed building structures. For these purposes smaller is better, and the ability to maneuver at slow speed and hover is important.

The UAV must operate autonomously (in accordance with pre-flight parameters), semi-autonomously (autonomous execution of high level operator commands), and in an operator controlled mode. The UAV platform is assumed to have sufficient navigational sensors such as GPS and others (see "Additional Considerations" below) as part of the platform (or added as part of the first prototype activity) to provide the autonomous navigation capability. Basic (GPS-enabled) navigational capability is assumed to include waypoint following, patterned coverage of contiguous areas (overlapping flight lines) and autonomous landing or return to operator.

The UAV platform must be able to collect, record/store and transmit UAV flight data and mission sensor data. UAV flight data must be in accessible open standard formats, and time and location stamped to include waypoints and time and distance traveled. Video imagery is highly desirable. Mission sensor data must use open standards or commonly accepted industry standards for sensor data format (e.g., MPEG for video), interaction (e.g., sensorML) and transmission (e.g. TCP/IP). Mission sensor data must be able to be correlated/integrated with UAV flight data to help responders easily locate the source of detected signals of interest.

Prototype 1: UAV Navigation Specification – The autonomous navigation capability of the selected UAV platform is the first prototype capability sought by this RFI specification. Given pre-flight parameters or high level commands (search the area within this bounding box, follow this set of waypoints, follow this linear feature), the UAV should be able to proceed to the search area and autonomously navigate the target environments in accordance with the commands. A key capability for the navigation system is the ability to avoid collisions with unexpected objects such as fallen debris, wires, or stairwells and still provide comprehensive coverage of the search space.

Another important feature is the ability of the navigation software to incorporate a variety of navigation-related sensors, due to the range of expected operating conditions. While GPS is an important capability, it may not be available in some operating areas. Visual imagery-based collision avoidance may be difficult in smoke-filled areas. The range of operational conditions in which the navigation system can succeed is an important consideration.

Prototype 2: WiFinder Sensor Specification – A WiFinder sensor is the second prototype capability sought by this RFI specification. Victims of events may sometimes be trapped in inaccessible areas or unable to respond, but the ubiquitous presence of personal transmitting devices may provide indications of potential survivors. Even when not actively making calls or connected to access points, devices such as phones transmit a variety of RF signals at various frequencies (such as requests to join WiFi, cellular or Bluetooth networks), and these signals are detectable even if attenuated by rubble or distance. A prototype sensor is sought using commercially available sensing elements (such as those currently employed in phones or base stations for determining signal strength; some Android phones already host a spectrum analyzer app) that can detect these signals and localize their position either indoors or outdoors.

The basic sensor must operate for a continuous detection time of 60 minutes in either a handheld or UAV-mounted configuration. In the handheld configuration a display capability is required, and in either configuration there is a requirement to collect, store, access and display locations of signal detections using open standards formats and protocols. The target weight of the device is 1-3 pounds, with lighter being desirable.

In addition to detecting and localizing the target signals, additional information collection is desired to the extent feasible. Parameters such as signal strength are important, and may be combined with other information to estimate the distance of target detection given various attenuation factors such as water/moisture, building materials and so forth. Information about the phone identity, such as Mobile Device Identifiers or Universal Device ID information is also valuable. The ability to differentiate a number of closely spaced individual transmitters is also important, as is the ability to operate in noisy RF background environments.

Prototype 3: Thermal Sensor Specification – A thermal sensor is the third prototype capability sought by this RFI specification. This sensor is intended to detect, differentiate and display relative strengths of thermal signatures from human, ambient, mechanical and fire sources.

The basic sensor must operate for a continuous detection time of 60 minutes in either a handheld or UAV-mounted configuration. In the handheld configuration a display capability is required, and in either configuration there is a requirement to collect, store, access and display locations of signal detections using open standards formats and protocols. The target weight of the device is 1-3 pounds, with lighter being desirable.

In addition to detecting and localizing the target signals, additional information collection is desired to the extent feasible. Parameters such as signal strength and intensity are important, and may be combined with other information to estimate the distance of target detection given various attenuation factors such as scattering, building materials and so forth. The ability to differentiate a number of closely spaced individuals is also important, as is the ability to operate in noisy thermal background environments.

<u>Exclusions:</u> The desired prototypes are those described above. Excluded from this request are UAV platform development programs (other than minor modifications to existing platforms to accommodate the desired capabilities), or actual flight operation services in support of the target missions. For the sensors, this is not intended to include development of new or improved sensing elements; high-performance, inexpensive sensors are commercially available. Rather this is seen as an integration of existing sensor elements to achieve the specified mission goals; see the Additional Considerations below.

<u>Additional Considerations</u>: This section provides some additional context and discussion of the desired prototypes, but is not considered to constitute requirements or guidance towards specific desired solutions.

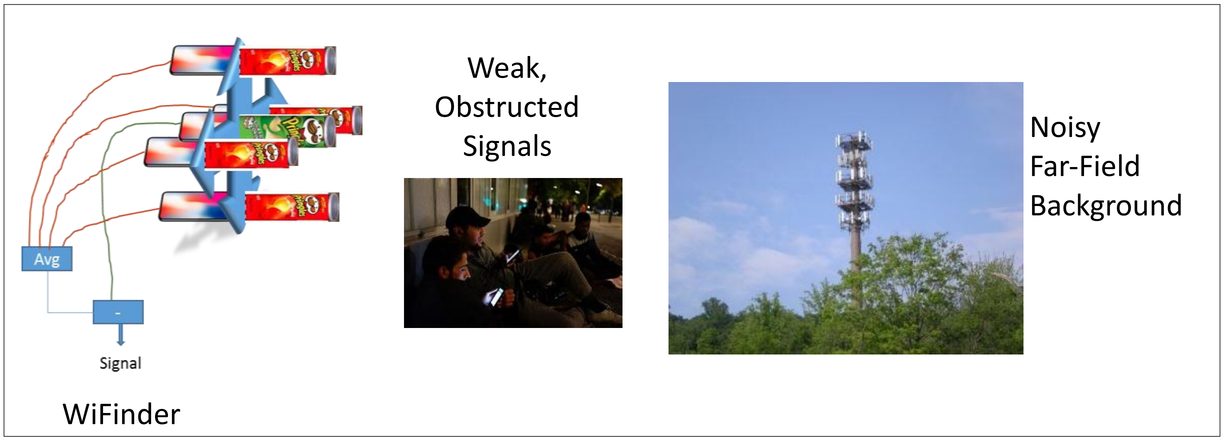
For all of the prototypes sought for this specification the ability to operate in difficult or degraded environments is critical. During the prototype evaluation cycles prototypes will be challenged with increasingly difficult scenarios using a variety of facilities available to responders throughout the country.

As one example the UAV navigation prototype must operate in unusual building configurations. A simple example is the CIT building, with exterior and interior views shown in the pictures below. It is anticipated that an initial proof-of-capability demonstration may involve flight tracks inside this building, with and without the use of satellite GPS.

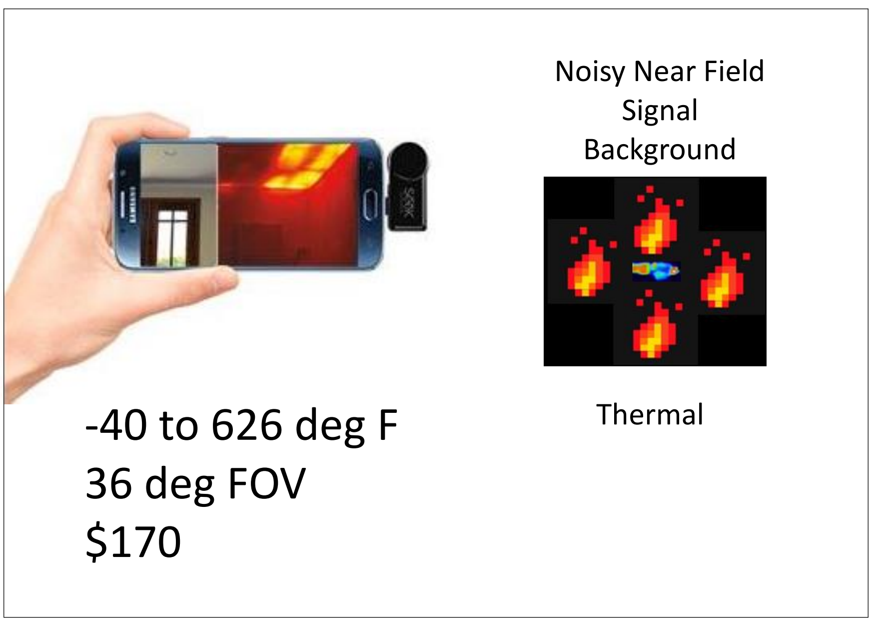
Because of the unusual shape of the building there are several features that may prove challenging to navigational software even without additional environmental challenges (ie, smoke), including:

- Non vertical exterior walls
- Non square corners
- Flight path not parallel to exterior walls
- Multi-floor opening
- Transparent obstacles
- Unusual shapes
- Different path lengths on different floors
- Square “search” area has inaccessible interior (elevator lobby)

For the sensors, a key additional consideration is the ability to operate in noisy background environments. The Wifinder sensor seeks to locate weak, obstructed signals, and is certain to operate in noisy far-field RF background environments such as the presence of nearby cell towers or indoor access points as depicted in the diagram.



The thermal sensor may similarly be seeking to detect weak thermal signatures, in this case most likely in the near field of the sensor due to fire, mechanical or other non-target signatures. This diagram shows one inexpensive thermal sensor on the market with many attractive characteristics, again suggesting that the sensor elements themselves already exist.



In both cases however it is anticipated that an array of several sensors combined with appropriate signal processing could allow configurable filtering of anticipated background noise features, bringing the resulting S/N to a point where the target use case functionality is significantly improved.

Additionally, combining signal processing for both sensors into a single processing device could allow a simple path for integrating the two sensing capabilities.

In all of these examples, the suggestion is that proposed solutions that characterize the problem space in novel or interesting ways are both welcome and may be able to achieve better performance for responders than simple incremental advances to existing solutions. Such innovation will be considered in a positive way when various solutions are evaluated.