DSIAC TECHNICAL INQUIRY (TI) RESPONSE REPORT

Research Efforts in Unmanned Aerial Vehicle Vital Sign Monitoring Systems

Report Number:

DSIAC-2020-1277

Completed April 2020

DSIAC is a Department of Defense Information Analysis Center

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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1. REPORT DATE *(DD-MM-YYYY)* 09-04-2020	2. REPORT TYPE Technical Research Report	3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE

Research Efforts in Unmanned Aerial Vehicle Vital Sign Monitoring Systems

5a. CONTRACT NUMBER FA8075-14-D-0001

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Taylor H. Knight

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Defense Systems Information Analysis Center (DSIAC)
SURVICE Engineering Company
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Belcamp, MD 21017-1505

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Defense Technical Information Center (DTIC)
8725 John J. Kingman Rd.
Ft. Belvoir, VA 22060-6218

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

Distribution A. Approved for public release: distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The Defense Systems Information Analysis Center (DSIAC) was asked to search for organizations researching vital sign monitoring systems for unmanned aerial vehicles (UAVs). The system is meant to consist of a radar sensor with novel algorithms for recognizing and monitoring life signs, including heart and respiration rates, from a moving platform. DSIAC staff searched open-source documents and the Defense Technical Information Center's repository for organizations performing this research. A list of organizations, including academia, industry, and government, was compiled and delivered to the inquirer. It was found a variety of methods are being researched to remotely detect and monitor vital signs. These methods include LiDAR mapping, sensors for search and rescue, and infrared thermography. While some of these methods are being researched for use with UAVs, others have the potential to be applied to UAV platforms for future use.

15. SUBJECT TERMS

LiDAR, infrared thermography, vital sign monitoring systems, search and rescue, UAV

16. SECURITY CLASSIFICATION OF: U			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON Ted Welsh, DSIAC Director
a. REPORT U	**b. ABSTRACT** U	**c. THIS PAGE** U	UU	11	**19b. TELEPHONE NUMBER** *(include area code)* 443-360-4600

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

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The Defense Systems Information Analysis Center (DSIAC) is a DoD IAC sponsored by DTIC to provide expertise in nine technical focus areas: weapons systems; survivability and vulnerability; reliability, maintainability, quality, supportability, and interoperability; advanced materials; military sensing; autonomous systems; energetics; directed energy; and non-lethal weapons. DSIAC is operated by SURVICE Engineering Company under contract FA8075-14-D-0001.

A chief service of the DoD IACs is free technical inquiry (TI) research, limited to 4 research hours per inquiry. This TI response report summarizes the research findings of one such inquiry jointly conducted by DSIAC.

ABSTRACT

The Defense Systems Information Analysis Center (DSIAC) was asked to search for organizations researching vital sign monitoring systems for unmanned aerial vehicles (UAVs). The system is meant to consist of a radar sensor with novel algorithms for recognizing and monitoring life signs, including heart and respiration rates, from a moving platform. DSIAC staff searched open-source documents and the Defense Technical Information Center's repository for organizations performing this research. A list of organizations, including academia, industry, and government, was compiled and delivered to the inquirer. It was found a variety of methods are being researched to remotely detect and monitor vital signs. These methods include LiDAR mapping, sensors for search and rescue, and infrared thermography. While some of these methods are being researched for use with UAVs, others have the potential to be applied to UAV platforms for future use.

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1.0 TI Request

1.1 INQUIRY

What organizations are researching vital sign monitoring systems (VSIMs) for unmanned aerial vehicles (UAVs)?

1.2 DESCRIPTION

The VSIM is meant to consist of a radar sensor with novel algorithms for recognizing and monitoring life signs, including heart and respiration rates, from a moving platform. Research is being performed on UAVs that can use radar or sensors to detect physiological motion up to 100 m through clothing, walls, and body armor. From this, the Warfighter will gain real-time remote monitoring of human biometrics from a single UAV suitable for access denied and beyond line-of-sight (LOS) environments. Knowing what other organizations are performing this type of research can help further develop VSIMs for UAVs.

2.0 TI Response

The Defense Systems Information Analysis Center searched open-source documents and the Defense Technical Information Center's repository for organizations performing this research. There are a variety of options that could potentially be used for VSIMs for UAVs. These include biosensors, infrared thermography (IRT), LiDAR mapping, and algorithms used for radar sensors. Different organizations are utilizing one or more of these options in their research.

2.1 ACADEMIA

Many universities are researching VSIMs for UAVs and collaborating with U.S. Department of Defense entities. A variety of methods is being employed to detect vital signs in humans, and even animals, from small UAVs.

2.1.1 University of Hawaii at Manoa

The University of Hawaii's Department of Electrical Engineering has studied the feasibility and fabrication of components of a life sign radar system on UAVs. A signal-conditioning circuit has been simulated and tested for data preparation and acquisition to detect vital signs. This is done using UAVs in real time by sending wireless transmission of baseband data to a monitoring station. To achieve this, a quadrature Doppler radar has been assembled using two single-channel, x-band MDU1020 radars. These radars can avoid null point distortion in physiological monitoring [1].

2.1.2 University of South Australia

Researchers at the University of South Australia have successfully trialed a system that uses UAVs to measure heart and respiratory rates while hovering up to 9 m away. The drones use remote-sensing imaging systems to detect changes in human skin tones and minute head movements in real time to read vital signs [2]. Much of their research has been done in collaboration with Australia's Defence Science and Technology Group (DST).

Other research is being done at the university to detect vital signs in search-and-rescue missions. Many times, natural disasters cover victims in dust, debris, or ashes, which makes it difficult to detect life signs or shapes. These search-and-rescue missions may also be in hard-to-reach areas or beyond LOS. A novel method to estimate the locations of people from aerial video using imaging and signal processing designed to detect breathing movements has been created [3]. The method has been successful in detecting those fully covered in debris. Aerial videos are stabilized using key points of image frames, which are then decomposed into tile videos. The temporal frequency bands of interest are motion magnified, while the other frequencies are suppressed, so that image differencing and temporal filtering can be performed on each tile to detect breathing signals. The detected frequencies are remapped to the image frame to create a life sign map that shows potential human locations [3].

2.1.3 University of Canterbury, New Zealand

In collaboration with the Center for Cetacean Research and Conservation and Cook Islands Whale Research, the University of Canterbury has found a way to measure humpback whale vital signs using UAVs with IRT. This system was deployed from shore-based positions in a humpback whale calving ground to detect and document biomedical vital signs, including blowhole and dorsal fin skin temperature, respiration rate, and heart rate [4]. This system may also potentially be used for human vital sign detection and monitoring.

2.1.4 University of Nevada

The University of Nevada is using the Doppler Radar Physiological Sensing (DRPS) technique on a 24-GHz, medium-range, human-detecting sensor for potential search-and-rescue and antidrone applications. DRPS systems are designed to monitor small movements of nonmetallic human tissues, such as respiration and cardiopulmonary activity, while also being able to detect moving and stationary human beings [5].

2.1.5 Arizona State University (ASU)

In 2018, Yu Rong of ASU submitted a dissertation outlining remote sensing for vital sign monitoring using advanced radar signal processing techniques. He showcases experiments to justify a heart rate monitoring algorithm in a single subject, multiple subjects at different ranges, multiple subjects at the same range, and monitoring through a wall. A remote-sensing

radar system using the proposed algorithm is also compared to the competing remote-sensing technology, a remote-imaging photoplethymography system [6]. This system shows potential for future applications with UAVs.

2.1.6 Massachusetts Institute of Technology (MIT)

MIT is researching a system to use with search-and-rescue drones to find lost forest hikers. Forests densely packed with trees can interfere with a global positioning system (GPS) connection, so MIT researchers proposed to use LiDAR to map, navigate, and search areas that are GPS denied. Each drone would be equipped with laser range finders for position estimation, localization, and path planning so when the drone is circulating in the air, it creates an individual three-dimensional (3-D) map of the terrain. An algorithm is used to help the drone recognize previously-searched areas while images are sent to a ground station where maps are stitched together to complete the 3-D view. The drones are using LiDAR to shoot laser beams at the surrounding environment to measure the pattern of pulses reflected by nearby objects [7].

2.2 GOVERNMENT

A few government organizations are researching technology that can be applied to UAV VSIMs.

2.2.1 The DST Group

The DST group in Australia is researching ways for drones to locate survivors of natural disasters in GPS-denied environments. A study was done to explore the utility of a drone equipped with human life detection with a novel computer vision system. The proposed system uses image sequences captured by a camera on the drone to remotely detect cardiopulmonary motion caused by periodic chest movement of survivors [8].

2.2.2 The National Aeronautics and Space Administration (NASA) Langley Research Center

NASA Langley Research Center is collaborating with MIT to research their multi-UAV system for GPS-denied search-and-rescue missions under the dense forest canopy. The proposed multi-UAV has been validated in simulation and during real-world collaboration missions at the center [9].

2.2.3 U.S. Army Research Laboratory (ARL)

ARL, in collaboration with Texas Tech University, has been researching Doppler radar for vital sign detection from four sides of the human body. An unmodulated radio frequency signal is transmitted toward the human body, where it is phase modulated by the periodic physiological movement and reflected to the receiver. The receiver captures the reflected signal and

demodulates it to extract the vital sign signal components [10]. This technology may potentially be used for future UAV VSIMs.

2.3 INDUSTRY

Two companies produce VSIMs for use in UAVs.

2.3.1 Tyco Fire and Security

A search-and-rescue UAV system and method were patented by Tyco Fire and Security in 2015. The UAV is equipped with at least one ultrawide band transceiver sensor to detect the presence of a survivor in a search-and-rescue mission. The UAV includes a data link transceiver for wirelessly communicating survivor information to a command center [11].

2.3.2 IntelliNet Sensors, Inc.

IntelliNet Sensors developed the Lynx6-A, a breathing and heartbeat sensor with remote connectivity capabilities designed to mount on a UAV. The ultralight sensor is designed to detect people trapped under rubble from a collapsed building, while its integrated, micro high-definition video camera enables guiding and landing a smaller UAV as a carrier [12].

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