Defense Systems Information Analysis Center

DSIAC TECHNICAL INQUIRY (TI) RESPONSE REPORT

Over-the-Horizon (OTH) Communications for Missile Integration

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ABOUT DSIAC

The Defense Systems Information Analysis Center (DSIAC) is a U.S. Department of Defense information analysis center sponsored by the Defense Technical Information Center. DSIAC is operated by SURVICE Engineering Company under contract FA8075-14-D-0001.

DSIAC serves as the national clearinghouse for worldwide scientific and technical information for weapon systems; survivability and vulnerability; reliability, maintainability, quality, supportability, and interoperability; advanced materials; military sensing; autonomous systems; energetics; directed energy; and non-lethal weapons. We collect, analyze, synthesize, and disseminate related technical information and data for each of these focus areas.

A chief service of DSIAC 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. For more information about DSIAC and our TI service, please visit www.DSIAC.org.

ABSTRACT

The Defense Systems Information Analysis Center (DSIAC) received a technical inquiry requesting research on over-the-horizon communications technologies for use in satellite-denied environments that have a form factor suitable for a missile. DSIAC searched open sources and the Defense Technical Information Center Research and Engineering Gateway for relevant information and articles. DSIAC also contacted subject matter experts from the Cyber Security and Information Systems Information Analysis Center for additional information. The results of DSIAC's efforts are summarized in this report.

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1.0 TI Request

1.1 INQUIRY

What small form factor systems exist or are in development to over-the-horizon (OTH) communications in a satellite-denied environment?

1.2 DESCRIPTION

The inquirer requested information on what systems exist or are in development that achieve OTH communications in a satellite-denied environment and are in a form factor that can fit on a missile.

2.0 TI Response

Defense Systems Information Analysis Center (DSIAC) staff completed literature searches using the Defense Technical Information Center (DTIC) Research and Engineering (R&E) Gateway and open sources to find articles and information relevant to the inquiry. DSIAC staff used the search terms “over the horizon,” “satellite-denied environment,” “communications,” and “beyond line of sight (BLOS).” Closed technical inquiries were also utilized, and DSIAC subject matter experts (SMEs) were contacted for relevant information. SMEs from the Cyber Security and Information Systems Information Analysis Center (CSIAC) [1] supplied documents and information for this report. The information gathered was compiled into a TI response report, which was sent to the inquirer.

2.1 OVER-THE-HORIZON SYSTEMS

DSIAC and CSIAC researchers compiled a list of potentially relevant OTH communications solutions in satellite-denied environments. This included network arrays, missiles, and other high-frequency (HF) transmitter/receiver technologies.

2.1.1 Robust BLOS Communications in Satellite-Denied Environments

The Canadian Department of National Defence released a challenge for new approaches to provide robust OTH/BLOS communications in satellite-denied environments, either by enhancing the reliability of HF and/or satellite communications (SATCOM) approaches or by exploring new technologies and techniques. The challenge was opened on 19 February 2018 and closed on 20 April 2018 [2]. The interested suppliers included L Engineering Services and EION Inc. [3].

2.1.2 HF Over-the-Horizon Robust Communications Enterprise (HFORCE)

Description: HFORCE communicates via the protected HF waveform and is unique in that it is a non-relay solution in the absence of SATCOM, with the potential to provide global coverage.

Status: Exploratory.

Developer: Massachusetts Institute of Technology Lincoln Labs (Lexington, MA) [4].

The High Dynamic Range Multi-Carrier Amplifier proposal details that this technology should be able to transmit and receive the following frequencies: very high frequency, ultra-high frequency, and HFORCE [5].

2.1.3 BAE Systems Jindalee Operational Radar Network (JORN)

BAE Systems Australia was awarded a $1.2 billion contract to upgrade and support the JORN, which bounces radar waves off the ionosphere. This work will provide important knowledge for

the major AIR 2025 JORN Phase 6 upgrade planned to start in 2018. The upgrade to the over-the-horizon radar (OTHR) network is designed to "open" the system's architecture, enabling the insertion of next generation technologies and extending the operational life of JORN to beyond 2042 [6-8].

2.1.4 High-Performance Wireless Research and Education Network (HPWREN)

HPWREN's project objectives include wide-area, wireless, high-performance networking and connecting sensor networks. HPWREN's network architecture has a high-performance backbone network and high-speed access links [9].

2.1.5 Talon Tactical Mobile Over-the-Horizon Radar (TACMOR)

Description: TACMOR will support air domain awareness and maritime domain awareness requirements over the Western Pacific region. The project will demonstrate a subscaled OTHR that is one quarter the size of traditional OTHR systems. In fiscal year (FY) 2017, TACMOR designed and fabricated transmit/receive enclosures, fabricated transmit/receive arrays, and integrated system components with partner nations [10].

TACMOR's FY 2018 plans include the following:

- Conduct critical design reviews, factory tests, and a military utility assessment of the system.
- Install the OTHR system at the site using partner funding.
- Integrate the system with other intelligence, surveillance, and reconnaissance assets.
- Develop system and training documentation.
- Transition the system to the U.S. Air Force and complete the Joint Capability Technology Demonstration.

2.1.6 RIM-66C Standard Missile-2 (SM-2) Blocks III/IIIA/IIIB [11]

Description: The RIM-66C SM-2 is the Navy's primary air defense weapon. SM-2 Block III/IIIA/IIIB configurations are all-weather, ship-launched, medium-range, surface-to-air missiles in service with the Navy and 15 allied navies. SM-2 enables forward naval presence, littoral operations, and projecting and sustaining U.S. forces in antiaccess and area-denied environments. SM-2 Block III/IIIA/IIIB missiles are launched from the Mk 41 vertical launching system installed in Aegis cruisers and destroyers. Block III features improve performance against low-altitude threats and optimize the trajectory shaping within the Aegis command guidance system by implementing shaping and fuse altimeter improvements. Block IIIA features a new directional warhead and a moving-target-indicator fuse design for improved performance and lethality against sea-skimming threats. Block IIIB adds an infrared (IR)-guidance mode capability developed in the missile homing improvement program to improve

performance in a stressing electronic countermeasure environment. Blocks IIIA/IIIB will be the heart of the SM-2 inventory for the next 20 years. The latest generation of Block IIIB missiles includes a maneuverability upgrade (SM-2 Block IIIB with MU2) to enhance weapon performance against low-altitude, supersonic maneuvering threats.

Status: The Navy established a depot (FY 2013) and rocket motor regrain program (FY 2014) to maintain the inventory out to 2030 and beyond. This will allow the SM-2 inventory to keep pace with the Navy's 30-year shipbuilding plan, keep infrastructure in place to convert SM-2 Block IIIA missiles to the unique interrupted continuous wave illumination/joint universal weapon link variant for the three Zumwalt (DDG 1000)-class warships, and support projected increases in fleet proficiency firings. In addition, to avoid significant hardware obsolescence impacts, a modification to SM-2 to incorporate SM-6 technology will result in a supportable missile with commonality benefits to the Standard Missile family. This effort will begin in FY 2017 and result in increased SM-2 capability from incorporating this latest technology.

Developer: Raytheon (Tucson, AZ).

2.1.7 Naval Integrated Fire Control–Counter Air (NIFC–CA) From the Sea (FTS) [11]

Description: The NIFC-CA FTS kill chain provides both an engage on remote (EOR) and OTH air defense capability, taking advantage of the full kinematic range of the Navy's missiles, manned aircraft, and cruise missiles. NIFC-CA is a non-acquisition category (ACAT) project established to ensure the alignment of the SM-6 missile, Cooperative Engagement Capability, E-2D Advanced Hawkeye, and Aegis Weapon System. The NIFC-CA "System of 51 Systems" project overcomes traditional radar horizon limitations and expands on cooperative engagement capability sensor netting capability to provide an EOR capability to kill targets OTH at greater ranges than conventional organic fire-control systems.

Status: The NIFC-CA project has conducted more than 200 live-tracking events. All seven live-fire tests successfully verified NIFC-CA capability. One of these tests, conducted in June 2014, was the longest Standard Missile engagement in history. The first deployment of initial capability deployed in FY 2015. Three live-fire events were conducted in the fall of 2016—an integration demonstration with F-35 Joint Strike Fighter, an at-sea test event, and a stream raid presentation.

2.1.8 KSQ-1 Amphibious Assault Direction System (AADS) [11]

Description: The AADS, with the Enhanced Position Location Reporting System, integrates the Navigation Satellite Timing and Ranging global positioning system (GPS) to form a jam/intercept-resistant, friendly, force-tracking, command and control system that supports the surface assault ship-to-shore movement in amphibious operations. It provides the

capability to launch, monitor, track, record, and control landing craft air cushion (LCAC), landing craft utility (LCU) vessels, Naval Beach Group/seabasing craft conducting amphibious assaults from up to 100 nautical miles OTH via radio relay group configuration. It integrates with the Marine Corps tactical radio (PRC-117G) and the Global Command and Control System-Maritime during ship-to-objective maneuver operations.

Status: AADS satisfies operational requirements for an OTH amphibious assault command and control system. AADS is installed in 32 amphibious ships, 78 LCACs, 32 LCUs, Assault Craft Units 4 and 5 control towers, and Expeditionary Warfare Training Group (Atlantic and Pacific) Amphibious Boat Control Team Trainer (ABCTT) classrooms. ABCTT upgraded with AADS Simulator to properly train Amphibious Boat Control Team per fielded boat control configurations. The AADS Program Office is executing the AADS modernization plan, which addresses program information technology risk assessment issues, Windows XP to Windows 7 migration, and other upgrades to improve system integrity. The AADS Program Office is also working to provide a coalition common operating picture with Australian and Canadian Forces using the KOK-23 Crypto Key Generator.

2.1.9 AGM-154 Joint Standoff Weapon (JSOW) [11]

Description: The JSOW is a family of weapons that enables naval aircraft to attack targets at standoff distances using GPS/inertial navigation system for guidance. All JSOW variants share a common body but can be configured for use against area targets, bunker penetration, and ship attack. Defeating emergent, time-critical threats, whether near or over the horizon, require an all-weather weapon capable of penetrating defended sanctuaries and destroying hostile targets while minimizing the danger of collateral damage to friendly and neutral shipping as well as friendly/neutral assets and personnel ashore. The JSOW Unitary (JSOW C) variant adds an imaging IR seeker and autonomous target acquisition to attack point targets with precision accuracy. The JSOW C-1 incorporates new target-tracking algorithms into the seeker for moving targets, giving the joint force commanders an affordable, air-delivered, standoff weapon that is effective against fixed and relocatable land and maritime targets. Used in conjunction with accurate targeting information and antiradiation weapons, JSOW C-1 will provide the capability to defeat enemy air defenses while creating sanctuaries that permit the rapid transition to low-cost, direct-attack ordnance.

Status: AGM-154A reached initial operational capability (IOC) in 1999, and the AGM-154C variant achieved IOC in FY 2005. JSOW C-1 began procurement in FY 2011 and achieved IOC in June 2016. JSOW C-1 was procured through FY 2016.

2.1.10 MPR5X0-MICA2DOT Sensor

The MICA2DOT wireless measurement system is a quarter-sized sensor that enables wireless communications with data logging in hard-to-reach places [12, 13].

2.1.11 MICAz Wireless Measurement System

The MICAz wireless system is a 2.4-GHz mote module used for enabling low-power, wireless sensor networks (WSN) [12, 14, 15].

2.2 DTIC R&E GATEWAY BIBLIOGRAPHY

DSIAC staff completed literature searches of the DTIC R&E Gateway using Boolean strings of the terms over the horizon, satellite denied, communications, missile, form factor, and names of programs found in open sources. The search was limited to the last 6 years, and the most relevant publications were Distribution A. (See the Appendix for more information.)

2.3 ADDITIONAL RESOURCES

The brochure “Making 5G New Radio (NR) a Commercial Reality” was supplied by CSIAC and highlights advances in 5G technology and mobile-sized form factor radio frequency front-end controllers and millimeter wave antennae [12, 16].

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APPENDIX: Defense Technical Information Center (DTIC) Bibliography

Highest Classification: UNCLASSIFIED

DTIC Bibliography

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Highest Classification: UNCLASSIFIED

Highest Classification: UNCLASSIFIED

Standard Display

Title: (U) Organic Over-the-horizon Targeting For The 2025 Surface Fleet

Accession Number: ADA632418

PDF URL: **- 3 MiB -** https://www.dtic.mil/DTICOnline/downloadPdf.search?collectionId=tr&docId=ADA632418

Personal Author(s): Johnson, Cale; Judy, Brian; Spurr, Nathaniel; Gulledge, Joseph; Harris, Paul; Haubold, Kyle; Riner, Jason; Goh, William; Hoo, Yew K.; Lau, Dylan Z.; Lua, Kwong Y.; Ng, Cheng L.; Phua, Weiyou; Poh, Yang S.

Corporate Author: NAVAL POSTGRADUATE SCHOOL MONTEREY CA

Corporate Source Code: 251450

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Distribution Code: A - 01 - APPROVED FOR PUBLIC RELEASE
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Citation Classification: Unclassified
Report Classification: Unclassified
Collection: Technical Reports

Report Date: 2015-06-01

Abstract: (U) Adversarial advances in the proliferation of anti-access/area-denial (A2/AD) techniques requires an innovative approach to the design of a maritime system of systems capable of detecting, classifying, and engaging targets in support of organic over-the-horizon (OTH) tactical offensive operations in the 2025 2030 timeframe. Using a systems engineering approach, this study considers manned and unmanned systems in an effort to develop an organic OTH targeting capability for U.S. Navy surface force structures of the future. Key attributes of this study include overall system requirements, limitations, operating area considerations, and issues of interoperability and compatibility. Multiple alternative system architectures are considered and analyzed for feasibility. The candidate architectures include such systems as unmanned aerial vehicles (UAVs), as well as prepositioned undersea and low-observable surface sensor and communication networks. These unmanned systems are expected to operate with high levels of autonomy and should be designed to provide or enhance surface warfare OTH targeting capabilities using emerging extended-range surface-to-surface weapons. This report presents the progress and results of the SEA-21A capstone project with the recommendation that the U.S. Navy explore the use of modestly-sized, network-centric UAVs to enhance the U.S. Navy's ability to conduct surface-based OTH tactical offensive operations by 2025.

Descriptive Note: Capstone project rept.

Supplementary Note: The original document contains color images.

Pages: 213 Page(s)

Document Location: DTIC

Report Number: *(XB NPS)*

Monitor Acronym: XB

Monitor Series: NPS *(NPS)*

Descriptors: (U) *AIRCRAFT , *OVER THE HORIZON DETECTION , *TARGETING , ARCHITECTURE , ATTACK , CLASSIFICATION , COMMUNICATIONS NETWORKS , COMPATIBILITY , FEASIBILITY STUDIES , GROUND LEVEL , INTEROPERABILITY , LIMITATIONS , MANNED , MILITARY OPERATIONS , NAVY , SYSTEMS APPROACH , SYSTEMS ENGINEERING , TACTICAL WARFARE , TARGETS , THESES , UNMANNED , WARFARE

Fields and Groups: 171100 - Target Direction, Range and Position Finding

Citation Creation Date: 2016-06-13

Citation Status: active

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Highest Classification: UNCLASSIFIED

Standard Display

Title: (U) Uav Position Optimization For Wireless Communications

Accession Number: AD1059967

PDF URL: **- 5 MiB -** https://www.dtic.mil/DTICOnline/downloadPdf.search?collectionId=tr&docId=AD1059967

Personal Author(s): Keegan,Benjamin P.

Corporate Author: Naval Postgraduate School Monterey United States

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Distribution Statement: Approved For Public Release;
Special Indicator Code: A
Special Indicator: abstract is unclassified, unlimited (U2)
Citation Classification: Unclassified
Report Classification: Unclassified
Collection: Technical Reports

Abstract: (U) This thesis explores autonomously positioning unmanned aerial vehicles (UAV) as wireless nodes in optimal locations to form robust, reliable communication links between static or slow-moving nodes, on land or at sea, in a wireless network. The presented approach explicitly accounts for variability associated with signal-to-noise ratio (SNR) estimates used for UAV navigation. A two-phased approach is presented to find a local SNR extremum as an optimal loitering point. This thesis focuses on phase one consisting of Kriging and semivariogram analysis as well as information theoretic local path planning. Kullback-Leiblerdivergence is used for path evaluation and selection. Phase two consists of an extremum control methoddeveloped in prior work for UAV navigation to the optimal loitering point. Emphasis is placed on accuracy and reducing model uncertainty. Simulated and experimental data is presented and used for Kriging of theSNR field produced by two ground nodes. Datasets produced with varying distances, altitudes, and flightpatterns provide insight into the behavior of SNR degradation and flight trajectories that are most efficient atreducing estimate uncertainty. Analysis provides a greater understanding of the current capabilities, benefits,and limitations of employing UAVs as autonomous, mobile communication nodes. This includes thepotential for implementing nonlinear optimal estimation and path planning processes onboard small UAVsin real time.

Descriptive Note: Technical Report

Pages: 125 Page(s)

Descriptors: (U) altitude , autonomous underwater vehicles , aircrafts , collision avoidance , experimental data , robotics , mobile communications , multiple input multiple output , navigation , wireless networks , wireless sensor networks , autonomous systems , communication systems , computers , motion planning , control systems , mesh networks , mobile phones , unmanned aerial vehicles , wireless communications

Citation Creation Date: 2018-09-18

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Highest Classification: UNCLASSIFIED

Standard Display

Title: (U) Robust Multi-agent Sensor Network Systems

Accession Number: ADA560933

PDF URL: - 10 MiB - https://www.dtic.mil/DTICOnline/downloadPdf.search?collectionId=tr&docId=ADA560933

Personal Author(s): Anderson, Brian D.; Bishop, Adrian; Mao, Guoqiang; Yu, Changbin

Corporate Author: NATIONAL INFORMATION AND COMMUNICATIONS TECHNOLOGY/AUSTRALIA (ICT)CANBERRA

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Report Date: 2012-05-08

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Distribution Statement: Approved for public release; distribution is unlimited.
Citation Classification: Unclassified
Report Classification: Unclassified
Collection: Technical Reports

Abstract: (U) Results obtained with the grant fall into several groupings: (a) Combinatorial conditions on the graphical representation of a two dimensional sensor network that will guarantee localizability of the network in the event of loss of any p sensors and/or q links in the network, for nonnegative integers p and q; (b) analysis of the effects of measurement error on the quality of localization of sensor positions in a sensor network, or more generally a target being localized; (c) the derivation of a measure, including algorithms for computing it, of the quality of connectivity of a network modeled by a graph with nodes and links, and in which the individual links are operative with defined a priori probabilities, and the probability that any one link is operative is independent of the probability that any other link is operative; (d) connectivity and capacity of networks with randomly positioned nodes and probabilistic channel models; (e) Doppler localization problems and miscellaneous multi-agent problems.

Descriptive Note: Final rept. 6 May 2010-5 May 2012

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Monitor Series: 104102 *(104102)* , AOARD *(AOARD)*

Contract/Grant/Transfer Number: FA2386-10-1-4102 *(FA23861014102)*

Descriptors: (U) *DETECTORS , *MULTIAGENT SYSTEMS , AUSTRALIA , COMMUNICATIONS NETWORKS , NODES , POSITION(LOCATION)

Identifiers: (U) CONNECTIVITY, FOREIGN REPORTS, LOCALIZATION, SENSOR NETWORKS

Fields and Groups: 120900 - Cybernetics

170800 - Miscellaneous Detection and Detectors

250200 - Radio Communications

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