VDES Small Satellite Constellation Enabling Ground-Breaking Opportunities for Environmentally Friendly Autonomous Navigation and Maritime Safety Applications

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ABSTRACT

The implementation of a global maritime communication system has the potential to reduce fuel and emissions in the global merchant fleet, resulting in significant environmental benefits. In this paper, a new collaborative partnership between AAC Clyde Space, ORBCOMM Inc. and SAAB, known as AOS, is presented, marking the beginning of a new era in maritime communications.

Through the development and demonstration of a space-based VHF Data Exchange System (VDES), which is the next generation of Automated Identification Systems (AIS), it will provide two-way communication with increased data exchange capability, improving the navigation and communication solutions for the shipping industry. AOS are in the process of developing a satellite, Njord-1 (3U CubeSat), and is expected to be followed by a larger constellation of satellites. The first satellite will be assembled at AAC Clyde Space's new integration facility in Uppsala, Sweden. The satellite will carry a miniaturised state-of-the-art VDES (VHF Data Exchange System) transceiver payload from SAAB for two-way communication between the satellite and the ship at the ocean. ORBCOMM will integrate the data in its distribution centre for maritime communications.

The addition of an enhanced two-way space-based capability will form a new part of the maritime communication infrastructure, converting what is currently a predominantly coastal system into a global maritime system, increasing the communication coverage from the shoreline to anywhere in the ocean.

1 INTRODUCTION

It's estimated that the global merchant vessel fleet have a potential of saving up to 25% of its fuel and emissions by utilisation of Sea Traffic Management (STM) systems through exchange of standardised route messages, optimising vessel environmental conditions for the journey like wind vector, sea current vector, waiting time and enabling just-in-time arrivals in both known

and new ports. Currently, 400 merchant and passenger vessels are sailing with this promising new STM technology, and if it's implemented globally, based on an enabling VHF Data Exchange System (VDES) infrastructure, there will be environmental benefits such as a reduction in time, fuel and greenhouse gas emissions.

When a ship is sailing a STM optimised route, the navigation critical information subset is broadcasted ship-to-ship via VDES. The route message broadcast is used as a means to indicate intended navigation and route information to nearby ships, allowing them to avoid ending up in a close-quarter situation. The route message information should be used as an aid to navigation and not interfere with existing watch-keeping practices of maintaining a proper lookout or compliance with the International Regulations for Preventing Collisions at Sea [1].

Route exchange is one of the core foundations for future autonomous vessel navigation. This includes both the monitored route that the specific ship is sailing and the navigation subset payload that is broadcasted over VDES.

The next generation of AIS [2] [3], internationally called VDES during the World Radiocommunication Conference 2019 [4], allocated frequencies for satellite communication. VDES makes available up to 32 times more bandwidth compared to AIS and can provide unique satellite-to-ship communication and improved integrity and cyber-security. The deployment of a VDES small satellite constellation could become the communication backbone and facilitator of these services and have a significant importance for the global shipping industry's contribution to reducing emissions. Based on standardised communication protocols, existing coastal base stations and equipment that is already available on the ship bridge, this infrastructure has the potential of worldwide acceptance and fast route to implementation. The business case is leveraging collaboration between world class leading industrial partners within the maritime services and space fields and using a miniaturized state-of-the-art payload and satellite technology together with innovative deployable antenna systems and mission architectures.

2 AOS OVERVIEW

AOS (https://aos-vdes.com) is a collaborative partnership between AAC Clyde Space, ORBCOMM Inc. and SAAB, developing the next generation of space-based VDES system, marking the beginning of a new era in maritime communications. The vision of the partnership is to create the first dedicated global maritime communication system, enabling significant improvements for the shipping industry as well as our planet.

The first satellite in the collaborative partnership is Njord-1, a 3U satellite, discussed further in Section 4. It is planned as the first satellite in an intended constellation and will be the first satellite assembled at AAC Clyde Space's new integration facility in Uppsala, Sweden. The satellite will carry a VDES (VHF Data Exchange System) payload from SAAB for two-way communication between satellite and the ground. ORBCOMM will integrate the data in its distribution centre for maritime communications.

An overview of AAC Clyde Space, ORBCOMM Inc. and SAAB is as follows:

- AAC Clyde Space specialises in small satellite technologies and services that enable businesses, governments, and educational organisations to access high-quality, timely data from space. Its growing capabilities bring together three divisions:
    - Space missions – turnkey solutions that empower customers to streamline their space missions
    - Space Data as a Service – delivering data from space directly to customers
    - Space products and components – a full range of off-the-shelf and tailor-made subsystems, components, and sensors

  AAC Clyde Space's main operations are located in Sweden, the United Kingdom, the Netherlands, the USA and South Africa, with partner networks in Japan and South Korea, as shown in Figure 1. Their subsidiaries include AAC Hyperion (Netherlands), AAC SpaceQuest (USA), AAC Omnisys (Sweden) and AAC Space Africa (South Africa).

Figure 1: AAC Clyde Space Locations

- ORBCOMM Inc. is a leading global industrial Internet of Things (IoT) satellite data communications company focused on Machine-to-Machine (M2M) and Automatic Identification System (AIS) communications. ORBCOMM is a U.S. based company with a significant global presence. Founded in 1993 by Orbital Science Corporation, ORBCOMM had a fully operational satellite network by the year 2000. Since 2001, ORBCOMM has grown to be a global player with over 800 employees, working from 14 offices in 10 different countries around the world. The company's current satellite constellation includes spacecraft carrying AIS receivers which made ORBCOMM the first commercial provider of globally collected AIS data from space. By means of a global network of AIS satellites, and the widest network of terrestrial AIS data sources, ORBCOMM is able to provide the most complete, low-cost, and reliable AIS service in the market. ORBCOMM is headquartered in Rochelle Park, New Jersey, USA and has a network control center in Sterling, Virginia, USA.
- SAAB serves the global market with world-leading products, services and solutions from military defence in all domains to civil security. SAAB's market offering is broad and consists of complex systems involving extensive research and development as well as services with a high degree of repetition. With operations on every continent, SAAB

continuously develops, adapts and improves new technology to meet customers' changing needs.
SAAB TransponderTech, a leading manufacturer of AIS, is providing all parts of the VDES system for this service, such as, shipborne VDES, shore based VDES and satellite VDES transponders, all based on their 5th generation Software Defined Radio platform. The new radio platform provides easy upgrade using existing antenna installations.

3 WHAT IS VDES?

An AIS (Automatic Identifications System) is a vessel coordination system that provides ship position, identification, and other information sets to other ships and to coastal authorities automatically. AIS however has its limitations, such as when it is deactivated on ships or when the system is overwhelmed.

VDES, the next generation of AIS, provide two-way communication with increased data exchange capability, improving the navigation and communication solutions for the shipping industry. VDES addresses the overload of the AIS VHF Data Link (VDL) and allows for improved navigation and communication solutions for the shipping industry. It adds a new, creating a global high-speed ship-to-satellite and satellite-to-ship communication link available for various applications.

By adding space-based capability to VDES, the communication system's range increases from the shoreline to anywhere in the ocean, converting what is currently a predominantly coastal system into a global maritime system. With up to 32 times more bandwidth than the currently widely used Automatic Identification System (AIS) communication, VDES can be integrated with e-navigation systems, enabling savings in fuel and emissions of up to 25 percent, aiding navigation, and increasing safety. The bandwidth also creates opportunities for a wide range of other services, from delivery of weather data to messaging.

4 NJORD-1 SATELLITE OVERVIEW

4.1 PLATFORM DESIGN

The VDES platform is a 3U CubeSat satellite as shown in Figure 2. The platform hosts a full suite of spacecraft avionics that enable the spacecraft to fulfil the system requirements whilst leaving sufficient mass and volume available for the payload.

Figure 2: Njord-1 Satellite (3U)

The breakdown structure for the satellite it provided in Figure 3, with an overview of the satellite design as follows:

- Power: consists of a set of two triple-deployed solar panels, leveraging heritage from an existing AAC Clyde Space design.
- Flight Software: the on-board software is based on Bright Ascension's GenerationOne flight software [5].
- Communication: the platform TMTC link with ground will make use of an S-band radio and two patch antennas, one on each Y-face of the spacecraft.
- ADCS: used to provide 3 axis pointing towards different targets. The sensors include Fine Sun Sensors, Coarse Sun Sensors, Star Tracker, magnetometers and GPS. The actuators include Reaction Wheels and Magnetorquers.

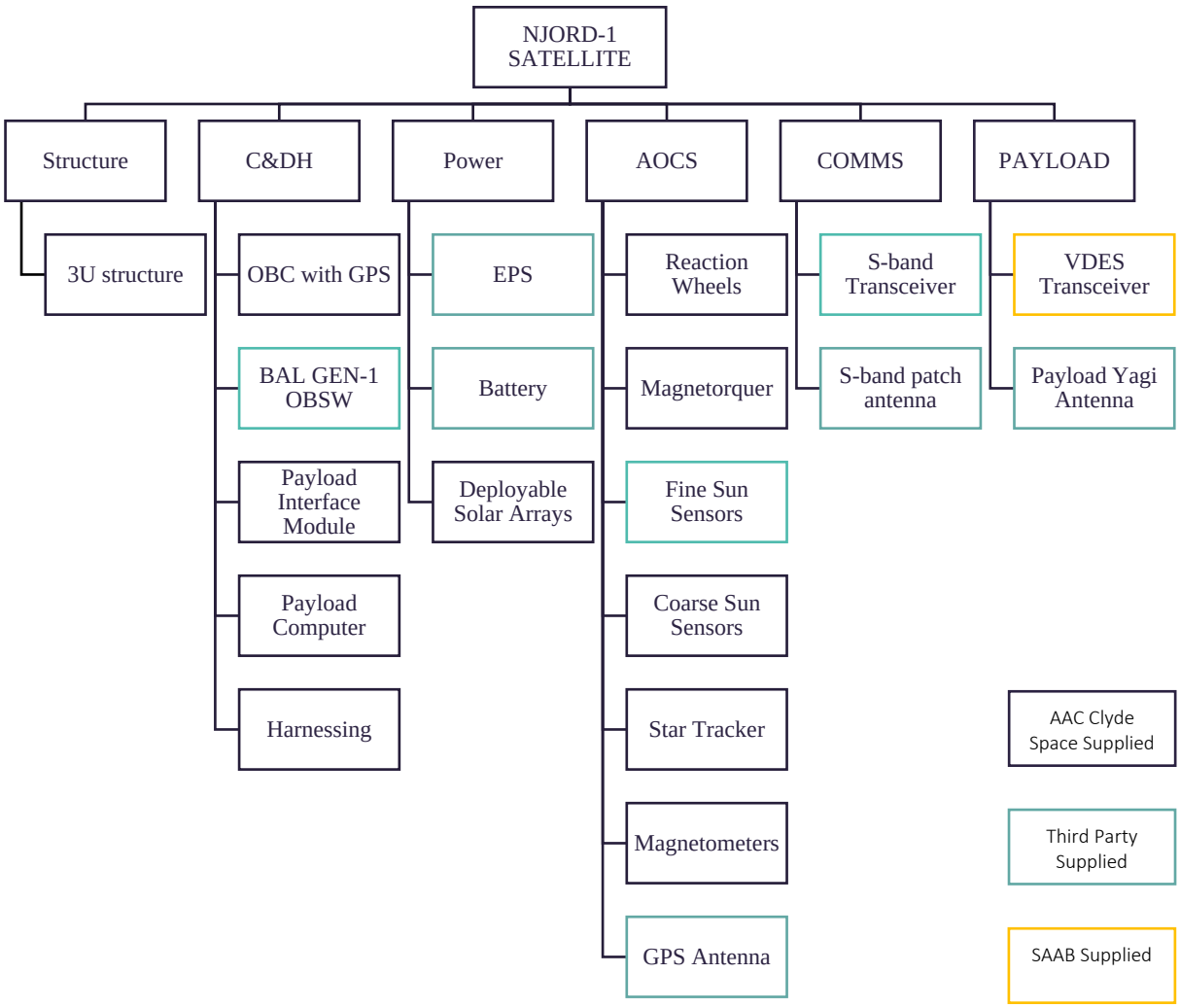

Figure 3: Njord-1 Satellite Product Breakdown

4.2 PAYLOAD DESIGN

The payload design is comprised of the following components:

- SAAB R6 VDES Sat Transceiver.
- VDES RF Front End (RFFE).
- Deployable Payload Yagi Antenna.

The SAAB R6 VDES Sat Transceiver, shown in Figure 4, is a VDES transceiver capable of receiving VDES and transmitting VDE messages over a VHF data link. The R6 VDES Sat Transceiver interfaces electrically with the satellite on-board computer via power supply lines

and data communication interfaces. Additionally, the R6 VDES Sat Transceiver connects to the on-board deployable VHF antenna via the R6 VDES Sat RF Front End module.

The payload antenna is a deployable 3-element cross-polarised Yagi antenna, designed and manufactured by Oxford Space Systems (OSS), as shown in the deployed view in Figure 2.

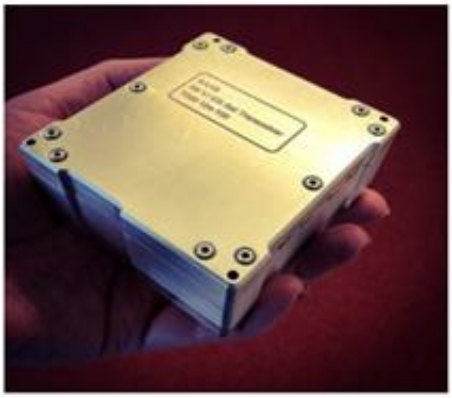

Figure 4: SAAB VDES Transceiver

5 CONCEPT OF OPERATIONS

The overall mission architecture is shown in Figure 5. This illustrates the overall concept with high-level overview of the main data interfaces. ORBCOMM operates a global constellation of low-earth orbit (LEO) satellites and accompanying ground infrastructure and a Network Control Center (NCC) to manage all of its IoT messaging services and AIS data flowing through the ORBCOMM network. The ORBCOMM network and existing worldwide ground infrastructure is designed to provide users the most reliable and resilient service available today. Customer Support is provided from ORBCOMM's Network Control Center located in Sterling, VA, USA. The center operates 24 hours per day, 7 days a week. This time-proven and robust network will be leveraged to provide global VDES communications for vessels and shore-side service users.

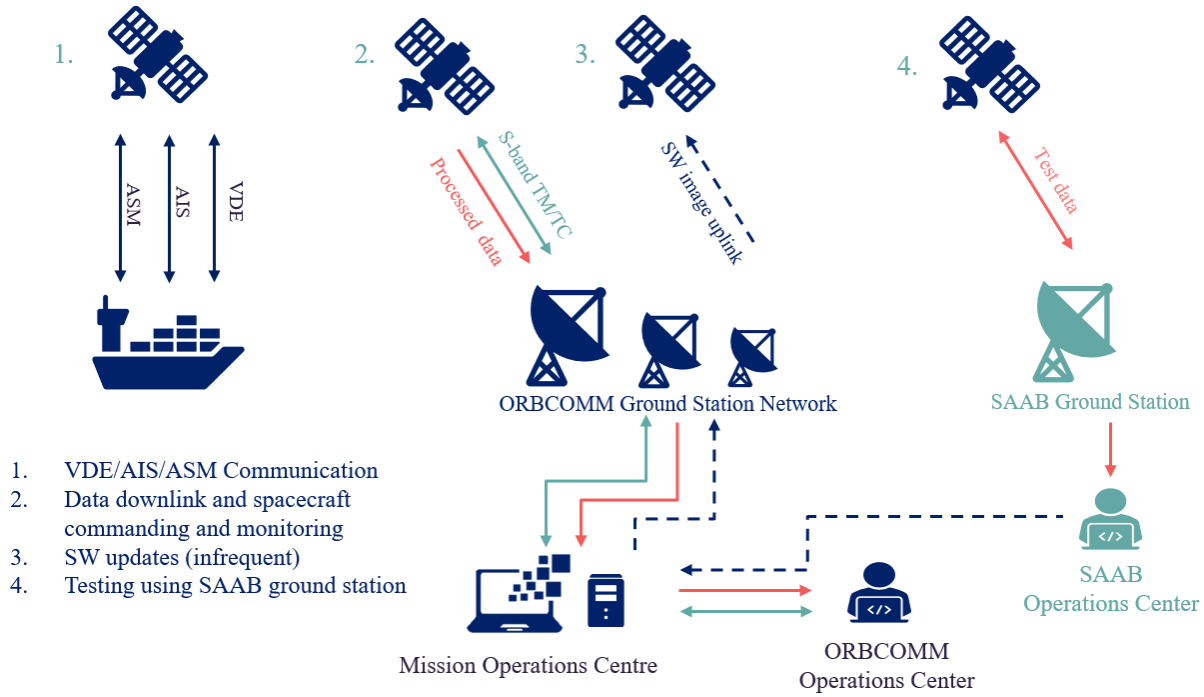

Figure 5: VDES IOD Mission Architecture

6 CONCLUSION

This paper has presented an overview of a proposed new global maritime communication system through the use of a VDES system. AOS, a collaboration partnership between AAC Clyde Space, ORBCOMM and SAAB, are developing a 3U demonstration satellite that is built by AAC Clyde Space, with SAAB providing an innovative state-of-the-art VDES payload and ORBCOMM providing the operations. It is planned that a constellation of satellites will follow, enabling a global maritime communication system that has the potential to reduce fuel and emissions in the global merchant fleet, resulting in significant environmental benefits.

7 REFERENCE

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