Electromagnetic Spectrum Performance Products Ashore (EMSPPA)

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ABSTRACT

The goal of this project is to provide a new ashore (reach back) radar/radio frequency (RF) and electro-optical (EO) performance products system called EMPPAS (Electromagnetic Propagation and Performance Assessment Suite) for U.S. Navy applications that is modular, extensible, and driven by a high fidelity environment model. This project started in October 2016 and leverages existing as well as emerging RF and EO capabilities in a unified electromagnetic spectrum (EMS) system and integrates them with an existing application called the Interactive Scenario Builder (or Builder) developed at the Tactical Electronic Warfare Division at NRL-DC. Builder, with integration of EMPPAS, will serve as a replacement for the current tactical decision aids (TDAs) for RF: AREPS (Advanced Refractive Effects Prediction System), and EO: TAWS (Target Acquisition Weapons Software). AREPS is a legacy application within the currently fielded Naval Integrated Tactical Environmental System-IV (NITES-IV) that is no longer supported, while TAWS is the only EO TDA used by the U.S. military and is no longer supported by its resource sponsor. This paper overviews the design and implementation plans for the new EMPPAS system.

1.0 BACKGROUND

A thorough understanding of how the atmospheric environment impacts both RF and EO propagation is critical to gaining, maintaining, and exploiting a tactical advantage in today's contested cyber warfare world. Strategies described in recent Navy directives all emphasize the critical need to achieve tactical superiority across the entire electromagnetic spectrum (EMS, to include both RF and EO). An important component of this strategy is the need for an EMS performance prediction capability (range and detection) as well as the quantitative quality and measure of uncertainty of these predictions. The skill of performance predictions using current propagation models (such as the Advanced Propagation Model, APM, or TAWS) is limited by lack of a high fidelity characterization of the atmosphere. Likewise there is little information of the quality of (or confidence in) the EMS performance predictions because there is no validated truth to compare against.

This paper describes the EMSPPA project that is focused on providing EMS performance products and their quality by (i) developing and testing a new method to quantify the quality of EMS performance predictions, and (ii) providing reach back (ashore) capability to easily produce and disseminate EMS products in a new capability called the EM Propagation and Performance Assessment Suite (EMPPAS; described below), integrated with the existing Builder architecture.

2.0 APPROACH

The project is composed of two complementary thrusts, one RF-focused and one EO-focused. Two existing RF and EO systems are leveraged: RFPPAS (RF Propagation and Performance Assessment Suite) and TrueView (EO/IR system), both developed at SPAWAR Systems Center-Pacific (SSC-PAC). These two systems are being modified and integrated with an existing RF TDA called Scenario Builder (or "Builder"). There is tremendous opportunity from science as well as engineering perspectives to leverage these related RF and EO thrusts to create a powerful new unified system with Builder that exceeds the individual impact of either RF or EO system independently.

EMPPAS is a modular system that uses the existing RFPPAS originally developed under the Naval Innovation Science and Engineering (NISE) in-house program at SSC Pacific (SSC-PAC). RFPPAS was established to improve, update, and compartmentalize the underlying software architecture of the propagation models and post-processing algorithms within AREPS. One of the goals of RFPPAS was to make these "AREPS-components" easily portable and easier to integrate within NITES-Next, and other Programs of Record (PORs) such as Real Time Spectrums Operations (RTSO), Maritime Tactical Command & Control (MTC2), Distributed Common Ground System - Navy (DCGS-N), or Ships Signal Exploitation Equipment, Increment E (SSEE-E), that require real-time RF performance predictions.

Builder is a three-dimensional, interactive RF TDA used by several U.S. military PORs, with a current Authorization to Operate (ATO). As a mission planning tool, Builder aids war fighters in the tactical decision making process by providing insight into and visualization of the RF capabilities of platforms in addition to providing geospatial and temporal situational awareness. Builder models communication and radar systems by calculating one- and two-way RF propagation loss. Computations incorporate complex antenna and radar cross section (RCS) pattern data as well as the effects of meteorology, terrain, and countermeasures. Builder enhances the war fighter's geospatial situational awareness by visualizing map products and can be used for pre-mission planning, near real-time situational awareness, and after-action debriefing.

The current RFPPAS configuration being integrated with the Builder architecture (to make EMPPAS) is composed of three main modules: 1) pre-processing, 2) propagation engine, and 3) post-processing. The new EMPPAS leverages that architecture, adding modular EO specific functionality where needed (see Figure 1). In general, the environmental input for both RF and EO propagation models are very similar, requiring atmospheric state variables such as air and sea surface temperature, pressure, winds, and moisture. Additional environmental forcing parameters important for EO, such as clouds, turbulence, aerosols, dust, smoke, ocean surface wave conditions, and sea salinity are being added to the pre-processor. The core atmospheric modelling component of the pre-processor is the current high-resolution, mesoscale state-of-the-art coupled numerical weather prediction (NWP) model developed for naval applications ([1]COAMPS®). The propagation engine is being modularized to include EO prediction, based on the new TrueView hyperspectral EO/IR scene simulator. TrueView models dynamic sensor and target trajectories from visible to long-wave infrared (VIS – LWIR) wavelengths, 3D scenario geometries, target and background visible and thermal signatures, and CONOPS of interest. It generates large-area, target-in-realistic-background hyperspectral scenes of high spatial and temporal resolution from which estimates of Probability of Detection (PoD) and Detection Ranges (DR) for given targets and sensors are derived. Finally, the existing RFPPAS post-processing are being generalized for RF and EO products and upgraded to include the new Large Eddy Simulation (LES)-based performance quality capability adapted for both RF and EO prediction. The system is extensible because the modular components can easily be adapted based upon results from the LES and environmental assessment experiments to include new, or exclude inaccurate, criteria for determining the lookup tables.

[1] COAMPS (Coupled Ocean/Atmosphere Mesoscale Prediction System) and COAMPS-OS (On-Scene) are registered trademarks of the Naval Research Laboratory.

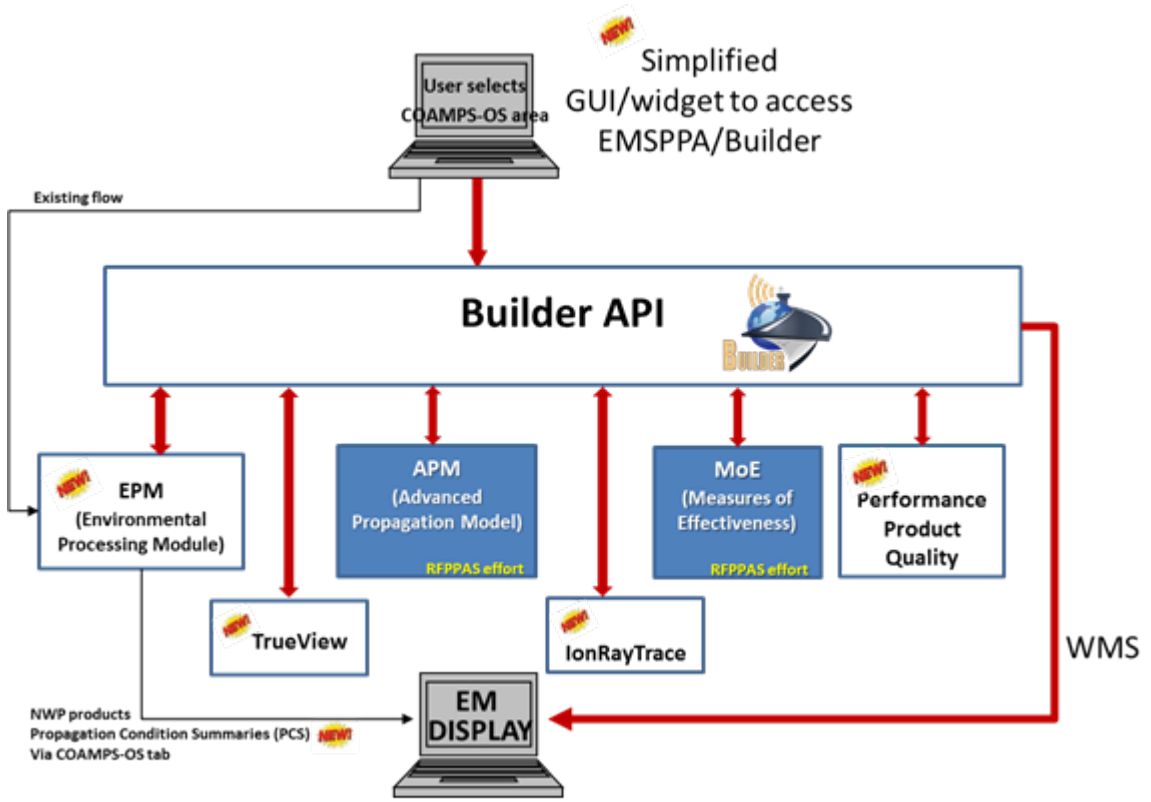

Figure 1: Prototype EMPPAS architecture integrated with Builder.

2.1 Performance quality capability

The LES-based performance quality capability uses a novel approach to determine product quality. The approach uses ultra-high-resolution (order of 10's of meters vertical and horizontal resolution to span a volume of ~10 x 10 x 3 km3) numerical simulations using Large Eddy Simulation (LES) to represent "truth", in combination with available data sets. Propagation models are then executed using these "true" LES-based data sets to provide "true" propagation. A series of experiments derived from this true data set (described below) are conducted to assess environmental conditions in which one would expect propagation model results to be of high confidence and quality or low confidence and quality. A set of look-up tables is then developed for operational use based on the LES results that associate certain environmental conditions (e.g., boundary layer (BL) stability and cloud regimes, synoptic, mesoscale, ocean state, etc.) to degrees of confidence in EMS performance prediction. These tasks are all done a priori to any operational propagation modelling or products generation. Subsequent operational computations of EMS performance predictions are then combined with these quality products to provide a powerful application within EMPPAS called the Performance Prediction Quality (PPQ). The LES model results are also used to improve future COAMPS capability by calibrating aspects of the COAMPS BL and vertical mixing parameterizations.

In coordination with the PPQ application, an additional output capability called Propagation Condition Summaries (PCS) is produced within EMPPAS. Prototypes were originally developed under the SSC-PAC RFPPAS effort. These PCS visuals are being further refined, extended to EO, and hosted on the COAMPS-OS site. While the COAMPS-OS products currently have similar RF visuals (e.g., evaporation duct height, modified refractivity (M)-excess, etc.), the emphasis is to extend to EO (slant path visibility, air-sea temperature difference, etc.) and target non-METOC users. These products include brief narratives to answer the question: "what does this EMS feature mean to me?" for the communications, crypto, radar and EO sensor operations, etc., personnel, and provide an awareness of propagation conditions that can

significantly affect EMS performance within an area of interest. Figure 2 shows a sample product for the Southern California COAMPS-OS region for minimum trapped frequency and maximum trapped wavelength.

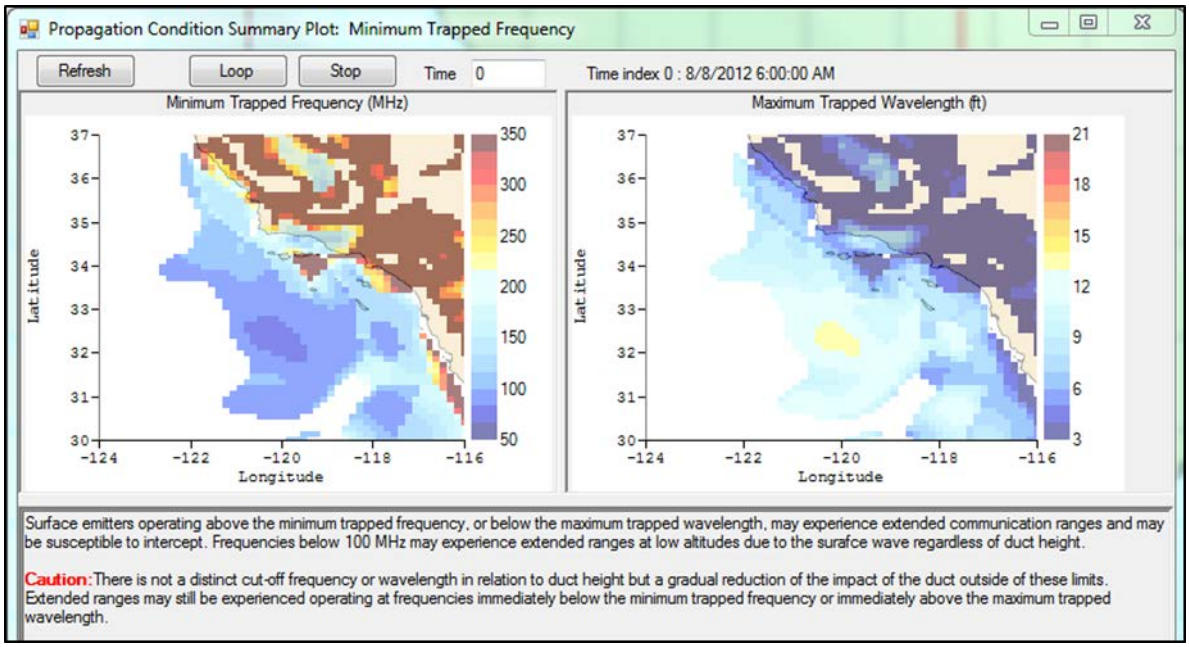

Figure 2: Sample Propagation Condition Summary for COAMPS-OS Southern California area.

For many naval operations, the near-surface atmospheric and oceanic surface to the BL top is the critical region impacting EMS propagation. COAMPS contains sophisticated physical parameterizations to predict BL structure and turbulence that can significantly impact EMS propagation. This new COAMPS-driven EMPPAS/Builder system in a reach back (ashore) configuration addresses a capability gap by providing simple yet useful RF and EO performance products that are intuitive and user-friendly. The PPQ and PCS products disseminated through the COAMPS-OS framework (using FNMOC computing capabilities) can provide useful theatre-scale information. The improved real-time and predictive capability provided by this project addresses a wide range of "what if" questions critical for keeping the initiative in spectrum operations, including: the impact of Blue Force emissions on non-hostile civilian systems, Blue Force de-confliction, and the susceptibility of Blue (Red) force emissions to Red (Blue) intercept.

3.0 SUMMARY

This paper provides an overview and general description of a new RF and EO performance products system called EMPPAS (Electromagnetic Propagation and Performance Assessment Suite) that is being developed for U.S. Navy applications. The system design is one that is modular, extensible, and driven by the current Navy operational high-resolution, mesoscale state-of-the-art coupled numerical weather prediction model COAMPS. The system integrates with the existing RF TDA called the Interactive Scenario Builder (or Builder) and extends it to include support for visible and thermal EO/IR wavebands. Builder, with integration of EMPPAS, will serve as a replacement for the current TDAs, AREPS and TAWS. The ultimate goal will be an implementation strategy that will allow for EMPPAS/Builder to be used in a forward-deployed capability when available.