Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
2008		**00-00-2008 to 00-00-2008**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Infrared Ship Signature Model Validation from Measurements at Chesapeake Bay Detachment	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Research Laboratory,4555 Overlook Avenue SW,Washington,DC,20375**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**2**	

Infrared Ship Signature Model Validation from Measurements at Chesapeake Bay Detachment

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Introduction: Increasingly, U.S. Navy ships are operating in the littorals where they may be exposed to many threat weapons and sensors. NRL uses infrared (IR) propagation and signature models to predict ship vulnerability and to evaluate the effectiveness of current and proposed self-defense systems against IR threats that are more prevalent in the littorals. Ship signature models are also being heavily used during the design phase for many of the Navy's new ship programs, such as DDG-1000, CVN-21, and CG(X). Reliance on the predictions of the models requires a validation of the model accuracy. With well-instrumented measurements of physical phenomena, a confirmation of the model predictions can be achieved. For this purpose, NRL organized and participated in the NATO SAPPHIRE (**S**hip and **A**tmospheric **P**ropagation **PH**enomenon **I**nfra**R**ed **E**xperiment) trial.

NATO SAPPHIRE Field Trial: The NATO SAPPHIRE trial was conducted at the NRL Chesapeake Bay Detachment (CBD)/Tilghman Island test site in June 2006. After considering many test sites worldwide, NRL's CBD facility was selected specifically for its warm water, littoral features, and environmental conditions likely to produce super-refractive propagation conditions. These unique features satisfied a wide set of conditions missing from previous IR model validation data sets. Additionally, this area of the Chesapeake Bay possesses many buoys and meteorological stations that provide crucial supplemental data.

The SAPPHIRE trial included the research teams of 10 NATO partner nations (United States, Canada, Denmark, France, Germany, Italy, Netherlands, Norway, Poland, and the United Kingdom). NRL was chosen to host and organize the trial due to NRL's expertise in this field. The trial was the product of 2 years of coordination by NRL along with organizations from the nine other NATO countries. Unlike many other trials, SAPPHIRE was designed from the onset for collecting data to support validation efforts of both ship/background signature prediction models and atmospheric scintillation/refraction models. The trial represents "state-of-the-art" techniques in experimental design and execution possible only through the experience and combined resources of the multinational participants.

During the trial, radiometric IR measurements were made on many types of targets: a 77-m research ship, small craft (such as a speed boat and a jet ski), IR ship decoys, and a small calibrated source that simulated the signature of an antiship cruise missile (ASCM). In addition to these "target" measurements, second-order propagation effects were characterized, such as scintillation and refraction. All of the participating countries combined their results into a comprehensive database, which is available to all NATO countries.

Validation of ShipIR for Littoral Environments: The data captured at the SAPPHIRE trial are being used to validate and improve the signature model ShipIR. ShipIR is a physics-based model that has been adopted by both NATO and the U.S. Navy as a common tool for predicting the IR signature of Navy ships in a maritime background. The model simulates the steady-state IR radiance of both the ship targets and the maritime background by employing several major submodels: sky radiance, sea radiance, ship surface temperature, ship surface emission/reflection, and plume radiance. Thorough validation of the model is performed by comparing measured data to predicted data for each submodel component. This approach is necessary because the output of one submodel is often the input of another submodel. Validating at the submodel level allows for the identification and prioritization of specific portions of the code that demonstrate need for improvement. Validating the model as a single system will not provide the data necessary to isolate the specific source of any errors. Since the original version of ShipIR was released in 1992, NRL has applied this submodel validation methodology to iteratively refine the code.

Using the data collected during the SAPPHIRE trial, NRL has continued to validate ShipIR to assess model accuracy and to further improve the code. NRL began the validation in 2007 by analyzing the measured SAPPHIRE data to identify the runs suitable for model validation. This step ensures that the model receives reliable input data, mitigating one source of potential error between the IR ship signature measurements and the eventual ShipIR predictions. ShipIR models the IR environments for each of the selected SAPPHIRE runs based on inputs of geography, date, time, measured meteorological conditions, and aerosols. The prediction of solar irradiance and thermal contributions of the environment on the ship surfaces were verified to be accurate by comparing the data to values recorded by instruments designed to measure these types of physical phenomena. The accuracy of these solar and thermal irradiance predictions is critical to the ship surface temperature model accuracy. The 3D ship geometry was then processed within each environment and the ship surface temperatures were computed. The surface temperature predictions were also found to be sufficiently accurate by comparing ShipIR

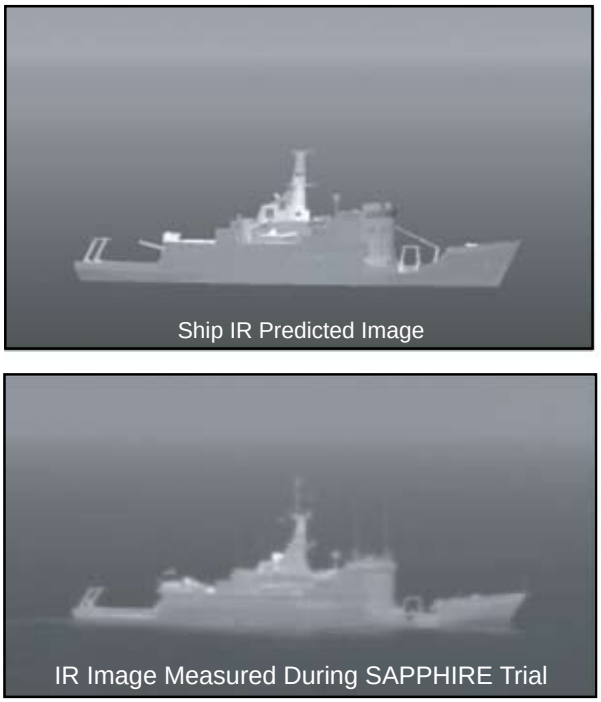

FIGURE 10
Images of the test ship used for validation.

output to data measured from thermal measurement instruments, which were installed at several locations throughout the ship.

Ultimately, ShipIR produces a radiometric image of the ship within the environment for a defined IR spectral band and observer location. Figure 10 shows an example of corresponding measured and predicted IR images, along with a visual photograph of the test ship. Such predicted ShipIR images are frequently used to run other types of simulations, such as missile engagement scenarios and hit-point analyses.

Contribution to the New Capability for the Fleet: The SAPPHIRE trial was a multinational IR phenomenology trial designed and executed with the sole purpose of capturing data to validate signature and propagation models. High-fidelity data were collected to support a variety of Electronic Warfare (EW) programs, not just in the U.S. Navy but for our NATO partners as well. The data collected provided essential information that resulted in the enhanced credibility of the ShipIR model. The 21st Century Navy now has the opportunity of applying very accurate IR models that can recreate many more "virtual field trials" over a wide range of environmental conditions in a cost-effective way.

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