



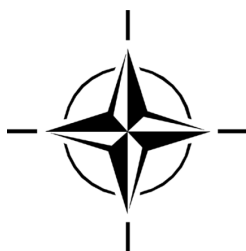
STO TECHNICAL REPORT

TR-SCI-224-Part-I

EO and IR Countermeasures Against Anti-Ship Missile

(Contre-mesures EO et IR contre
les missiles antinavires)

Final Report of SCI Task Group 224.



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The NATO Science and Technology Organization

Science & Technology (S&T) in the NATO context is defined as the selective and rigorous generation and application of state-of-the-art, validated knowledge for defence and security purposes. S&T activities embrace scientific research, technology development, transition, application and field-testing, experimentation and a range of related scientific activities that include systems engineering, operational research and analysis, synthesis, integration and validation of knowledge derived through the scientific method.

In NATO, S&T is addressed using different business models, namely a collaborative business model where NATO provides a forum where NATO Nations and partner Nations elect to use their national resources to define, conduct and promote cooperative research and information exchange, and secondly an in-house delivery business model where S&T activities are conducted in a NATO dedicated executive body, having its own personnel, capabilities and infrastructure.

The mission of the NATO Science & Technology Organization (STO) is to help position the Nations' and NATO's S&T investments as a strategic enabler of the knowledge and technology advantage for the defence and security posture of NATO Nations and partner Nations, by conducting and promoting S&T activities that augment and leverage the capabilities and programmes of the Alliance, of the NATO Nations and the partner Nations, in support of NATO's objectives, and contributing to NATO's ability to enable and influence security and defence related capability development and threat mitigation in NATO Nations and partner Nations, in accordance with NATO policies.

The total spectrum of this collaborative effort is addressed by six Technical Panels who manage a wide range of scientific research activities, a Group specialising in modelling and simulation, plus a Committee dedicated to supporting the information management needs of the organization.

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS System Analysis and Studies Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These Panels and Group are the power-house of the collaborative model and are made up of national representatives as well as recognised world-class scientists, engineers and information specialists. In addition to providing critical technical oversight, they also provide a communication link to military users and other NATO bodies.

The scientific and technological work is carried out by Technical Teams, created under one or more of these eight bodies, for specific research activities which have a defined duration. These research activities can take a variety of forms, including Task Groups, Workshops, Symposia, Specialists' Meetings, Lecture Series and Technical Courses.

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EO and IR Countermeasures Against Anti-Ship Missile (STO-TR-SCI-224-Part-I)

Executive Summary

The aim of SCI-224 “Countermeasures Against IR and Visible Band Anti-Ship Missiles” was to run a scenario from generic data in different national simulations to compare modelling methodologies and results against different seeker models. Another goal set out in the Programme of Work was to collect data whenever possible for validation purposes, a goal met at the 2016 Naval Electronic Warfare Maritime Operational test held in Andoya, Norway. This data collection effort yielded an unclassified data set of EO and IR sequences from both the Lear aircraft and the shore side installations.

The SCI-224 members developed a common scenario involving generic target and IR decoy sequence able to be tested by each national simulation. The common scenario included target and decoy model, decoy deployment tactic, geometry engagement information and missile/sensor characteristics. An existing unclassified ShipIR model was provided by W. R. Davis Engineering Ltd. (DAVIS) as a common model for use in the common scenario. The ship model used for the generic runs is a model of air warfare destroyer DDG Type 052C. This common scenario was used as input data to each nation’s model. The final objective was not to optimize a sequence but validate the methodology applied with each national digital tool. If the comparison of results converges on the same conclusion, simulation processes are considered effective.

This report deals with models and simulations used by each nation to implement the common scenario and exploit the run results. Several nations in the SCI-224 Task Group, including Australia, Canada, Germany, France, Netherlands, Turkey, and the US, reported on the model results. This report describes each nation’s model and the results of the model. Results of a two and four decoy technique used in the common scenario against the simple binary centroid tracker will be reported by many of the national simulation tools. Several nations proposed more advanced countermeasures that could be used to defeat the binary centroid tracker.

The SCI-224 group demonstrated the common scenario could be developed and used as an input to national simulation tools to test countermeasure techniques against modern imaging EO/IR missile seekers. These tools and unclassified data set can be used to support future NATO EW Trials by providing scenarios involving modern imaging seekers such as the Norwegian and the United States flyable simulators. The tools can also be used for EO/IR countermeasure development by the NATO nations.

Contre-mesures EO et IR contre les missiles antinavires (STO-TR-SCI-224-Part-I)

Synthèse

L'objectif du SCI-224 « Contre-mesures contre les missiles antinavires en bande visible et IR » était d'exécuter un scénario à partir de données générales dans différentes simulations nationales, afin de comparer les méthodologies et résultats de modélisation par rapport à différents modèles d'autodirecteurs. Le programme des travaux mentionnait également comme objectif la collecte de données chaque fois que possible, à des fins de validation. Cet objectif a été atteint lors de l'essai maritime opérationnel de guerre électronique navale, organisé à Andoya, en Norvège. Cette collecte a produit un ensemble de données non classifiées de séquences EO et IR, provenant de l'avion Lear et des installations côtières.

Les membres du SCI-224 ont élaboré un scénario commun impliquant un objectif général et une séquence de leurre IR pouvant être testés par chaque système de simulation national. Le scénario commun incluait un modèle d'objectif et de leurre, une tactique de déploiement du leurre, les informations géométriques nécessaires à l'engagement et les caractéristiques du missile / capteur. W. R. Davis Engineering Ltd. (DAVIS) a fourni un modèle ShipIR non classifié existant, destiné à être utilisé par tous pendant le scénario commun. Le modèle de navire employé pendant les simulations générales était un modèle de destroyer antiaérien DDG de type 052C. Ce scénario commun a fourni les données d'entrée pour la modélisation de chaque pays. L'objectif final n'était pas d'optimiser une séquence, mais de valider la méthodologie appliquée avec chaque outil numérique national. Si, lors de la comparaison, les résultats convergeaient vers la même conclusion, les processus de simulation étaient jugés efficaces.

Le présent rapport traite des modèles et des simulations employés par chaque pays pour mettre en œuvre le scénario commun et en exploiter les résultats. Plusieurs pays du groupe de travail SCI-224, parmi lesquels l'Australie, le Canada, l'Allemagne, la France, les Pays-Bas, la Turquie et les Etats-Unis, ont fait part des résultats du modèle. Le présent rapport décrit le modèle et les résultats de chaque pays. Les résultats de la technique à deux et quatre leurres utilisés dans le scénario commun contre le dispositif de poursuite centroïde binaire simple seront rapportés par bien des outils de simulation nationaux. Plusieurs pays ont proposé des contre-mesures plus perfectionnées pouvant servir à contrer le dispositif de poursuite centroïde binaire.

Le groupe SCI-224 a fait la preuve que le scénario commun pourrait être établi et utilisé comme élément d'entrée dans les outils de simulation nationaux pour tester les techniques de contre-mesure au regard des autodirecteurs de missile à imagerie EO/IR. Ces outils et ces ensembles de données sans classification peuvent appuyer les futurs essais de guerre électronique de l'OTAN, en fournissant des scénarios qui impliquent des autodirecteurs à imagerie moderne, tels que les simulateurs pilotables de la Norvège et des Etats-Unis. Les outils peuvent également servir au développement de contre-mesures EO/IR par les pays de l'OTAN.

EO AND IR COUNTERMEASURES AGAINST ANTI-SHIP MISSILE

1.0 INTRODUCTION

It is difficult to defend against anti-ship missiles. In general, a layered defence is used after the missile is detected at long distance. The outer layer will typically use interception missiles while the final active defence is taken care of by a Close-In-Weapon-System (CIWS). The layer in between involves the use of soft-kill: either active Electronic Countermeasures (ECM) or passive decoys (chaff and decoys against respectively RF and IR guidance systems). In some cases, soft-kill is the preferred option for ship self-defence. For optimum deployment of these decoys, timing and positioning is critical. With the advent of IR and visible band imaging seekers the situation has become even more difficult because these types of seekers can often distinguish between the target ship and potential countermeasure decoys. Therefore, tools for the evaluation of the effectiveness of decoy deployment strategies are required.

While anti-ship seeker simulators for the evaluation of RF decoy countermeasures already exist, facilities for the evaluation of infrared countermeasure deployment strategies for ships are lacking. At their fall 2008 meeting, AC/141 MCG8 on “Electronic Warfare” recommended that the STO/SCI Panel set up a Task Group to investigate the development of countermeasure evaluation tools for future use in MCG/8 (Now NEMO) Trials. In the long term this can also provide inputs for future updates of the NATO Anti-Ship Missile Defence Evaluation Facility (NASMDEF) package with an IR capability.

2.0 BACKGROUND

The Group’s collective capabilities in EO/IR ASM simulation with regard to data collection, all digital modeling and ASM engagements led to the overall course of work. This was an evolution that mirrored overall community trends leading from hardware captive carry resources into all-digital modeling. This marriage of approaches was then captured in our planning.

From the SCI-224 Terms Of Reference (TOR) [2], activities conducted by the group will include: cooperative image data collection/evaluation from field tests; sharing results of national simulation studies as well as software tools when possible; and sharing and hosting generic seeker algorithms to evaluate field tests; and countermeasure testing.

These common study results will be analyzed using common assessment criteria developed by the group using digital modeling from the countries in the group.

2.1 Norway Flyable Research Pods

At the Norwegian Defence Research Establishment (FFI) a research pod is being developed that contains cameras, navigation hardware and processing computers and will be used for image acquisition and Automatic Target Recognition (ATR) algorithm testing. The pod will be mounted on the wing of an RNoAF F-16 aircraft, enabling image acquisition and ATR algorithm tests at high speeds. Norway provided a detailed description of the research pod in Chapter 8 of STO-TR-SCI-224-Part-II [1].

Norway has used similar flyable pods with EO/IR sensors in past NATO EW Trials. Norway described the development of their new flyable pods in Chapter 8 of STO-TR-SCI-224-Part-II [1]. Although no model results were provided, these flyable generic pods can be used to collect data useful for validating the group's models.

2.2 US Flyable Research Pods

NRL Code 5752 has been developing flyable EO/IR missile simulators since the mid-1970s. These flyable simulators were developed and continue to be funded by the Office of Naval Research (ONR) program titled Effectiveness of Navy Electronic Warfare Systems (ENEWS). A brief overview of these flyable simulators and other NRL EO/IR test assets was presented to the SCI-224 Group by the chairman in February 2015. A description of these test assets can be found in the US chapter of STO-TR-SCI-224-Part-II [1].

NRL supported the NATO SWG-4 (now NEMO) Electronic Warfare Trials¹ from the mid-1980s to 2003 using a modified US Navy NP-3D aircraft and two flyable simulators (Foxtrot and Victor). From the many years of using the flyable simulators to evaluate the effectiveness of IR countermeasures, the following characteristics and requirements of successful IR countermeasures were determined by the US and the NATO countries involved in the trials:

- An effective IR countermeasure has the following attributes:
 - 1) Persistence – burn time must be greater than engagement (~ 45 sec).
 - 2) Signature – should match the spectral signature of a ship.
 - 3) Geometry – placement must get a seeker's attention.
 - 4) Separation – must be able to merge with ship's hot spots and then separate.
 - 5) Timing – must be deployed at proper time during engagement.

2.3 All Digital Modeling of EO/IR ASM

As the problem of simulating EO/IR Anti-Ship Cruise Missiles (ASCMs) had become more complex, and expensive, the NATO community has followed the path of either moving towards computer modeling OR starting with modeling outright. In the case of the United States, modeling is leading the analysis of these types of engagements. The benefits include all weather simulation, statistically significant engagements, and hit point analysis. The role of hardware simulation is still very important, but modeling has offered many nations the ability to analyze their national tactics and study NATO interoperability issues.

The development of digital modeling in the EO/IR ASCM simulation world has come a long way over the past decade. The NEMO EW Trials should continue to use digital modeling to aid in the planning and analysis of the trials. Running digital scenarios prior to testing should reduce the cost of the trials and make better use of trial assets by eliminating ineffective scenarios. As mentioned in the introduction of this report, in a workshop conducted in 2008, AC/141 MCG8 on "Electronic Warfare" recommended the STO/SCI Panel set up a Task Group (SCI-224) to investigate the development of countermeasure evaluation tools for future use in NATO EW trials. This goal is also being furthered in STO SCI-258 and its follow on, SCI-293, focusing on pre-trial planning and modeling.

¹ NATO NEMO Trials Design Aide Memoire 1.0.

2.4 SCI-224 Evolution

After the initial three meetings, it became clear the Group had to limit its program of work. The Task Group realized that the best way to narrow the scope of the group and accomplish this goal would be to define a generic environment, generic threat, generic target ship, and set time of day and location to run several modeled engagements. This would then allow for a comparison of these baseline engagements including countermeasures.

Table 1: Task Group SCI-224 Meetings.

MTG NUM	Date	Number of Days	Location
ET 1	2/20/2011	2	STO CSO Neuilly-sur-Seine, France
ET 2	5/25/2011	2	STO CSO Neuilly-sur-Seine, France
TG 1	3/28/2012	2	TNO, The Hague, Netherlands
TG 2	11/15/2012	3	DGA, Rennes, France
TG 3	4/15/2013	3	Dstl, Salisbury, United Kingdom
TG 4	12/17/2013	3	DRDC, Quebec City, Canada
TG 5	4/8/2014	3	CCC, Istanbul, Turkey
TG 6	12/9/2014	3	STO CSO Neuilly-sur-Seine, France
TG 7	5/15/2015	3	FRAUNHOFER, Ettlingen, Germany
TG 8	4/14/2016	3	DGA, Rennes, France

3.0 REPORT APPROACH

As work progressed on preparing the analysis and report writing it became apparent that the classification of much of the work had to be more restrictive. Initially our hope was that we could prepare unclassified chapters for the final report. We also hoped to keep papers brief and to the point, but the subject matter ended up requiring a more detailed and substantive approach. It was decided that this final report would be an overview to the more in depth addendum, classified at the NATO restricted level in order to properly protect this body of work.

The conclusions from countries willing to provide an unclassified synopsis are reported in this report (Part I). The over 300-page NATO RESTRICTED report (STO-TR-SCI-224-Part-II) provides greater detail and compilation of all digital modeling of IR systems. As a first pass on the evolving topic, the subject matter is well thought out and demonstrates how several nations are approaching the problem of IR anti-ship missile simulation and the variances in fidelity influencing trends in results.

3.1 Overall Technical Approach

A common scenario involving a generic target and flare sequence able to be tested by each national simulation was developed by the SCI-224 members [1]. The common scenario included target and flare model, flare deployment tactic, geometry engagement information and missile/sensor characteristics. This common scenario was used as input data to each nation’s model. The final objective is not to optimize an engagement sequence but to validate the methodology applied with each national digital tool. If the comparison of results

converges on the same conclusion, simulation processes are considered effective. Details of the input parameter list such as geometry, generic engagement, generic environment, ship heading, decoy placement and deployment that were proposed during working group meetings are described in the next few sections of the report. Decoy placement and deployment models included two and four submunitions deployed from a trainable launcher. More advanced countermeasures such as lasers, laser and decoy combinations, and laser and obscurants could be input to each nation’s model if the nation desired.

An existing unclassified ShipIR model was provided by W. R. Davis Engineering Ltd. as a common model for use in the common scenario. The ship model used for the generic runs is a model of air warfare destroyer DDG Type 052C. The ShipIR model, with subsections on the CAD model, isotherm layering, radiation view factors, paint property analysis, thermal modeling (theory), stack design and exhaust gas conditions, thermal boundary conditions, scenario input and creation, and the exporting of the model to other engagement tools (i.e., Fly-In 2000, TESS, SADM, FEMIRES, US-NRL Testbed) are described in Section 1.4 of the STO-TR-SCI-224-Part-II [1]. Some effort was required to share the ShipIR model of the DDG Type 052C with engagement modeling tools from other nations. Most cases used a new script command added to ShipIR/NTCS (v3.6) to export the geometry, temperature, and radiance data from a ShipIR scenario. The common scenario sensor parameters included number of pixels: 640 pxl * 512 pxl, FOV = 5° * 4°, frame rate = 25 Hz, and spectral bandwidth = 3 μ to 5 μ (perfect filter: gate).

All input engagement parameters are described above and listed in Table 3-1 of STO-TR-SCI-224-Part-II [1]. Figure 1 gives a schematic representation of those parameters.

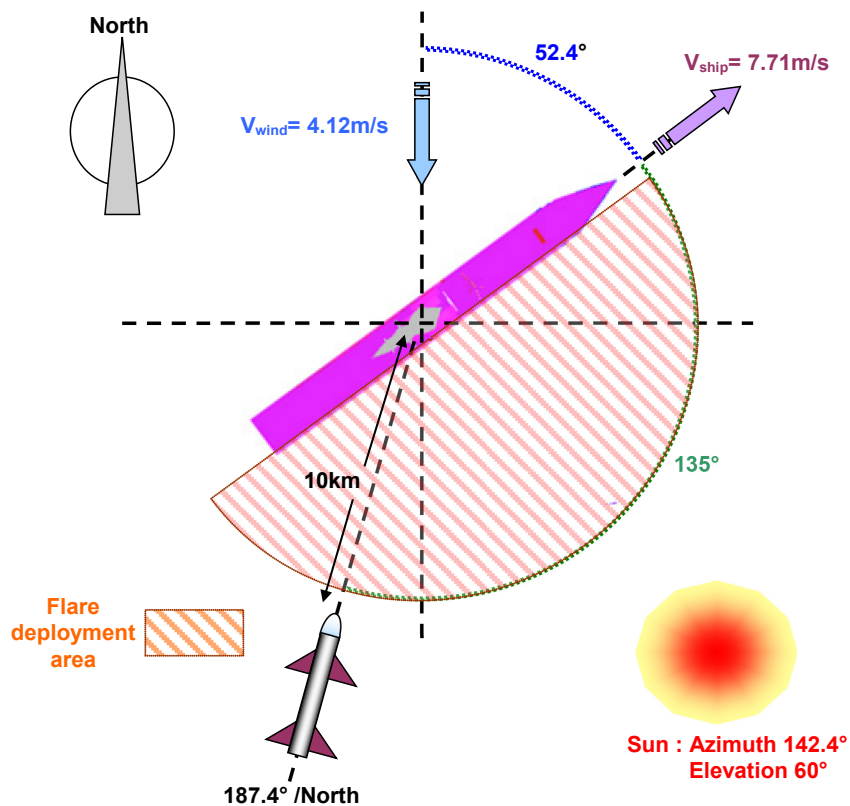


Figure 1: Common Scenario for SCI-224.

4.0 OVERVIEW OF NATIONAL MODEL EFFORTS

The NEMO 16 Trials offered a perfect opportunity to create and collect a dataset of IR imagery for future Science and Technology Organization (STO) Task Group exploitations. This dataset can be used in modeling runs for several member nations' digital ASCM models. The critical component was to use an unclassified decoy, unclassified target ship and unclassified imager(s).

Several nations in the SCI-224 Group including Australia, Canada, Germany, France, Netherlands, Turkey, and the US reported on the model results. The following pages briefly describe each nation's model and software tool sets. A detailed description of all this work is given in the NATO RESTRICTED Addendum – STO-TR-SCI-224-Part-II [1].

4.1 Australia

Australia used an infra-red scene generation library called VIRScene to generate synthetic band-averaged radiance imagery in the 3 – 5 μm band for the seeker model. VIRScene is a synthetic infrared and visible real-time scene generator developed by Defence Science and Technology Organisation (DSTO) over a period of more than 15 years for the test and evaluation of imaging infrared weapons. VIRScene is one library from a suite of tools collectively called VIRSuite2. Historically VIRScene has primarily been used for the test and evaluation of air-to-air imaging infrared weapons. Scenarios involving air targets typically did not require detailed modeling of the terrain or ocean.

A number of signature models were included as part of the ship composite model. The ship signature model is in the VIRScene model format. The platform signature model used in the study was based on the ShipIR model of an unclassified destroyer provided by W. R. Davis Engineering. ShipIR was used to generate the ship's thermal signature for the environment and operating conditions specified in the baseline scenario. For this study a script was developed to convert the ShipIR geometry into the VIRScene model. The ship plume signature generated by VIRScene closely matched the plume signature from ShipIR.

Using VIRSuite2, Australia was able to input all of the parameters in the common scenario including the geometry, the environment, the ship model, and the decoy model for both the two and four submunition decoys.

The key element of the simulation was the seeker model. In this study an existing seeker model that had been developed in C# for NATO SET-144 (releasable to SCI-224) was used. The seeker model was comprised of two main components; the sensor model and the seeker detection and tracking algorithms. Two seeker models were used in this study. Both models shared the same sensor component model but used different variations of the processing algorithm.

The baseline scenario required that a bin-centroid (area-centroid) algorithm be used to calculate an aim-point for the missile. Both the two or four flare decoy were not effective against the area centroid algorithm. The additional runs used an intensity-centroid algorithm (most modern seekers would not use this algorithm) which weighted more intense pixels of the target more heavily than the less intense pixels. For more detailed results, read Australia's chapter of the final report in classified Addendum – STO-TR-SCI-224-Part-II [1].

4.2 Canada

The Canadian national simulation chapter is a NATO RESTRICTED document and is published separately from this report in the SCI-224 Addendum – STO-TR-SCI-224-Part-II [1]. Davis Engineering is based in Canada thus reported in this section.

4.2.1 Davis Engineering Canadian ShipIR/NTCS Software and Simulations

David A. Vaitekunas (W.R. Davis Engineering, Ltd.) provided a good description and overview of SHIPIR/NTCS (V3.6) in Chapter 4 of the TR-SCI-224-Part-II [1]. David also provided the development history of ShipIR/NTCS starting in 1992 with release 1 to the present with release 4 in the report. STO-TR-SCI-224-Part-II [1] reviews some of the quantitative differences in the ShipIR model output from different options used by both the thermal model (to predict ship surface temperatures) and the surface radiance model. The average spectral contrast ($W/m^2/sr/cm^{-1}$) of the ship (total) and plume at ranges of 2, 10, and 20 km is described in detail.

The results of the common run assessment using the ShipIR/NTCS engagement model are presented in the large final report. The original results were obtained using ShipIR/NTCS (v3.6b) and are presented first. Based on these results using the Davis Engineering version of the binary centroid tracker, a modified version of the decoy tactic (modified six flare deployments) is also analysed using ShipIR/NTCS (v3.6b), and the same modified decoy tactic is also tested using a newer release of ShipIR/NTCS (v3.7-x1), still under development, which includes a new 3D flare particle model to better represent the spatial distribution of the decoy radiance.

ShipIR/NTCS includes a threshold intensity centroid tracker algorithm. Previous versions of this algorithm were found to be unstable in both track-area and aim-point because of its simplicity (i.e., threshold calculation) and lack of an adaptive track gate algorithm

4.3 Germany

The German model is named “Maritime Analysis Tool for Ship Protection” (MANALYST). The main purpose of this software is to assess the effectiveness of countermeasures against imaging Infrared (IR) anti-ship missiles.

The software consists of three main components:

- 1) The creation of the images for a simulated fly-in of an anti-ship missile, called Semi-Synthetic Scene Generator (SSSG).
- 2) The application of tracking algorithms of different complexity on the simulated image sequence.
- 3) The assessment of the effectiveness of the countermeasures.

Most (but not all) of the common scenario input parameters were input to MANALYST. Since there is no reacquire mode yet in the MANALYST tool, both the two decoy and the four decoy tactics were effective against the simple tracking algorithm. In the future, further validation of the tool is planned based on real scenarios (e.g. NEMO trials). For more detail, please refer to SCI-224’s classified Addendum – STO-TR-SCI-224-Part-II [1].

4.4 France – DGA Maîtrise de l’Information

The software used to design the generic flare model is FLY-IN 2000. FLY-IN 2000 was developed on behalf of Dstl (UK) over a 20-year period. The software was designed to assess the effects of countermeasure deployment on the performance of IR seekers in guided missiles engaging air targets. FLY-IN 2000 is a suitable tool to implement generic warfare scenarios with air targets; that is why it was used in the frameworks of other NATO groups like SCI-139, SCI-192 or currently SCI-239. Because France is involved in these NATO groups and knows the software, FLY-IN 2000 was selected to design the generic flare for the SCI-224 and contribute to the generic scenario. A detailed description of the FLY-IN 2000 modeling suite was written by France in STO-TR-SCI-224-Part-II [1] including CELAR v4 and CELAR v4 MARINE.

The CELAR v4 MARINE was derived from the CELAR v4 algorithm. A new version of the CELAR v4 tracker was developed because major parts of the criteria used are dedicated to the air domain like the target trajectory estimator, which makes no sense for the criterion for naval applications. New criteria were also added for focusing on naval tracking needs.

Most of the common scenario input parameters were used as input to the CELAR v4 MARINE algorithm. The target used for the generic runs is a model of an air warfare destroyer DDG provided by Davis Engineering Company. The sensor model was the generic sensor defined by the group. The two and four flare decoy model was used and the results for both the CELAR v4 algorithm and the CELAR v4 MARINE algorithm decoy runs follow.

4.4.1 Run Results – Common

France entered the common scenario input parameters to both the CELAR v4 (air-to-air) and the CELAR v4 MARINE tracking algorithm. The two flare tactic was not effective against either the modified air-to-air or the marine tracking algorithm. The two flares did merge with the target for 22 seconds, but separated from the target when the missile was 3615 meters (CELAR v4) and 3920 meters (CELAR v4 MARINE) from the target. In both cases, the missile seeker had time to reacquire the ship target and track the ship for the remainder of the run. The four flare tactic was also not effective against either the modified air-to-air or the marine tracking algorithm. Again the four flares did merge with the target for 23.5 seconds (slightly longer than the 2 flares), but separated from the target when the missile was 3440 meters from the ship target for both the CELAR v4 and the CELAR v4 MARINE tracking algorithms. In both cases, the missile seeker had time to reacquire the ship target and track the ship for the remainder of the run. More details of the common run results are provided in STO-TR-SCI-224-Part-II [1].

4.4.2 Run Results – Additional: Advanced Tactic

France described additional scenarios against different types and generations of seeker models. The seeker models used in this study are just generic, and have no link with specific national threats. In the framework of SCI-224 task flow, nations have tested the generic tactic against older generation models using hot spot tracking, and also against more sophisticated seeker models with Counter-Counter Measure (CCM) using complex criteria to determine the aim point. Details of these additional advanced tactic runs are described in the French chapter of STO-TR-SCI-224-Part-II [1].

4.5 Netherlands

The Netherlands (TNO) full NATO RESTRICTED contribution can be found in Chapter 7 of in STO-TR-SCI-224-Part-II [1]. TNO's Electronic Warfare Model (EWM) was used for the common engagement simulations performed by the group. In the Addendum the EWM will be described in detail together with results from the simulations. EWM is a closed-loop missile-ship engagement model designed to test decoy deployment tactics against anti-ship missile threats. The model is designed to handle engagements in both the Infrared (IR) and Radio Frequency (RF) domain.

Within the scope of this task group, only the IR domain was investigated. For the IR, both a hotspot as well as a generic imaging seeker is available. EWM was primarily designed to support the investigation of the seeker's behavior up to and including the moment of decoy and target separation. This allows for analysis of the decision whether the seeker goes for the target or the decoy.

4.5.1 Target Model

EWM was initially designed to use a rather simple scene generation module (also called “the shoe-box” model). As seekers evolved, more sophisticated sensors and algorithms became available. Nowadays, modern seekers use imaging sensors and are therefore more capable of resolving and exploiting spatial details of the target. For simulating this type of more advanced threats, detailed scene generation is required. To fulfil this requirement, TNO is currently implementing a more detailed IR scene generator that uses TNO’s Electro-Optical System Transmission And Ranging (EOSTAR) tool as its core model. EOSTAR contains a more detailed ship target model as well as a more realistic background model, an exhaust plume model and more sophisticated atmospheric modeling. Furthermore, EOSTAR contains a sensor model that simulates the properties of a sensor’s optical system and a detailed IR decoy model. The implementation and validation of the EOSTAR scene generator into EWM occurred parallel to the lifetime of the Task Group. This process was not finished in time in order to use the result for simulations within SCI-224. Therefore, TNO had to revert to the existing “shoe-box model” for our simulations.

4.5.2 Imaging Seeker Algorithm

Since the simulations were performed using TNO’s generic Imaging Infrared (IIR) seeker algorithm, only this seeker algorithm is described in more detail in this section of the report. The IIR seeker algorithm is not representative of a specific threat and no specific infrared counter-countermeasures were implemented. Therefore, its logic is unclassified and thus easier to share within the task group. Technically, the seeker was inspired by a system with a linear array detector. TNO described the generic tracker used to evaluate the decoy runs in the report (see Ref. [1]). The TNO IIR seeker algorithm uses the center of the tracking box as its aim point (a binary centroid seeker could not be implemented in time due to budget constraints and other research priorities).

4.5.3 Deviation from Generic Definitions

For the common SCI-224 simulations, a generic target ship was defined. The DDG target model supplied by Davis Engineering was used for this purpose. The current version of EWM only uses a basic target model and is not able to import CAD models. Instead, a target has to be manually built from a number of boxes. Scaling of the EWM target to the DDG target data was described in this section of the report. Even though the seeker’s sensor model processes radiometrically correct imagery, EWM only outputs greyscale seeker imagery to the user. Therefore, it was not possible to perform a full validation by comparing the lower resolution target in EWM with the radiance imagery produced in ShipIR.

4.5.4 Scaling of the EWM Decoy to the DGA Decoy Data

For the decoy in EWM a similar procedure as with the target had to be performed. In this case, the decoy was scaled to the parameters decided by the task group and data supplied by DGA. In the existing version of EWM a predefined shape of the decoy intensity profile was implemented based on measurements. This model offered too little freedom to scale the profile. Therefore, additional functionality was added to EWM to be able to read decoy data from a look-up table.

4.5.5 Run Results – Common

This section contains the results of TNO’s simulations of the common scenario defined by SCI-224. The common scenario consists of 3 individual runs. In run 1, no decoys are fired. This run is used as baseline to

make sure the missile is able to hit the ship if it is not deceived by countermeasures. In runs 2 and 3 the ship deploys 2 and 4 decoys respectively.

4.5.6 Summary of Results

The results from the three runs using the common scenario are summarized in STO-TR-SCI-224-Part-II [1].

4.5.7 Conclusions

The conclusions from the runs using the common scenario can be found in STO-TR-SCI-224-Part-II [1].

4.6 Turkey – Turkish Naval Research Center Command / ASELSAN

ASELSAN develops algorithms and simulation tools to simulate the electronic warfare environment with all of its components and to examine the effectiveness of threat seekers or countermeasures. Since the tools generated by ASELSAN are not available for the purposes of SCI-224 Group, Tactical Engagement Simulation Software (TESS) is used by ASELSAN. Anti-Ship Missile in IR (ASM (IR)), which is the Passive Infrared Guided Anti-Ship Missile Simulation Software tool of TESS is used for the purposes of the SCI-224 engagements and analysis.

Engagements are composed of a target ship, threat system, environment, launcher system and decoy models. These models need to be generated and saved to a database before the engagement scenario is generated. Weather and ground conditions (wind speed/direction, sea surface temperature), threat system settings with launch conditions and missile control system parameters, ship's initial conditions with heading, velocity and maneuver values are set for each scenario. Four different missile target discrimination techniques were used (by size, by peak power, by total power, and by average centroid). The average centroid technique is the closest to the binary centroid technique used in the common scenario.

In the SCI-224 group meetings, a common target, decoy models, and engagement scenarios were decided. Before inputting the common scenario parameters, a preliminary engagement is formed with generic models already included in the database of TESS. Then common scenarios with the common target and decoy models are input to the capabilities of TESS.

4.6.1 Results

Turkey took a more realistic approach to modeling by doing preliminary scenarios using a MEKO class ship with fixed launchers to deploy the decoys available to the ship. All of the fixed launcher locations were used to deploy the decoy and only a few of the launcher train angles allowed the decoy to merge with the ship's hot spots and then provided minimal separation. This was done to show that the TESS software can be used for the SCI-224 Group modeling effort.

Next the common scenario developed by the SCI-224 Group was tried. It was not possible to generate the common models and scenarios with all of its parameters but the aim was to be as close to the group model parameters as possible. Scenarios with the DDG ship model, launching 2 flares and 4 flares with the launcher train angles used by the MEKO class ship. Again, only a few of the launcher train angles allowed the decoys to merge with the ship's hot spots and then provided minimal separation. For this reason, the two and four flare decoys were not effective. For more detail, please refer to STO-TR-SCI-224-Part-II [1].

4.7 United States – Naval Research Laboratory

The US NRL model is based on the Davis Engineering ShipIR/NTCS physics based model of background and ship signature. Unfortunately, the NRL licensed copy of ShipIR and MATLAB are on the classified computer network and cannot be used for unclassified projects. Davis Engineering helped NRL by providing an open-loop generic engagement as radiance (rad) map files. NRL wrote a file parser using the C++ programming language that converted the rad map images into images using integer pixel values. A closed-loop model was created by combining the imagery from Davis Engineering with the binary centroid tracker developed by NRL.

The common scenario input parameters were used by ShipIR for the environment, the decoy model using both two and four flares, and the ship model from Davis Engineering. The NRL Binary Centroid Tracker Tool was used as the seeker for the US model.

The imaging IR algorithms such as the Binary Centroid Tracker Tool used for the US National model runs were developed over many years for the flyable simulators such as Foxtrot and Victor. The flyable simulators used for many years for the NATO NEMO EW Trials are described in STO-TR-SCI-224-Part-II [1].

Davis Engineering provided NRL with two open-loop generic engagements in the form of rad map files; one with a two flare model and the other with a four flare model as input to the NRL Tracker Tool. These two engagements were turned into eight total runs that were fed through the NRL Tracker Test Bed in the following manner. The radiance to pixel normalization used either +/- 2 standard deviation or min/max to determine the start and end points for normalizing the imagery. These points were either updated every frame or locked at frame 100 before the flares appear in the scene (AGC of the missile.)

4.7.1 Common Run Results

Please note that Runs 6 and 8 had seductions but they were not caused by the flares. Contrast between the ship and the background was greatly diminished due to using the min/max pixel values for the start and end points of the normalization in the sensor model and the normalization being unlocked and calculated every frame. This is a prime example of how flares can defeat sensors with automatic gain control even if the geometry, timing and persistence of the flares are not correct. For more detail, please refer to STO-TR-SCI-224-Part-II [1].

4.7.2 ROSY Decoy Demonstration

The evaluation of the decoy effectiveness against the Imaging Infrared (IIR) seekers was planned using the Foxtrot Flyable seeker simulator flying captive-carry on the Lear Jet and the Foxtrot portable system set up on the shore site.

Rheinmetall generously loaned the organizers two ROSY tank defence decoy launchers and 120 rounds of red phosphorus decoys. The test organizers found a tug boat as the launch platform. The two launchers were mounted fore and aft at 15 degrees off axis as they faced forward, as shown in Figure 2. Figure 3 shows the ROSY installation on HNoMS Mjølner. STO also approved supplemental funding for expendables under their established policies. This allowed the Lear Jet to fly against the tug and collect data. Netherlands provided a calibrated black body for Foxtrot to collect black body data before and after the sortie – a needed step for data to be used in modeling work.

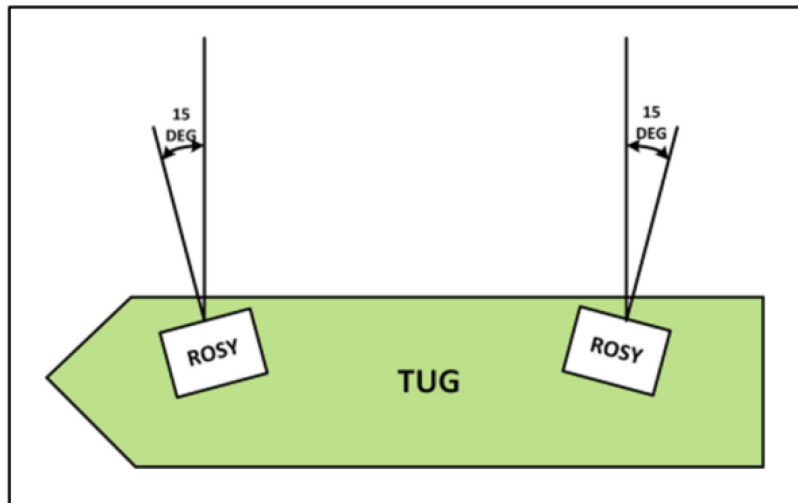


Figure 2: ROSY Installation Locations.

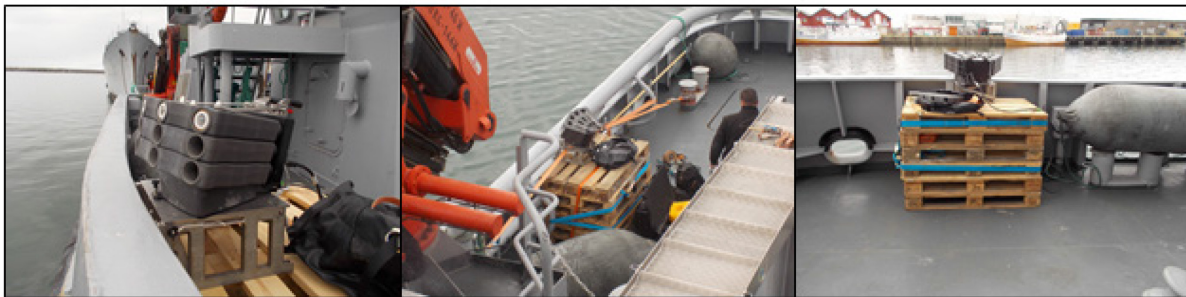


Figure 3: ROSY Installation on HNoMS Mjølnær.

The test was separated into two phases. The first set of runs was conducted against the tug placed within the operational area of the IR shore site. This allowed for the assets at this site to image the event. The Lear Jet then flew a very tight approach against this configuration. This portion occurred at the beginning of the sortie. The Foxtrot ground system collected IR and high resolution EO imagery.

The second phase was done towards the end of this sortie and was conducted in the land/sea sector. This allowed for more variations in the approach angle. Data collection included flying into the sun. Also collections approaching the bow were done to allow for decoy signature/capture for future work.

Each run was to use ten rounds per event. One concern was the short duration of the rounds (3 seconds) but this proved to be more than enough. The tug was 25 m long and the coverage offered was more than sufficient to allow for investigations into multi-munition decoy systems.

4.7.3 ROSY Demonstration Quick Look Post Process Run Results

For purposes of this Task Group, and to expand upon the USA results, the data collected at the Above Water Warfare Capabilities Group (AWWCG) Electronic Warfare Trials, Naval Electro-Magnetic Operational

(NEMO) 16 trials in the ROSY runs was post processed using the Tracker Test Bed. The same track algorithm was used. Table 2 below shows the results of the ROSY decoy demonstration runs from the Foxtrot Flyable and Portable simulators on June 9, 2016. Both the Foxtrot Flyable and Portable simulators were used to collect imagery only. The operator used a joystick to keep the ship and the decoy in the FOV of the simulator mid wave IR camera. This digital tracker test bed used the same binary centroid algorithm and the man-in-the-loop method used in the US National model runs. A decoy run was considered successful if the track gate initially on the ship was merged with the decoy and separated from the ship and then lost to some other parts of the background. If the decoy was launched such that it did not seduce the track gate away from the ship or later the track gate jumped back on the ship, then the run was considered a failure. From the flyable simulator runs, eight runs were used to evaluate the success or failure of the ROSY decoy. Seven of the eight runs against the model track gate pulled away from the ship, so seven runs were successful and one run failed. From the seven portable simulator runs, only three runs were successful and four runs failed. All of the failed flyable and portable simulator runs were due to the poor geometry and the decoy was not able to seduce the track gate away from the ship.

Table 2: ROSY Decoy Demonstration Results.

ROSY Decoy Demonstration Results		
	S/F/U/NO	S = Successful; F = Failed; U = Unknown; NO = No Decoy
		Results of Foxtrot Flyable Simulator
Run	Result	Comments
12 – 15	U	Runs unable to be post-processed.
16	F	Separation between decoy and tug was clear enough, so Track Gate (TG) stayed on tug.
17	S	Decoy covered tug completely. Elongated decoy cloud pulled TG away from tug and to the center of a cloud.
18	S	Similar to Run 17.
19	S	Similar to Run 17. Size and intensity of decoy moved TG away from tug.
38	NO	Calibration Run. Not post-processed.
39	S	Decoy covered tug completely. After TG moved to the center of decoy cloud, tug moved away from cloud swiftly.
40	S	Similar to Run 39; Cloudy sky; Background was gray. Tug was hot on cooler water.
41	S	Similar to Run 39; Cloudy sky; Tug was hot on cooler water.
42	S	Similar to Run 39; Gray background but still clear horizon.
43	NO	Tug was overlapped with other ship. Not post-processed.
44	U	Tug was in negative contrast; Unable to perform man-in-the-loop decoy test; sky was cooler (black) and water had lots of glints. Not post-processed.
45	NO	Tug was in negative contrast. Not post-processed.

Results of Foxtrot Portable Simulator on Shore Site		
Run	Result	Comments
12a	F	Separation between tug and decoy was clear from seeker; Starboard Rear Quarter.
13	S	Decoy fully covered tug; TG lost on water; Starboard Side.
14	F	Separation between tug and decoy was clear from seeker; Bow Port Quarter.
15	F	Separation between tug and decoy was clear from seeker; Bow Port Quarter.
16	F	Decoy covered tug and TG expanded, seduced initially, but TG returned to the center and recaptured tug; Starboard. 10 Rounds.
17	S	Decoy fully covered tug; tug escaped from decoy swiftly. TG lost on water; Starboard. 10 Rounds.
18	S	Similar to Run 17; TG lost in sky; Starboard. 10 Rounds.

The table above shows the results of the ROSY decoy demonstration runs from both the Flyable and Portable Foxtrot simulators. A run was considered successful if the track gate initially on the ship was merged with the decoy and separated from the ship and then lost to some other parts of the background. If the decoy was launched such that it did not seduce the track gate away from the ship or later the track gate jumped back on the ship, then the run was considered a failure. For the Flyable simulator, seven of the eight runs against the model track gate stayed away from the ship. Three of the seven runs against the portable simulator were successful, and four runs failed. The four runs failed due to poor geometry and the decoy did not seduce the track gate away from the ship.

5.0 CONCLUSIONS

The main objective of the SCI-224 was to establish a common scenario and try to simulate it with every member's simulation tools. The common scenario developed by SCI-224 and involving generic target and flare sequence was a realistic modern day EO/IR anti-ship missile engagement test platform. The flare sequence used in the common scenario included both a two flare and a four flare decoy tactic. Seven nations (Australia, Canada, Germany, France, Netherlands, Turkey, and the US) reported results of the common scenario countermeasures against seekers from each nation's simulation tool. The assessment criteria used by the nations were based on the guarantee that the missile doesn't hit the ship. The lethality level is more significant for missile capabilities assessment. This is why the minimum criterion proposed here is a binary criterion: hit/ not hit. More complex criteria were proposed by some of the nations in the SCI-224 Group. The US proposed using the criteria used in past NATO EW Trials to evaluate countermeasure effectiveness and described in the background section of this report.

The two and four flare decoy technique used in the common scenario against the simple binary centroid tracker was not effective for almost all of the national simulation tools. Several nations proposed more advanced countermeasures that could be used to defeat the binary centroid tracker. France proposed the use of lasers combined with decoys or the use of obscurants and decoys and showed results for these advanced techniques. Canada (Davis Engineering) proposed a six flare decoy that was successful against the binary centroid tracker. Canada also showed results of a slightly modified tracker algorithm that defeated the six flare decoy.

The SCI-224 Group demonstrated that the common scenario could be developed and input to national simulation tools to test countermeasure techniques against modern imaging EO/IR missile seekers. The Task Group therefore met its objectives and was mutually beneficial to all participating countries. These tools can be used to support future NATO EW Trials by providing scenarios involving modern imaging seekers such as the Norwegian or the US flyable simulators and EO/IR countermeasure development by the NATO nations. Also, the tools will help the development of a NASMDEF IR simulator in the future.

Turkey took a more realistic approach to modeling by demonstrating the miss distance outputs with respect to launcher azimuth angle and number of flares using their model TESS. It would be useful for the group to continue this realistic approach as well as the more generic scenarios in future modeling efforts.

6.0 RECOMMENDATIONS FOR SCI-224

The Task Group has learned that a common scenario could be used as input to an unclassified version of the NATO nation's model and produce results of the engagement that could be shared with all nations in the group. Seven nations within the group developed an unclassified version of a classified model to input the common scenario and provide the effectiveness of a countermeasure to the whole Task Group. The methodology for conversion from a classified to an unclassified model was completed during the period of performance of the SCI-224 Task Group (2011 to 2016). The period of performance was expanded by one year to allow for the classified to unclassified conversion of models and to report to the group the results of the models.

In order to continue to build on the success of the Task Group during the first period of performance, the following must be accomplished. The common scenario consisted of only a small subset of the hundreds of variables in an ASCM engagement. The SCI-224 Task Group needs to study the effectiveness of IR and visible band countermeasures against advanced EO/IR anti-ship missiles. The Task Group needs to continue to survey the available anti-ship missile seekers and their characteristics, ship signature reduction methods, countermeasures available to the NATO Nations, and other anti-ship missile engagement parameters that could be input to the Group's available models. To accomplish this continual learning task, the SCI-224 needs to continue to engage with other Task Groups within NATO. At their fall 2008 meeting, AC/141 MCG8 on "Electronic Warfare" recommended the SCI Panel set up a Task Group to investigate the development of countermeasure evaluation tools for future use in MCG/8 (Now NEMO) Trials. In the long term this can also provide inputs for future updates of the NATO Anti-Ship Missile Defence Evaluation Facility (NASMDEF) package with an IR capability. Therefore, the SCI-224 Task Group has a responsibility to continue to support and deliver technical recommendations on ASMD issues to the ongoing NEMO EW Trials and other NATO groups. The Task Group must also provide inputs for the development of the IR capability of NASMDEF.

One of the biggest issues that SCI-224 faced was funding for many of the nations in the Group to travel and participate in group meetings. Compared to the cost associated with the annual NATO EW Trials, the cost of developing simulation tools by SCI-224 that aid in the planning for the field trials is minimal.

Several nations in the SCI-224 Group proposed future efforts for SCI-224 and these efforts are presented in the following sub-sections.

6.1 Australia

For future studies it is recommended that the focus either be on comparing scene generation tools or comparing seeker algorithms and countermeasure tactics. In the first case all of the simulation parameters should be fully specified, including the seeker algorithm used, and the scene generator varied between nations. In the second

case a common simulation environment should be used including a single scene generation tool and each nation would then provide variations of seeker algorithms and countermeasure tactics for analysis.

6.2 Davis Engineering

The ShipIR/NTCS software could serve as a common NATO tool in a future NATO Task Group. The software already serves as a common NATO tool for the analysis of background and ship signatures, and is commercially available to all member nations. It is also the only naval ship infrared signature model to be accredited by the US Navy. Davis Engineering also described some planned improvements to ShipIR/NTCS that could be used by the Task Group in future efforts.

6.3 France

The conclusion of this study leads to the second part of the job, which is to develop new tactics and to test these tactics, first in simulation, and then in hybrid simulation with surrogate seeker and IR scene projector. The aim is to investigate future concepts to defeat future seeker generations.

6.4 United States

From the many years that the US supported the NATO SWG-4 Electronic Warfare Trials using the flyable simulators to evaluate the effectiveness of IR countermeasures, the following characteristics and requirements of successful IR countermeasures were determined by the US and the NATO countries involved in the trials:

- An Effective IR Countermeasure has the following attributes:
 - 1) Persistence – burn time must be greater than engagement (~ 45 sec).
 - 2) Signature – should match the spectral signature of a ship.
 - 3) Geometry – must be placed in order to get a seeker’s attention.
 - 4) Separation – must be able to merge with ship’s hot spots and then separate.
 - 5) Timing – must be deployed at proper time during engagement.

In future SCI-224 modeling efforts, these more stringent assessment criteria should be used to evaluate countermeasures. Also, the group should continue to add requirements for an effective countermeasure based on the advancing threat characteristics.

The Group should continue to support the NEMO EW Trials as was done in the 2016 Trials and collect a dataset of IR imagery for future Science and Technology Organization (STO) Task Group exploitations such as the ROSY Decoy Demonstration.

7.0 REFERENCES

- [1] STO-TR-SCI-224-Part-II, Addendum to the Final Report “EO and IR Countermeasure against Anti-Ship Missile” (forthcoming).
- [2] SCI-224 Terms of Reference (ToR) May 2011 VER 1.



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