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Integrated HSI-System Model Demonstration

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In an earlier project, the Coast Guard (CG) Research and Development Center (RDC) contracted with Science Applications International Corporation (SAIC) to develop and test a human performance model (HPM) of an Unmanned Aerial System (UAS) Sensor System Operator (SSO). The SSO HPM was developed using the U.S. Army's Improved Performance Research Integration Tool (IMPRINT). The IMPRINT HPM was integrated with a mission simulation that SAIC had developed previously for the Air Force. The mission simulation provided a UAS that was controlled by the HPM, along with maritime traffic, in a Florida Straits surveillance scenario. In that scenario, the UAS flew a fixed ladder search pattern (the UAS could not depart from the ladder route) and the SSO tried to detect, classify, and identify targets of interest (TOI) that consisted of illegal immigrant vessels (called Chug-Chugs) and drug runner vessels (called Go-Fasts). The test results demonstrated that the HPM added an important dimension to the representation of the total UAS and provided much-needed insight into the impact of the human operator on overall system performance.

The RDC Analysis, Modeling & Simulation Branch is upgrading its tools and capabilities to support Human Systems Integration (HSI) analysis and modeling. RDC lacks the HSI models needed to support a human-in-the-loop analysis and, thus, cannot predict "total system performance," an important metric for analyzing acquisition alternatives and understanding/minimizing acquisition risk. The objectives of this project were to:

1. Integrate the SSO HPM developed earlier with the Coast Guard Tactical Modeling Environment (CGTME). CGTME would provide vessel traffic, targets of interest (Chug-Chugs and Go-Fasts), and a UAS entity. The IMPRINT SSO HPM would control the CGTME UAS sensors to search for and identify TOIs.
2. Conduct UAS TOI search scenarios using the stand-alone CGTME simulation and the integrated HSI-system model (IMPRINT SSO HPM integrated with CGTME). These scenarios would employ a Florida Straits surveillance operation similar to that employed in the first study.
3. Compare the outputs of the stand-alone system model and the integrated HSI-system model to show how (if at all) the modeled human performance affects predicted measures of performance and effectiveness.

This presentation reports on the outcomes of these three objectives.

Topics



- **Introduction**
- **Coast Guard Tactical Modeling Environment (CGTME) Overview**
- **IMproved Performance Research INtegration Tool (IMPRINT) Sensor Systems Operator (SSO) Human Performance Model (HPM) Overview**
- **Integrated IMPRINT-CGTME Architecture Overview**
- **Data Collection Capabilities of the Integrated Simulation**
- **Test Scenarios and Test Design**
- **Test Results**
- **Conclusions**
- **Recommendations for Going Forward**
- **List of Acronyms**



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These are the topics covered in the presentation. We begin with an overview of the component simulations – CGTME and the IMPRINT SSO HPM – and then proceed to a brief description of the integrated HSI-system model. This should provide the reader with a basic understanding of the capabilities of the two simulations. Next, we discuss the data collection capabilities of the integrated HSI-system model. Different types of data and performance views are provided by both sides of the simulation. This section discusses how they can be combined to provide an understanding of the total system. The scenarios used to test the stand-alone CGTME and integrated HSI-system model configurations are described next. Results of the comparison of the two configurations follow. We finish with a discussion of conclusions and recommendations for the way forward.



INTRODUCTION



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The introduction provides a brief overview of the purpose of the project.

Study Objectives



- **Integrate IMPRINT SSO HPM with CGTME**

- Reproduce Phase I Florida Straits scenario
- SSO HPM controls CGTME UAS sensors to find targets of interest
 - Illegal immigrant vessels (Chug-Chugs)
 - Drug runners (Go-Fasts)
- Compare results of integrated simulation vs. stand-alone CGTME

- **Key questions**

- How, if at all, does the IMPRINT HPM add value to the simulation?
 - Provides a more realistic representation of the human's contribution to/ impact on mission performance?
 - Provides insight into human performance limitations that constrain mission performance?
 - Enables rapid, detailed testing of CONOPS alternatives?
- What are the costs of incorporating the HPM into CGTME?
 - Run-time impacts?
 - Increased data volumes and analysis times?



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As noted above, this presentation reports on results of a study that compares the mission performance outcomes of a stand-alone CGTME simulation of UAS searching for TOIs to that of an integrated HSI-system model in the same scenarios. The scenarios generally replicated the Florida Straits surveillance operation employed in the earlier study. TOIs were illegal immigrant vessels (Chug-Chugs) and drug runner vessels (Go-Fasts).

The question of initial interest was whether the two simulations produce different results. Given that differences are found, what factors were responsible for the differences? Other issues of interest included identification of any added value provided by the use of an HPM. Did the HPM, for example, provide meaningful insight into how human performance affects overall system performance? Did it provide insight into human performance limitations that constrain mission performance?

Beyond mission performance results, there was interest in other, more practical, factors. This included impacts on runtime. If the integrated HSI-system model took much longer than the stand-alone CGTME simulation to run a scenario, it could significantly extend the time required to run large numbers of scenarios. This could affect test event cost and responsiveness of providing results to customers.

Acronyms not previously defined

CONOPS Concept of Operations

Study Scenario (Overview)



- **Platform being modeled**
 - Unmanned Aerial System (UAS)
 - Predator-type UAS capabilities
 - Sensor System Operator (SSO) is modeled in the human performance model
- **Scenario being modeled**
 - Surveillance mission over the Florida Straits
 - Objective is to find vessels carrying illegal migrants or drugs
 - Attempt to detect, classify, and identify as many vessels as possible in the operating area



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For those not familiar with the earlier study, this slide gives an introduction to the scenario being modeled. The UAS being modeled has capabilities similar to a Predator unmanned aerial vehicle. While the UAS does not carry a crew aboard, it is controlled from the ground by a pilot and an SSO (Sensor System Operator). Our human performance model (IMPRINT) simulates the tasks and decisions made by the SSO while conducting the surveillance mission.

As already mentioned, the scenario being modeled is a surveillance mission over the Florida Straits, in which the SSO is looking for small, speedy “Go-Fast” boats, which carry drugs, and slow-moving “Chug-Chugs,” which carry illegal migrants. In order to find these TOIs, the SSO must use the UAS’s sensors to detect, classify, and identify vessels in the UAS’s operating area.

In layman’s terms, “detection” means first noticing that “something” is out there, usually as a result of a new “blip” on the radar screen. “Classification” means determining the type of vessel (e.g., recreational boat, fishing vessel, freighter). To classify a target, the UAS must be close enough to obtain a camera view of the size and shape of the vessel. “Identification” means determining the specific vessel (e.g., the fishing vessel “Clam Chowder”). The UAS would need to be even closer to the vessel in order for its cameras to pick up the vessel name or registration number on the hull.

CGTME and IMPRINT simulate the detection – classification – identification process. Specifics on how each model defines each step in the process are given in the next two sections.



CGTME OVERVIEW



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This section provides a brief overview of the CGTME environment and how the UAS and sensor operator performance was modeled.

The CGTME

- **Modeling and simulation environment built in 2009 for the purpose of doing force package trade studies**
- **Accredited by the USCG RDC**
- **Result of 10+ years of RDC analysis and simulation development work for USCG**
- **Platform, sensor, comm system, and CONOPS tradeoffs for maritime interdiction operations at the engagement, mission, and sector (theater) levels**
- **Powered by the General Campaign Analysis Model Core Tool Suite (GCAM-CTS)**



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The CGTME is a customized interface to control a specific GCAM simulation. Within the simulation, only certain parameters can actually be modified such as platform performance values, number of entities (vessel traffic, TOIs) within the simulation, high-level tactics options, motion specifications, etc. The CONOPS and behavior within the simulation have been developed over the past decade with the input from the USCG RDC. It should be stressed that the results from CGTME should not be regarded as “absolute” predictions of system performance. Not every aspect of the real system can or should be taken into account (e.g. ship maintenance, crew scheduling, ship-board accidents, real-time weather, equipment malfunction/misuse, ...). The critical aspects considered, as determined by subject matter experts (SMEs), are those which will yield results which are properly representative of the system and will react appropriately given changes to the input set. The key use of the CGTME is to compare output metrics between various scenarios. This enables an analyst to identify which performance or CONOPS changes are likely to have a significant impact on measures of effectiveness (MOEs) such as Maritime Domain Awareness (MDA) and number of threat interdictions. The key consideration when evaluating CGTME results is the relative MOE values across test conditions as opposed to the absolute MOE value for each condition. The magnitude of the relative difference is the indicator of the impact of a condition and its associated actors.

Acronyms not previously defined

SPA Systems Planning and Analysis
USCG United States Coast Guard

How CGTME is Applied



- **Analytic modeling and simulation environment to support research and acquisition trade-off analyses**
- **Measure impact on bottom line effectiveness for system and force deployment/employment options through assessment of effectiveness in four key areas**
 - Force utilization
 - Area coverage
 - Detection and monitoring
 - Interdictions



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The primary use for CGTME is trade-off analysis – comparing the potential impact of future acquisitions or CONOPS decisions. The primary Measures of Effectiveness (MOEs) examined are:

- Force Utilization – are USCG assets being used appropriately?
- Area Coverage – how well is the desired area actually covered by the given schedule and search areas?
- Detection and Monitoring (Maritime Domain Awareness) – how effective are we at processing found targets?
- Interdictions – how effective are we at actually stopping violators?

As stated before, results from CGTME should be used to compare different alternatives to determine if future acquisitions or CONOPS decisions have a significant impact on the desired MOEs.

CGTME Analyses



- **Force Package Assessments**
 - What is the impact of additional assets on bottom-line effectiveness?
 - How many/which assets are required to reach specific effectiveness thresholds?
- **Alternatives Analysis**
 - Given a set of candidates, which asset mixes most effectively contribute to meeting mission demands?
- **CONOPS Development**
 - How should an additional asset be deployed to best improve force effectiveness?
 - What is the best schedule for a certain type of asset?
 - What patrol tactics show promise for specific platform-sensor combinations?
- **Requirements Development**
 - What performance thresholds must new platforms meet in order to positively impact bottom-line measures of effectiveness?
- **Impact of Emerging Technologies**
 - What is the relative gain in force effectiveness with the implementation of new wide area surveillance systems (Generic WAS, HFSWR, Aerostats, ...)?
 - What new platform technologies show the greatest promise if they were implemented across the board?
 - Examples: Use of Force, automated identification, and advanced propulsion systems



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CGTME and its predecessors were used to help inform a wide array of USCG decisions. The program helped determine which potential acquisitions, current and future, had the most promise and which maybe should be deferred. Further, the program can be used to determine what specifications (speed, probability of detection, endurance, ...) a future system should have to be an effective alternative to current systems. These system performance tests can be performed against perceived current threat capability and future threat capability. In addition to identifying promising acquisitions, CGTME has helped inform USCG how best to use these new systems. Many times a new system used in an old way does not produce the best benefit for the USCG. The important point is that simulation does uncover potential questions with the use of new technology and does provide some analytic rigor for acquisition decisions.

Acronyms not previously defined

HFSWR High-Frequency Surface Wave Radar
WAS Wide Area Surveillance

CGTME Entity Processing in the UAS TOI Search Scenario



Function	Sensor(s)	Criteria
Detect	Radar-PPI, MMTI (all sensors used simultaneously)	Entity falls within sensor FOV Average time for single sensor detection is 15 sec
Classify	All EO Sensors and ISAR (all sensors used simultaneously)	Entity falls within sensor FOV Average time for single sensor detection is 60 sec
Identify	All EO Sensors and ISAR (all sensors used simultaneously)	Entity falls within sensor FOV Average time for single sensor detection is 60 sec
Clear	All EO Sensors, ISAR, and AIS (all sensors used simultaneously)	Entity falls within sensor FOV All commercial traffic uses AIS Average AIS clearance time is 30 sec Average time for single sensor detection is 60 sec Can transition to cleared at any point along Detection→Classify→Identify→Clear chain
Potential TOI	PPI, MMTI, EO Wide	Detection + Heading North + Appropriate Size + Appropriate Speed
Log	N/A	N/A
Report	N/A	N/A



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The UAS uses a mix of sensors to process (detect, classify, and identify) surface vessels. Within CGTME, either individual sensors or suites of sensors can be modeled. A drawback to modeling individual sensors within the model is that all of them are used simultaneously which can lead to unintentional performance gains. For comparative analysis, this may not be a problem because all simulations will receive the same type of benefit. In general, it is best to run CGTME in a mode with sensor suites which already account for the combined effectiveness for the available systems. Because MDA is an important MOE, CGTME works to clear all targets from being TOIs. Heading, speed, and size are used to sort all available contacts to determine which ones should be investigated first; but CG assets within CGTME try to investigate all targets.

Acronyms not previously defined

AIS	Automatic Identification System
EO	Electro-Optical
FOV	Field of View
ISAR	Inverse Synthetic Aperture Radar
MMTI	Maritime Moving Target Indicator
PPI	Plan Position Indicator



IMPRINT SSO HPM OVERVIEW



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This section provides a brief overview of the IMPRINT modeling tool and the SSO human performance model.

The IMPRINT HPM Environment



- **A dynamic, stochastic, discrete event network modeling tool designed to help assess the interaction of Warfighter and system performance**
- **Developed by the Army but applicable to HSI issues in any domain**
- **Well-suited to address HSI issues in acquisition**
 - Addresses task performance and workload demand
 - Supports integration with system and environment models to create constructive testbeds
 - Detailed performance reporting
 - Supports modeling at multiple levels of abstraction



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The Improved Performance Research INtegration Tool or IMPRINT is a human performance modeling environment developed by the U.S. Army and now used in various forms by the services and civilian communities. A task network methodology is used to provide “dynamic, stochastic, discrete event networks” that represent human actions and even perceptions and decisions. Both time and accuracy attributes can be specified for each behavioral event. These events are connected via procedural pathways that can vary based on both probabilities and decision logic, such that trial-to-trial outcomes from the same model may be different (i.e., performance of modeled operators will vary just like that of live operators).

IMPRINT models can be created to represent a wide range of individual and team performance situations and can be used to address a number of human-system integration issues. These include function allocation among team members and between people and machines. It also includes assessment of workload and situation awareness issues, specification of human performance requirements, and development of procedures and tactics. A variety of reports provides the objective data needed to support HSI decision-making. Custom data collection can be generated when needed.

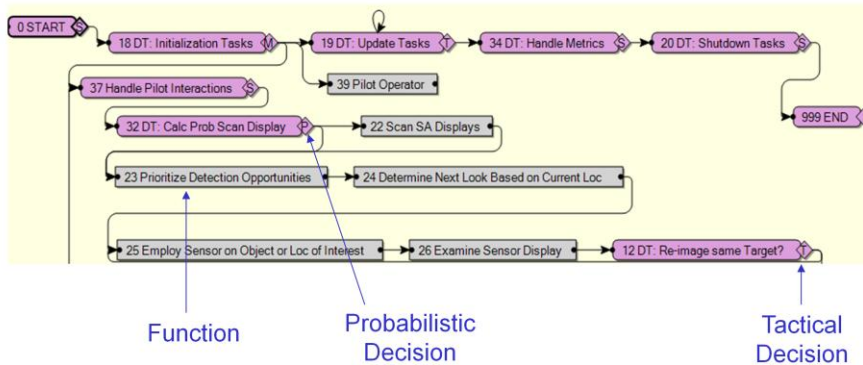
A unique feature of IMPRINT is its ability to connect to other models and simulations. This means that an IMPRINT model of an operator or operator team can be connected to a simulation of the platform they operate and the HPM can “sail,” “fly,” “drive,” etc. that platform in a dynamic mission simulation that provides all of the entities and events with which the operator and system interact. This allows performance of the IMPRINT HPM to be driven by attributes and characteristics of the platform that are impacted dynamically by the mission simulation. The result is a clear understanding of the demands the system and mission environment place upon the operator. This knowledge provides a basis for modifying the system design, CONOPS, tactics, etc. to better accommodate the operator in the system.

A final IMPRINT feature that should be noted is its ability to model performance at multiple levels of abstraction. By “multiple levels of abstraction” we mean different levels of detail can be employed within a given model to match the question being addressed in a given test. For example, if a 4-hour mission is being modeled and one component of the model is a 30-second manual data entry task, the task can be represented as a single 30-second task in the model. However, if the focus of the study is on the data entry task itself, the data entry activity should be broken into a series of smaller, detailed tasks that represent visual perception of the display, short-term memory recall of the data being entered, and fine motor inputs representing individual keystrokes. This ability to “pick-and-choose” the level of detail employed in a model makes for a much more efficient and cost effective modeling process.

Some IMPRINT Features



- Task network modeling environment
- High-level functions comprised of operator tasks
- Decision logic includes tactical and probabilistic decisions



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This slide shows an IMPRINT task network model and provides an opportunity to discuss some key features of task networks.

IMPRINT represents operator performance as a series of Functions and Tasks laid out in Networks. Here we show a top-level function network in a human performance model. The gray rectangles represent high-level operator functions. Functions are used to group and organize tasks that accomplish a particular function. Pink rounded rectangles represent tasks in IMPRINT. Time and accuracy values and expressions can be assigned to tasks. Most of the tasks shown in the graphic on the slide are so-called “dummy tasks.” Generally, they perform simulation management and administrative functions and have no time or accuracy values associated with them. The tasks that do the real work of the modeled operator are under the functions.

Pathways through the network can vary based on probabilities or decision logic (which allow the model to examine the state of the world and then choose a course of action). For example, consider a model of a vehicle operator who faces a decision whether to take a main highway through town or the bypass. The decision in the model could be represented as a probabilistic decision where the driver takes the main highway 75% of the time and the bypass 25% of the time. Alternatively, it could be represented as a tactical decision based on the current state of the world. For example, the model could examine a time variable and decide if the current time falls within a defined rush hour. If the time is within the rush hour window, the driver model would choose the bypass. Otherwise, the model would choose the main route.

Key Behaviors in SSO HPM



- **Monitor ownership position relative to search area boundaries and flight restrictions**
- **Plan sensor employment strategy based on target detections and aircraft position**
- **Employ sensors**
- **Monitor sensor displays for new detections**
- **Cross-cue among sensor data sources**
- **Hook and mark detected objects**
- **Interpret imagery to classify and identify detected objects**
- **Refer to target reference material for assistance in classification/identification**
- **Log Classifications, Identifications, Potential TOIs, Confirmed TOIs, and Confirmed Non-TOIs**
- **Report Potential and Confirmed TOIs, Confirmed Non-TOIs**
- **Interaction with Pilot Operator**



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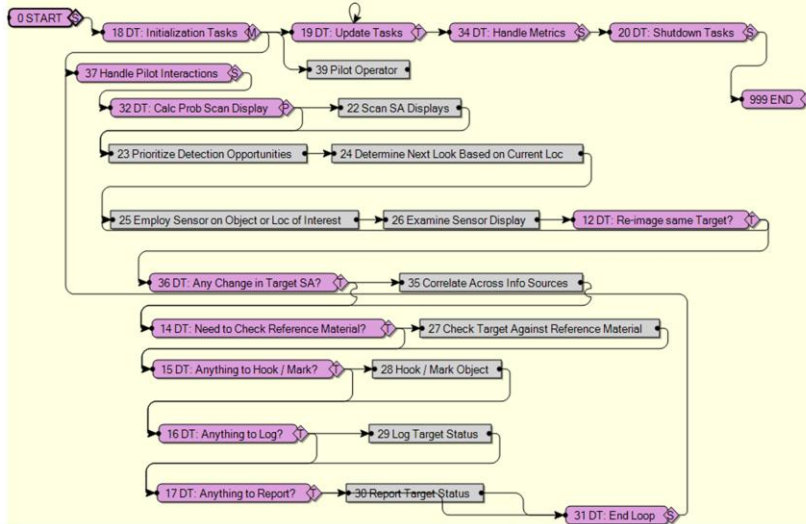
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This slide lists the key behaviors in the IMPRINT SSO human performance model. In the actual model there are many discrete tasks that accomplish these behaviors. The statements are generally self-explanatory but we would like to point out the range of behaviors that are involved. They range from maintaining situation awareness, to initially detecting entities, to selecting and manipulating individual sensors to classify and identify targets, to using reference materials to aid classification and identification, to logging and reporting results.

SSO Model's High-level Function Network



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This slide presents the top-level task network for the IMPRINT SSO HPM.

The high-level functions organizing SSO performance are represented in the function network of the model. These are the grey rectangles. The SSO performs a “loop” of these activities which involves:

- Maintaining situation awareness by scanning the Navigation, AIS, and Common Operating Picture (COP) displays
- Prioritizing imaging opportunities
- Determining the highest opportunity available given aircraft and target position
- Employing the sensor
- Examining the image

Given what is perceived in the image, and mapping this against its mission goals and situation awareness, the SSO HPM may perform a number of other functions including:

- Correlating the target
- Accessing reference material to better classify or identify the target as a TOI
- Marking the object on the radar display
- Logging the target
- Reporting the target

SSO Model IMPRINT Entity Processing



Function	Sensor(s)	Criteria
Detect	Primary: Radar-PPI, MMTI	Entity falls within sensor FOV; Radar: Signal-to-noise ratio (SNR) ≥ 13 EO: Johnson's criteria (display lines subtended by entity) $>$ detection criteria
Classify	Primary: EO Wide, EO Med, and ISAR	EO: Johnson's criteria $>$ classification criteria ISAR: SNR & Length ≥ 80 & Speed ≤ 20
Identify	EO Med, EO Narrow, EO Ultra-Narrow	EO: Johnson's criteria \geq identification criteria
Clear	Not Applicable	Not modeled in IMPRINT HPM
Potential TOI	PPI, MMTI, EO Wide	Detection + Heading North + Appropriate Size + Appropriate Speed
Log	N/A	Detection of Potential TOI, Classification, Identification, and TOI Status Confirmation (TOI/not TOI)
Report	N/A	Potential TOI, Confirmed TOI, Confirmed Not TOI



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Entity Detections occur primarily due to the use of the radar sensor in PPI and MMTI modes. Detection requires that the entity fall within the sensor FOV and have a computed signal-to-noise ratio (SNR) of at least 13. Entities can be detected with the EO sensor as well. EO uses Johnson's Criteria (lines subtended by each entity on the display; i.e., is the "blip" on the display large enough for a human to see it?) to compute whether an entity exceeds the detection threshold (2 lines).

Entity Classifications occur primarily due to the use of the EO sensor in Wide, Medium-Wide, or Medium mode. Larger entities can also be classified using the radar sensor in ISAR mode. For the EO sensor, classification occurs when the entity's display size exceeds the Johnson's Criteria for classification (8 lines). ISAR classification occurs when an entity's SNR permits detection, length exceeds 80 feet, and speed is less than 20 knots.

Entity Identification occurs primarily via the EO sensor in Medium, Narrow, or Ultra-Narrow mode. Identification occurs when the entity size (on the display) exceeds the Johnson's Criteria for identification (12.8 lines).

Unlike the stand-alone CGTME simulation, an entity state of 'Clear' is not modeled in the SSO HPM. This is because the two simulations were built to represent two slightly different identification processes. The process used by each simulation was driven by use of different sets of subject matter experts (SME) at different points in time and most likely reflects the fact that concepts for UAS employment still are evolving within the USCG.

Though the SSO HPM does not apply a 'Cleared' status to entities, it makes some very similar assessments internally. As part of the entity prioritization process, the SSO HPM will assess an entity as a "Potential Target of Interest" (TOI). Potential TOIs generally arise from entities sensed by the radar in PPI or MMTI mode or using the EO in Wide mode. Sufficient information is not available to identify the entity, but it can be classified as a vessel similar in size to a TOI. At this point other factors, such as speed and heading, are evaluated; and if these factors are consistent with those expected of a TOI, the entity is assessed as a Potential TOI. This gives it a higher priority for identification, and the SSO HPM will look for opportunities to complete the identification process for that entity to the exclusion of other entities that are not Potential TOIs. Later Identification of the entity will cause the Potential TOI to become either a "Confirmed TOI" or a "Confirmed Not TOI." Confirmed Not TOI entities are a type of "Cleared" entity as defined by CGTME but not the complete set. Entities classified as vessel types dissimilar to TOI also would be included as "Cleared" entities.

A Log is maintained for Detection of Potential TOIs, Classification, Identification, and TOI Status Confirmation (i.e., TOI or not TOI). A Report occurs when an entity is logged as a Potential TOI, a Confirmed TOI, or Confirmed Not TOI. The reports represent a potential handoff of the entity for further interdiction (by other blue assets).



INTEGRATED IMPRINT- CGTME ARCHITECTURE OVERVIEW



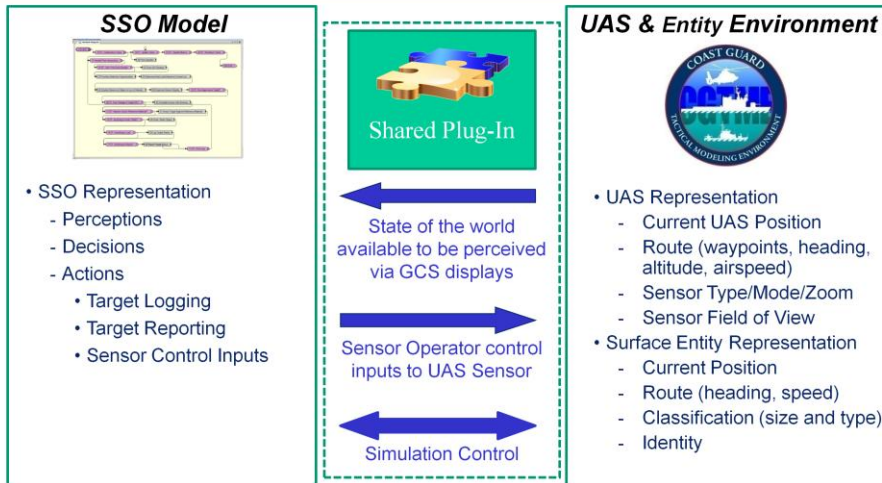
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This section provides an overview of the integrated IMPRINT-CGTME simulation architecture.

Integrated Simulation Architecture



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The SSO Model is a modified version of the IMPRINT model developed under an earlier project. The UAS & Entity Environment is a modified version of CGTME. The shared plug-in is the mechanism for the two environments to communicate with each other.

The CGTME component represents the state of the world in terms of UAS position, UAS sensor selections, and surface traffic position data across the 4-hour test scenarios described later in the presentation.

The integrated simulation of the vessel traffic, the UAS, and the IMPRINT SSO task network model allows SSO operator performance to be driven dynamically by movement of the UAS and surface traffic through time and space.

The entity state model plug-in is the mechanism through which the IMPRINT SSO model perceives and interacts with the UAS. The plug-in passes data to IMPRINT from CGTME that pertain to vessel type, position, heading, etc. This information feeds IMPRINT's simulation of UAS sensor displays, where it is "perceived" by the SSO model. Conversely, the SSO can act upon the UAS entity to change its view of the world. Specifically, the IMPRINT model can pass data through the plug-in to CGTME that selects a specific sensor, sets the mode, and adjusts the aimpoint to enable detection, classification, and identification of vessels.

The result is an integrated simulation in which the three main components (the scenario as defined by vessel types and routes, the UAS platform and sensors, and the SSO model) can all be manipulated somewhat independently. For example, the number, types, and densities of vessels can be changed without modifying the UAS entity and SSO models. This would allow analysts to study the effectiveness of a UAS/SSO capability combination under different track loads. Similarly, the SSO model can be changed to employ different procedures or search tactics without the need to change anything in the UAS model. Finally, sensor characteristics such as range and field of view can be changed in the UAS model without the need to change the SSO model. This relative independence of components simplifies and makes more efficient the process of changing the overall simulation.



DATA COLLECTION CAPABILITIES OF THE INTEGRATED SIMULATION



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Both simulations (IMPRINT and CGTME) have their own data collection capabilities. When combined, they offer the potential for significant insight into simulation outcomes. This section provides a brief overview of the more relevant data collection and reporting capabilities of the two simulations. We do this to provide the reader with a sense of the information possibilities of the integrated HSI-system simulation. We should point out that only a few of the capabilities discussed here actually were used in the test event. That is because both simulations currently have some problems with some of their data collection and reporting capabilities that precluded their use. Fixing these problems during the verification and validation (V&V) phase should be a high priority.

IMPRINT-Side Data Collection Support



- **Custom-developed data files for the SSO model**
 - Log
 - Entities that would be entered into duty log
 - Report
 - Entities reported via radio/phone
 - Potential/confirmed TOIs
 - Performance data
 - By-vessel identification results file
 - Entity ID; detect, classify, and identify time(s); identification phase; MDA classification
- **IMPRINT analyses (3 most relevant)**
 - Task performance
 - Task sequence chart
 - Operator workload detail



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The IMPRINT side of the simulation outputs data and reports from two sources. One is IMPRINT itself, which has data collection and reporting designed into the system. The other is custom-developed output that is tailored to the SSO HPM. Each set of reports is discussed separately below.

There are three custom reports for the SSO HPM. Two of these are analogs of the operational outputs of a real SSO. The first is a representation of the duty log in which entities encountered by the UAS are recorded. The second is a record of entities that would have been reported by the SSO via radio or phone. These are the potential and confirmed TOIs.

The third custom report is the by-vessel identification results file. It provides a summary of the identification history of each vessel in a scenario. For each vessel, the report provides:

1. The simulation run within which the data were collected (for tests involving multiple scenario runs).
2. Its unique ID.
3. The time it was detected (if it was).
4. The time it was classified (if it was).
5. The time it was identified (if it was).
6. The closest distance the vessel came to the UAS.
7. Its identification phase (the highest level achieved in the detect-classify-identify process).
8. Its MDA classification, which indicates the type of vessel it was (e.g., a Chug-Chug, a medium sized sailboat, or an extra-large commercial vessel).

A copy of this report is presented on the next slide.

As noted above, IMPRINT provides a number of reports. We present three of those reports most commonly used for analyses. Excerpts of these reports are presented and described on slides that follow.

Acronym not previously defined

ID Identify / Identification

Excerpt from By-Vessel Identification Results File



Run	ID	NAME	DETECT	CLASSIFY	IDENT	CLOSEST_RANGE	IDENT_PHASE	SA_CLASS
1	1	ID_0001	1738.5	2440.5	2451	2.58	Identified	CHUGCHUG
1	2	UNKNOWN	0	0	0	99999	Undetected	UNKNOWN
1	3	UNKNOWN	0	0	0	99999	Undetected	UNKNOWN
1	4	ID_0004	2991.5	9577.5	9577.5	8.29	Identified	SAILBOAT_MED
1	5	ID_0005	347.5	745	745	1.09	Identified	SAILBOAT_MEDSM
1	6	ID_0006	4237.5	12009	14164	7.33	Identified	COMM_XLG
1	7	ID_0007	2327	3079	0	9.42	Classified	RECVSL_SM
1	8	ID_0008	793.5	0	0	16.25	Detected	FV_MED
1	9	ID_0009	31	5368	5376.5	3.37	Identified	RECVSL_SM
1	10	ID_0010	2327	8920	8920	0.89	Identified	SAILBOAT_MEDSM
1	11	ID_0011	2700	12210.5	0	8.93	Classified	COMM_MED
1	12	ID_0012	2327	0	0	19.73	Detected	RECVSL_MED
1	13	ID_0013	2327	8477	9736.5	4.97	Identified	RECVSL_MEDSM
1	14	ID_0014	1738.5	0	0	8.66	Detected	FV_MEDSM
1	15	ID_0015	31	5612.5	5622	4.26	Identified	FV_MEDSM
1	16	ID_0016	347.5	6943	11423.5	2.15	Identified	RECVSL_SM
1	17	ID_0017	347.5	7387.5	7387.5	4.9	Identified	FV_MED
1	18	ID_0018	347.5	930	930	2	Identified	RECVSL_SM



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This slide provides an excerpt of the SAIC-developed by-vessel identification results file. It is output in a space-delimited format. This makes it easy to import into standard analysis tools like Microsoft® Office Excel® and Access®.

IMPRINT Analysis: Task Performance (Continued)



ID	Function	Task	Operator	Time				
				Times Performed	Standard	Minimum	Maximum	Mean
Root (Root)		START	Operator	1	00:00:00.00	00:00:00.00	00:00:00.00	00:00:00.00
Root (Root)		DT: Re-image same Target?	SimSupport	56	00:00:00.00	00:00:00.00	00:00:00.00	00:00:00.00
Root (Root)		DT: Need to Check Reference Materiz	SimSupport	41	00:00:00.00	00:00:00.00	00:00:00.00	00:00:00.00
Root (Root)		DT: Anything to Hook / Mark?	SimSupport	41	00:00:00.00	00:00:00.00	00:00:00.00	00:00:00.00
Root (Root)		DT: Anything to Log?	SimSupport	41	00:00:00.00	00:00:00.00	00:00:00.00	00:00:00.00
Root (Root)		DT: Anything to Report?	SimSupport	41	00:00:00.00	00:00:00.00	00:00:00.00	00:00:00.00
Root (Root)		DT: Initialization Tasks	SimSupport	1	00:00:00.00	00:00:00.00	00:00:00.00	00:00:00.00
Root (Root)		DT: Update Tasks	SimSupport	7,200	00:00:00.00	00:00:00.50	00:00:00.50	00:00:00.50
Root (Root)		DT: Shutdown Tasks	SimSupport	1	00:00:00.00	00:00:00.00	00:00:00.00	00:00:00.00
22 Scan SA Displays		START	Operator	33	00:00:00.00	00:00:00.00	00:00:00.00	00:00:00.00
22 Scan SA Displays		DT: Prob COP	SimSupport	33	00:00:00.00	00:00:00.00	00:00:00.00	00:00:00.00
22 Scan SA Displays		Attend to NAV	Operator	20	00:00:00.00	00:00:01.74	00:00:02.23	00:00:01.98
22 Scan SA Displays		Perceive NAV Display	Operator	20	00:00:00.00	00:00:03.70	00:00:06.54	00:00:05.28
22 Scan SA Displays		Attend to AIS	Operator	22	00:00:00.05	00:00:01.70	00:00:02.44	00:00:02.04
22 Scan SA Displays		Perceive AIS Data	Operator	22	00:00:01.00	00:00:03.24	00:00:07.19	00:00:05.19
22 Scan SA Displays		Attend to COP	Operator	16	00:00:00.05	00:00:01.55	00:00:02.47	00:00:01.97
22 Scan SA Displays		Perceive COP Display	Operator	16	00:00:00.00	00:00:04.16	00:00:07.45	00:00:05.23
22 Scan SA Displays		DT: Prob NAV	SimSupport	33	00:00:00.00	00:00:00.00	00:00:00.00	00:00:00.00
22 Scan SA Displays		DT: Prob AIS	Operator	33	00:00:00.00	00:00:00.00	00:00:00.00	00:00:00.00
22 Scan SA Displays		END	Operator	33	00:00:00.00	00:00:00.00	00:00:00.00	00:00:00.00
23 Prioritize Detection Opportunities		START	Operator	41	00:00:00.00	00:00:00.00	00:00:00.00	00:00:00.00
23 Prioritize Detection Opportunities		DT: UAV Position recent?	SimSupport	41	00:00:00.00	00:00:00.00	00:00:00.00	00:00:00.00
23 Prioritize Detection Opportunities		Attend to NAV Display	Operator	2	00:00:00.00	00:00:01.91	00:00:02.03	00:00:01.97
23 Prioritize Detection Opportunities		Perceive NAV Display	Operator	2	00:00:00.00	00:00:03.97	00:00:04.32	00:00:04.15



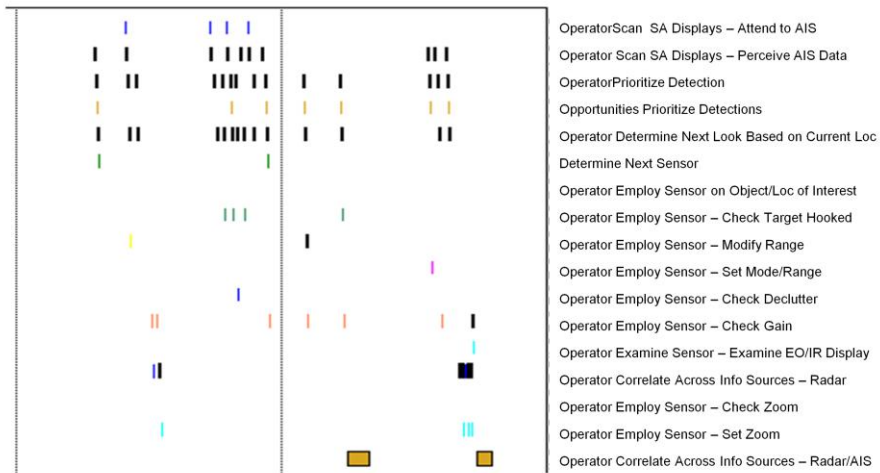
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This slide provides an excerpt of an IMPRINT Task Performance report. For each task performed, the report shows the function that contains the task, the task name, the operator who performed the task (a model can represent performance of multiple operators), the number of times the task was performed, plus several time (min, max, mean, etc.) statistics. If time criteria have been specified, the report will specify whether the criteria were met (not shown). The report is especially helpful for analyses of the relative time spent performing certain functions and tasks. The IMPRINT Task Report also provides information on task accuracy performance (not shown). Task accuracy information is used less frequently than the task time information. The preferred method for representing accuracy in an HPM is to incorporate it as an effect that can propagate through, and directly influence, the outcomes of other tasks in a model. For example, accuracy of an aiming task should directly affect outcome of a fire weapon task that follows.

IMPRINT Analysis: Task Sequence Chart



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This slide provides an excerpt of an IMPRINT Task Sequence chart. It provides a depiction of task performance events (colored bars) across scenario time. These data can provide insight into performance features such as the frequency of performance of a task, the density of performance of multiple tasks in time, and long-duration tasks that consume significant portions of a scenario. From these data, analysts can identify potential high-workload points, mission-critical tasks, and/or candidate functions for off-loading to automation.

Acronym not previously defined

IR Infrared

IMPRINT Analysis: Operator Workload Detail



Task Name	Overall Workload	Single Task Demand	Total Conflict Value	Visual	Fine Motor	Speech	Cognitive
Attend to AIS	4.00	4.00	0.00	3.00	0.00	0.00	1.00
Perceive AIS Data	9.30	9.30	0.00	4.00	0.00	0.00	5.30
Prioritize Detections	8.60	8.60	0.00	4.00	0.00	0.00	4.60
Attend to Radar Display	4.00	4.00	0.00	3.00	0.00	0.00	1.00
Determine Next Sensor Look	8.60	8.60	0.00	4.00	0.00	0.00	4.60
Examine EO/IR Display	12.80	12.80	0.00	6.00	0.00	0.00	6.80
Attend to Radar Display	4.00	4.00	0.00	3.00	0.00	0.00	1.00
Perceive Radar Data	9.30	9.30	0.00	4.00	0.00	0.00	5.30
Attend Radar for Coords	4.00	4.00	0.00	3.00	0.00	0.00	1.00
Check Target Hook	4.00	4.00	0.00	3.00	0.00	0.00	1.00
Hook Target	13.60	13.60	0.00	4.40	4.60	0.00	4.60
Attend EO/IR Controller	4.00	4.00	0.00	3.00	0.00	0.00	1.00
Enter Tgt Coords and Slew	17.40	17.40	0.00	5.10	7.00	0.00	5.30



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This slide provides an excerpt of an IMPRINT Operator Workload Detail report. If desired, IMPRINT can apply a workload model called the multiple resource theory (MRT). MRT posits that there are key input/output “channels” that enable (and constrain) human performance. These include visual, fine motor, speech, and cognitive channels. Tasks can be characterized in terms of the channels involved, and the channels can be associated with objects or features of the performance environment (e.g., a sensor display, or buttons and knobs that control the sensor). During task performance, the MRT model monitors task performance and calculates channel demands. This information is used to compute moment-to-moment workload scores that are presented in the Operator Workload Detail report. The data include:

- an Overall Workload score that sums workload across active tasks (in the IMPRINT example above, only one task was active at a time),
- a single task demand score (the workload associated with a particular task), and
- a conflict value that identifies instances in which channel demands exceed capacity.

Scores are also provided by channel (shown), as well as for specific objects in the performance environment with which the operator interacts (not shown). The data provide the analyst with insight into when the operator would experience excessive workload and the source of that workload. This information provides a basis for redesign of the operator’s environment or development of new procedures that mitigate the workload.

CGTME-Side Data Collection Support



- **Raw CGTME data**

- Store results from both a CG and traffic perspective
- CG MDA events
 - Store number of times CG assets classify, identify, and clear entities
- Traffic status transitions queue summaries
 - Store number of times an entity type was detected, classified, identified, and cleared
- Traffic state transition queue log
 - Each time an entity updates its status along the SDCIP process, the time for that transition is recorded

- **Integrated output processing within CGTME**

- Basic MDA statistics (%Detected, %Classified, %Identified, %Cleared)
- Breakdown of MDA statistic by traffic type

- **Export of summarized data**



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During the CGTME simulation run, data are collected regarding traffic vessel status and CG MDA actions. Data are logged every time there is a change to a traffic entity's status (detected, classified, identified, and cleared). Anytime a given vessel is re-statused (for example, a vessel might be classified more than once), that information is saved as well, allowing an assessment of how much work is redone by a CG asset. From the output, summaries for the primary MDA statistics are generated and can be exported.

Acronyms not previously defined

SDCIP Surveillance, Detection, Classification, Identification, Prosecution



TEST SCENARIOS AND TEST DESIGN



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This section provides an overview of the scenarios used to compare the stand-alone CGTME simulation with the integrated HSI-System Model simulation.

Test Scenario Overview



- **Location:** Florida Straits
- **Weather:** Fair
- **CG platform:** UAS controlled from remote ground station
- **Threat**
 - 3 Go-Fast (G/F) vessels: 2 northbound, 1 southbound, 40 knots
 - 3 Chug-Chug vessels: all northbound, 5 knots
- **Legitimate traffic:** All classes
- **Action**
 - UAS executes simple ladder search, no divers permitted (FAA constraint)
 - Threats attempt transits at random times along random paths that cross the patrol area
 - Legitimate traffic (a.k.a. “White”) either meanders (local) or passes through (transits)
 - UAS processes all contacts according to embedded rules – details vary with simulation configuration

Florida Straits



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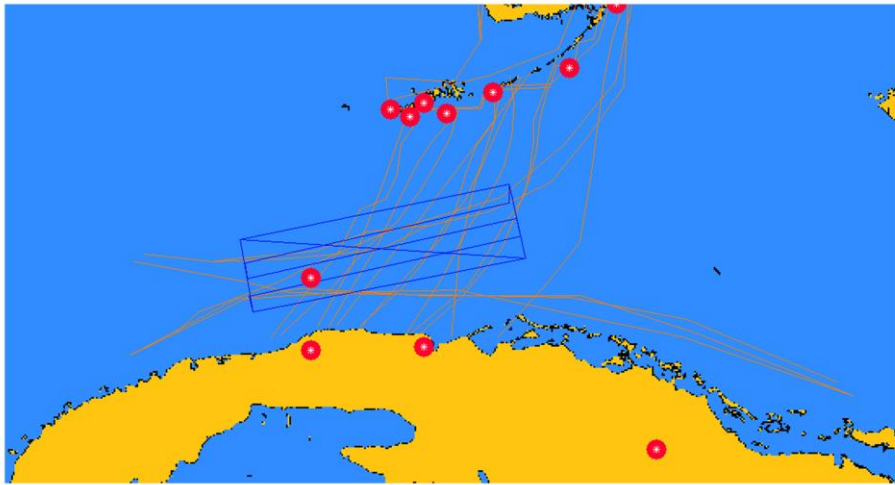
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The CGTME was written in such a way as to allow the user to define the location for a scenario and the density of the traffic and threat. In addition to random traffic and threat, specific special events can be added to ensure that the desired number of threat events are generated. For this particular analysis, the USCG is operating in a patrol area between Florida and Cuba with the mission to locate and identify northbound Go-Fasts, southbound Go-Fasts, and northbound migrant Chug-Chugs. The only USCG entity in this scenario is a single UAS which will perform a 4-hour ladder search in a patrol area between Florida and Cuba. The search box was sized so that the UAS will complete approximately one pass of the patrol area in the 4 hours. While patrolling, the UAS will not divert to investigate any contacts but will try to identify all contacts that it does encounter. Until identification, the UAS would not know if a target was a threat or benign traffic.

Traffic Transit Paths



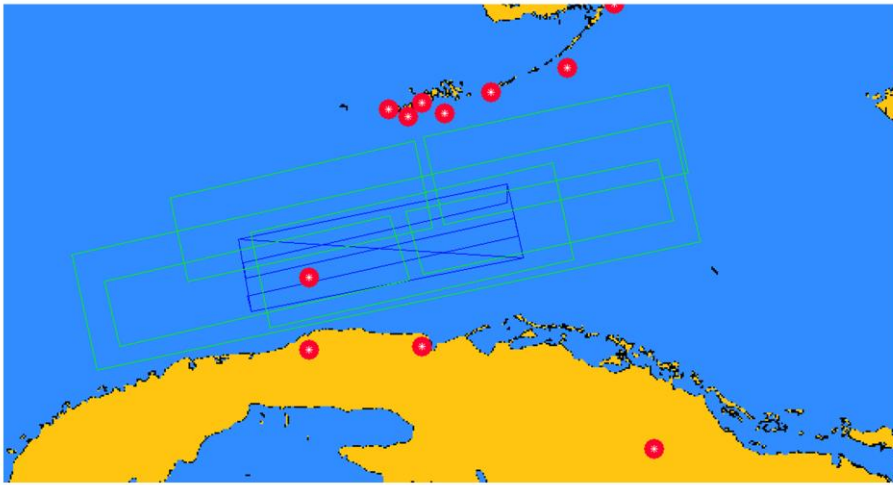
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This slide shows a depiction of the benign and threat traffic paths with an overlay of the UAS patrol box in blue (red dots mark locations such as Key West and Havana). The paths going from Cuba to Florida are the potential threat paths. The paths that threat and benign traffic take during the simulation are weighted by the user (i.e., different paths are assigned different probabilities) and randomly chosen during the simulation. Where a vessel starts along a path depends upon when the vessel is generated in the scenario. For vessels that are generated at scenario start-up, the simulation randomly sets a start point some distance along the chosen path and the vessel starts there. Traffic generated after start-up start at the beginning of their chosen path and follow the path to its end.

Legitimate Traffic Meander Paths



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This slide shows a depiction of the potential meander areas with an overlay of the UAS patrol box in blue. Only benign traffic meanders. The meander locations which can be used are weighted by the user and randomly chosen during the simulation. Meandering traffic generated at start-up are assigned random locations within their meander boxes and immediately appear there. Meandering traffic generated after start-up starts from the closest shore point to their eventual initial random location within a meander area. Once the initial meander area is reached, the benign vessel wanders within the area for a user-specified amount of time, and then transits back to shore.

Traffic Data



- **Types of vessel traffic generated**
 - Commercial vessels
 - Sizes: medium, large, extra-large (200-600 ft.)
 - Have AIS
 - Transit
 - Fishing vessels
 - Sizes: medium-small and medium (20-90 ft.)
 - Meander
 - Recreational vessels
 - Includes motor boats, yachts, sailboats
 - Some meander, others transit
 - Targets of interest
 - Go-Fast
 - Chug-Chug
 - USCG and Navy vessels



This slide shows the types of vessel traffic generated in the scenario. Traffic generation rates and densities were based on realistic data for the Florida Straits context. The initial generated values are determined by how long different traffic elements would be active within the simulation given their motion characteristics. Knowing the generation rate and the approximate initial traffic density allows us to determine the total number of traffic elements which would be generated in a 4-hour scenario. These values were scaled to achieve the two desired traffic amounts for the analysis (~150 total traffic entities and ~250 total traffic entities).



TEST RESULTS



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This section presents the results of the data collection and analysis that compare the performance of the stand-alone CGTME simulation and the integrated HSI-system simulation.

Run Matrix



- **Four run configurations**

- Two run modes
 - CGTME stand-alone
 - Integrated HSI-system simulation
- Two traffic rates
 - ~150 vessels (surface traffic entities)
 - ~250 vessels

	Simulation Mode	
Scenario Size	Integrated	Stand-alone
150 Entities	10 Data Collection Runs	10 Data Collection Runs
250 Entities	10 Data Collection Runs	10 Data Collection Runs



The run matrix for the test consisted of four test conditions created by combining two states for each of the two main variables. The two main variables were run (simulation) mode and scenario size (number of traffic vessels). The two states of run mode were CGTME in the stand-alone configuration and the integrated HSI-system simulation. As described earlier, the two states for scenario size were approximately 150 vessels and approximately 250 vessels. We say approximately because CGTME produces vessels in a given scenario run probabilistically. Across runs the average number of vessels generated would approximate 150 or 250.

Ten scenario runs were conducted for each test condition. The number of runs was limited because the run-time for the integrated HSI-system simulation conditions was significantly greater than for stand-alone CGTME runs. The duration of scenario runs is discussed in more detail later in the results section.

Scenario Crosscheck



- **Mean number of entities generated is consistent across simulation modes**
- **Mean number of vessels detected ~ number of vessels that fell into a sensor footprint**
 - About 60% of vessels in a scenario consistently fell within a sensor footprint
 - Results not due to major differences in vessels generated and detected across test conditions

Vessels Generated

	Simulation Mode	
Scenario Size	Integrated	Stand-alone
150 Entities	152	154
250 Entities	249	248

Vessels Detected

	Simulation Mode	
Scenario Size	Integrated	Stand-alone
150 Entities	97	98
250 Entities	156	157



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This slide examines the mean number of vessels generated and detected in each test condition. It verifies that the number of vessels generated under the two simulation modes were very close. Consequently, the results reported in the slides that follow were not skewed by differing numbers of vessels. The number of vessels detected also was very close across simulation modes. The number of vessels detected also was very close to the number of vessels that fell within a sensor footprint (had the opportunity to be detected). Across all integrated mode runs, only one vessel that fell within a sensor footprint was not detected. All vessels that fell within a sensor footprint during stand-alone runs were detected. This is important because it means the two simulations had about the same number of vessels to attempt to classify and identify. There were no large differences here to skew the results.

There is one additional result here that is of interest. Of the vessels generated, only about 60% were actually “sensed” by the UAS. This is due in part to traffic patterns that took some vessels outside the area covered by the ladder search pattern. It also is due to the timing and routing of some vessels that placed them within the search area for a period of time but the time there did not coincide with the presence of the UAS in that area. The number of vessels detected probably is a more realistic metric of scenario size than the number of entities generated because this is the actual number of vessels the simulations actually “processed”.

Mission Performance Results – Threats



- **Metric: % Threats Identified =**

$$\frac{\text{Number_Threats_Identified}}{\text{Number_Threats_Generated}}$$
- **There were 6 threats in each scenario**
 - 3 Chug-Chug
 - 3 Go-Fast

% Threats Identified

CGTME identified all threats in all scenarios. The integrated HSI-system identified fewer threats than CGTME and was more sensitive to number of entities in a scenario.

Scenario Size	Simulation Mode	
	Integrated	Stand-alone
150 Entities	80%	100%
250 Entities	67%	100%



As noted earlier, there were six threats in each scenario. There were three Chug-Chugs and three Go-Fasts. In this test, mission performance was all about finding and identifying the threats. So, to assess mission performance we want to know what percent of the six threats were identified as such. The table in the slide presents the results. The stand-alone CGTME simulation always found all of the threats. The integrated HSI-system simulation found fewer threats and the percent found was sensitive to the number of vessels in the scenario. CGTME's insensitivity to the number of entities is, perhaps, the most remarkable result. While CGTME is not expected to predict system performance in absolute terms, we do expect it to reflect the effect of significant factors in relative terms. Consequently, we would have expected the percentage of threats identified in the stand-alone mode to be lower in the 250 entity condition than the 150 entity condition.

The slides that follow will explore why these differences were observed between the two simulation modes.

Function Performance Results – All Vessels



These metrics assess the functions detect, classify, and identify

% Vessels Detected

Scenario Size	Simulation Mode	
	Integrated	Stand-alone
150 Entities	64%	63%
250 Entities	63%	63%

Similar results because both modes use same sensors, and almost all vessels falling within a sensor footprint were detected.

% Vessels Classified

Scenario Size	Simulation Mode	
	Integrated	Stand-alone
150 Entities	30%	63%
250 Entities	15%	63%

Substantially fewer targets were classified in the integrated simulation mode than the stand-alone mode. Also, the integrated mode was more sensitive to number of vessels.

% Vessels Identified

Scenario Size	Simulation Mode	
	Integrated	Stand-alone
150 Entities	22%	57%
250 Entities	13%	57%

Results are similar to vessel classification, though ID percents are even lower.



Because the location of the threats is unknown in a given scenario run, it seems reasonable that overall detection, classification, and identification performance across all vessels would be somewhat indicative of the threat identification results. The tables on this slide present percent detection, classification, and identification results for the four test conditions as computed across all vessels.

Percent detections were almost identical in all conditions. These results are driven more by sensor coverage than how SSO performance was represented. As noted on a previous slide, virtually all vessels that fell within a sensor footprint were detected by both simulation modes.

Results for vessels classified were dramatically different. All vessels that were detected were classified in the stand-alone simulation mode under both levels of vessel traffic. Again, CGTME was insensitive to the number of vessels in a scenario. In the integrated simulation mode, only about one-half (150 vessel scenarios) to one-quarter (250 vessel scenarios) of the vessels that were detected were later classified. Number of vessels clearly had an impact on SSO HPM performance, as would be expected from human vigilance and workload studies.

In terms of vessels identified, most (but not all) vessels detected and classified in the stand-alone simulation mode were identified. Thus, CGTME does show some sensitivity to the differences between classification and identification behaviors. Identification results for the integrated simulation mode were similar to those obtained in the percent classified results. Approximately one-third to one-quarter of the vessels detected were identified. Alternatively, most vessels classified were eventually identified.

For both simulation modes, the percentage of all vessels identified is noticeably less than the percentage of targets identified (as seen on the previous slide). These results demonstrate the effectiveness of the entity evaluation criteria applied by both simulations. These criteria enable the SSO portion of the simulations to isolate those entities most likely to be threats and focus on identifying them to the exclusion of other vessels. This is particularly true of the SSO HPM, which yielded low identification percentages across all vessels and relatively high percentages of threats identified.

The Behavioral Scope and Level of Detail Used in the SSO HPM Drives the Differences



IMPRINT SSO Key Behaviors and Times

Major Actions/Sub-actions	Mean (sec)
Scan SA displays	
Perceive Nav Disp	5.00
Perceive AIS	5.00
Perceive COP	5.00
Prioritize detection opportunities	4.00
Determine next look based on location	4.00
Employ sensor on Object of Interest*	
Employ radar	16.5
Employ EO/IR	10.8
Employ EO/IR but use radar to get coords	42.0
Examine sensor display*	
Examine radar display	5.0
Examine EO/IR display	2.0
Correlate across sensors	138.0
Check target against reference material	87.0
Hook/mark classified Object of Interest so it appears on COP	12.0
Log object status	17.0

*Per employment event. Multiple employment events can be required to classify and/or identify one vessel.

CGTME SSO Key Behaviors and Times

Function	Sensor(s)	Criteria
Detect	Radar-PPI, MMTI (all sensors used simultaneously)	Entity falls within sensor FOV Avg single sensor detection time is 15 sec
Classify	All EO Sensors and ISAR (all sensors used simultaneously)	Entity falls within sensor FOV Avg single sensor detection time is 60 sec
Identify	All EO Sensors and ISAR (all sensors used simultaneously)	Entity falls within sensor FOV Avg single sensor detection time is 60 sec
Clear	All EO Sensors, ISAR, and AIS (all sensors used simultaneously)	Entity falls within sensor FOV All commercial traffic uses AIS Avg AIS clearance time is 30 sec Avg single sensor detection time is 60 sec Can transition to cleared at any point along Detection→Classify→Identify→Clear chain
Potential TOI	PPI, MMTI, EO Wide	Detection + Heading North + Appropriate Size + Appropriate Speed
Log	N/A	N/A
Report	N/A	N/A



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The differences observed between results seen in the CGTME stand-alone and integrated HSI-system modes can be attributed to two main factors:

1. The level of detail at which detection, classification, and identification events are represented.
2. The scope of SSO behaviors modeled.

The tables presented in this slide provide a basis for understanding both of these factors. The table on the left lists the key behaviors performed by the IMPRINT SSO HPM and the approximate mean performance times of each. We say approximate mean performance times because there can be multiple paths used to accomplish many of these behaviors and each path can take a different amount of time. The table on the right lists the key SSO behaviors represented in CGTME and provides average performance times.

Level of detail used to represent detection, classification, and identification events

Comparing the two approaches to representing SSO performance is a bit like comparing apples and oranges because the two simulations use very different approaches. The CGTME is the simplest, so we begin there. In CGTME, each event – i.e., detection, classification, identification, and clear – is treated as a single action. All vessels falling within the footprint of a sensor used for detection, classification, or identification are given that categorization automatically. Time to accomplish the event is based on a single mean and associated variance. Average time to detect a vessel is ~ 15 sec. Average time to classify, identify, or clear a vessel is 60 sec. The detection, classification, and identification process is not so straightforward in the IMPRINT SSO model. Target detection can involve a collection of key behaviors that might include: examining the radar display to observe new tracks; then observing the AIS and COP displays to see vessels already identified; and then correlating the information on the radar, AIS, and COP to determine which tracks on the radar are new. This process can take over 160 seconds. Vessel classification and identification can require a number of sensor employment events. Evaluation of a target with the EO/IR sensor usually begins by taking entity coordinates from the radar and using those to initially point the sensor in the widest angle view to ensure the target is acquired in the sensor field of view. Then the sensor is stepped through increasingly higher resolution modes until the vessel image is large enough to classify or identify. If the range to the target is too far for the target size, classification is not possible and the operator must wait to get closer to the target before trying again. The classification and identification process for one vessel can range from about 1 minute (the same time used by CGTME) to several minutes depending upon vessel size and its position relative to the UAS flight path. Thus, the level of detail used in the two simulations can lead to very different results.

The scope of SSO behaviors modeled

The IMPRINT SSO HPM include behaviors not represented by CGTME. Checking a target against reference material is one of these. This task is a routine component of the TOI classification and identification process. It takes 87 seconds each time it is executed. Also included in this list is the process of “hooking” vessels that have been detected so they show up on the COP. This helps the HPM know which targets have been processed so time is not wasted evaluating them again. Finally, the act of logging vessel status is included. This action occurs every time new targets are detected and again when they are classified and identified. Taken together, these additional behaviors require the HPM to devote significant time to activities not performed by CGTME. This impacts the time available to devote to new target detection and classification and identification of detected targets.

Runtime Results: Approximate Average Minutes per Run



Scenario Size	Simulation Mode	
	Integrated	Stand-alone
150 Entities	~75 Minutes	~7.5 Minutes
250 Entities	~120 Minutes	~10 Minutes



One other dimension of simulation performance that was evaluated was the average time that it took to run a scenario under the different conditions. Past experience integrating simulations has taught us that run-time performance of integrated simulations can increase substantially over stand-alone performance of the individual simulations. That certainly was the case here. The stand-alone CGTME runs about 32 to 24 (150 entity and 250 entity scenarios, respectively) times faster than real-time. This speed permits large numbers of scenario runs in a relatively short period of time. In the integrated mode, however, scenario runs took 10 to 12 times longer than stand-alone CGTME runs.

Time and resource limitations would not allow a detailed analysis of the factors driving the relatively slow performance of the integrated simulation. If possible during the V&V some time should be devoted to exploring potential ways to improve runtime performance of the integrated simulation. If runtime performance cannot be improved, this can make the integrated HSI-system configuration unusable for tests that require large numbers of runs with a rapid turn-around of results.

Hope for improving integrated simulation runtime performance is provided by the performance of the simulation environment used in the SSO HPM demonstration that preceded this study. In that environment, IMPRINT was connected to a different mission simulation via a plug-in similar to the one used in the current study. That earlier integrated simulation ran at least 50 times faster than real-time for a four-hour (simulation time), 150-vessel scenario. We hasten to point out, however, that the mission environment simulation used in the earlier study was much less complex than CGTME, and the integrated simulation existed as a single executable rather than two separate applications with a shared plug-in (the simulation architecture used in this study). Consequently, while architectural aspects of the integrated CGTME-IMPRINT simulation probably preclude achieving runtime performance comparable to the initial demonstration environment, significant gains might be possible. This is worth exploring.



CONCLUSIONS



This section offers some conclusions based on the results of the study.

Conclusions



- **CGTME simulation architecture readily supports integration with other simulations**
 - Not just IMPRINT – plug-in also could integrate high-fidelity sensor, weapon, and other simulations
- **IMPRINT SSO model yields very different results from stand-alone CGTME**
 - The result of more-detailed modeling of more operator activities
 - Demonstrates sensitivity to factors expected to drive human performance (e.g., number/density of vessels)
 - Leads to more conservative expectations of total system performance



Early on in the project, the first issue was whether it was even feasible to integrate the IMPRINT SSO HPM with CGTME. It turned out that it was not only feasible but easier than expected. It is important to recognize that the new CGTME plug-in architecture offers possibilities other than simply integrating IMPRINT. It can be used to integrate other simulations as well. Suppose, for example, the RDC wishes to evaluate the effectiveness of some new sensor technology and a vendor or another laboratory has an executable model of the sensor. The plug-in could be used to integrate the sensor with the CGTME UAS platform and test its impact on mission performance. We expect that the RDC will find many new uses for this capability.

As demonstrated in the discussion of results, the IMPRINT SSO model yielded very different results from the stand-alone CGTME simulation. This appears to be the result of the more detailed representation of SSO performance provided by the HPM. More time was consumed by more activities in the HPM. Hence, there was less time available to classify and identify more vessels like CGTME could. Another interesting feature of the SSO HPM was its sensitivity to the number of vessels to be processed. Intuitively, these results are consistent with other studies of human performance in other domains in which performance is observed to decline as demands increase. In summary, the SSO HPM provides more conservative estimates of TOI search performance that seem more human-like. An important component of the verification and validation (V&V) process that is to follow will be an in-depth examination of the SSO HPM to determine the validity of the model and underlying data for representing the TOI search process.

Conclusions (Continued)



- **IMPRINT provides a more in-depth, flexible representation of human performance than is provided by CGTME**
 - Because it was designed to do that
 - Provides an easier means for evaluating processes, procedures, tactics
- **Integrated IMPRINT-CGTME runs much slower than stand-alone CGTME**
 - A limiting factor for tests requiring large numbers of runs
- **Need guidance for how best to use integrated simulation vs. stand-alone CGTME**



Clearly, an advantage of IMPRINT is its ability to represent human behavior in detail: that is what it was designed to do. CGTME was designed to represent systems, people, and mission environment objects and events in a more summary fashion. This is not a deficiency of CGTME; it is how CGTME and all other simulations like it gain their efficiency. One of the biggest challenges for all constructive simulations is obtaining good data upon which to base their summary performance estimates. Historically, such data have been very difficult to obtain. Now, with its IMPRINT integrated mode, CGTME has a means for generating detailed human performance data that can be translated into algorithms and parameters that CGTME can internalize. IMPRINT's graphical interface and multi-level modeling features simplify the process of representing human performance and obtaining the data that CGTME requires. How this process will work in practice requires more exploration, but it holds the potential for significantly strengthening CGTME's representation of human performance while retaining its computational efficiency.

An impact upon run-time for the integrated HSI-system simulation was not unexpected, but the surprise was the magnitude of the impact. The team explored some initial "fixes," but time and resources precluded conducting an in-depth assessment of the simulation architecture to find ways to speed up performance. This might be a worthwhile effort as part of the V&V. To the extent that run-time performance cannot be improved, the integrated HSI-system simulation might not support the run size and results-turn-time needs of some RDC customers. Guidance should be developed for using IMPRINT to generate human performance data that can be incorporated into CGTME.



RECOMMENDATIONS FOR GOING FORWARD



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The presentation concludes with some recommendations for how we go forward with the next phase of the project.

Recommendations



- **V&V phase provides opportunity to improve integrated simulation as well as evaluate it**
 - Performance domain representation, technical and scientific foundation strengths/weaknesses will be identified
 - Be prepared to enhance simulation to provide acceptable level of utility
- **Some potential areas for improvement**
 - Pilot model: add pilot component that controls UAS to depart search route to intercept/identify targets; realistically maneuvers UAS to accomplish ID, etc.
 - Add SSO perceptual error and forgetting functions
 - A real operator might “miss” vessels in high density environment; previously detected, classified, identified targets not always remembered



The V&V phase of the project will be more than just an assessment of the current integrated HSI-system simulation. As part of the process, we are very likely to identify elements of the simulation that must be modified to provide some threshold level of utility to the user community. While the V&V process is designed explicitly to surface these needed enhancements, there are some that we can anticipate at this point. We list and discuss them here as recommended enhancements to the simulation that should be assessed during the V&V.

- The current model represents the pilot in a very limited fashion. There is some interaction between the SSO and pilot as the UAS approaches a turn. Also, there is some random “chatter” that occasionally distracts the SSO. Given that we are modeling a UAS, we are excluding half the system’s crew by not modeling the pilot. We also are excluding functionality of the UAS that is likely to be of interest to RDC customers. Specifically, this is the ability to depart a planned course line and fly the UAS to an object or point and intercept a target to identify it or to maintain contact and monitor it. This would provide a much more functional UAS representation.
- At present, the SSO model “remembers” all targets once it detects them. This feature was driven by an assumption that there would be integrated sensor coverage from other sources across the search area that would enable persistent tracking of objects and that would display those objects on the COP. It is not clear whether that is a viable assumption in all situations. Also, the model does not have a problem distinguishing between closely-positioned vessels. That is, it does not get “confused” about which of two closely-spaced entities have been processed. We know that such confusion occurs in other systems. As part of the V&V, some thought should be given to the need to incorporate perceptual errors and forgetting into the model.

Recommendations (Continued)



- **Some potential areas for improvement (continued)**

- Develop CONOPS for using HPM to establish performance benchmarks and then translate HPM parameters into CGTME parameters for stand-alone simulations
- Fix broken data collection and reporting functions in IMPRINT and CGTME
- Explore ways to enhance runtime performance



- For the benefit of the HPM to be maximized within CGTME, the process for translating IMPRINT performance modeling and results into summary algorithms and data needs to be established. This will not be as simple as just coming up with one mean and variance that CGTME always uses. One of the strengths of the SSO HPM is its ability to adapt its behavior to fit the evolving situation. Similarly, some degree of adaptation will need to be provided within CGTME. How this can best be accomplished without adversely impacting the CGTME architecture and performance will take some experimentation.
- We noted earlier in the presentation that both IMPRINT and CGTME provide varied and extensive data collection products which can enhance the analysis of simulation results. Unfortunately, some of the capabilities are not functional at present. During the V&V process, some effort should be devoted to getting these capabilities fixed. For IMPRINT this will mean working with the Army Research Laboratory who owns the IMPRINT simulation.
- Finally, run-time performance of the integrated HSI-system simulation has been disappointing. To the extent possible, some time should be devoted to exploring ways to improve this.



List of Acronyms



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<u>Acronym</u>	<u>Meaning</u>	<u>Acronym</u>	<u>Meaning</u>
AIS	Automatic Identification System	PPI	Plan Position Indicator
CG	Coast Guard	RDC	CG Research & Development
CGTME	CG Tactical Modeling Environment	Center	
CONOPS	Concept of Operations	SAIC	Science Applications International Corporation
COP	Common Operating Picture	SDCIP	Surveillance, Detection, Classification, Identification, Prosecution
GCAM-CTS	General Campaign Analysis Model Core Tool Suite	SME	Subject Matter Expert
EO	Electro-Optical	SNR	Signal-to-Noise Ratio
FOV	Field of View	SPA	Systems Planning and Analysis
HFSWR	High-Frequency Surface Wave Radar	SSO	Sensor System Operator
HPM	Human Performance Model/Modeling	TOI	Target of Interest
HSI	Human Systems Integration	UAS	Unmanned Aerial System
ID	Identify / Identification	USCG	United States Coast Guard
IMPRINT	IMproved Performance Research INtegration Tool	V&V	Verification and Validation
IR	Infrared	WAS	Wide Area Surveillance
ISAR	Inverse Synthetic Aperture Radar		
MDA	Maritime Domain Awareness		
MMTI	Maritime Moving Target Indicator		
MOE	Measure of Effectiveness		
MRT	Multiple Resource Theory (workload model)		