Track 3 Participant Guide

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Overview

The Office of Naval Research (ONR) recently co-authored the Navy's Science and Technology Strategy for Intelligent Autonomous Systems[1] to guide the development of capabilities that synthesize unmanned vehicles, artificial intelligence, and autonomy into a future enabled by Intelligent Autonomous Systems (IAS). Alongside this effort, the Program Executive Office for Integrated Weapons Systems (PEO IWS) produces many of the Navy's sensors and mission management systems. PEO IWS is adopting the use of models to guide digital engineering of their acquisition programs. HACKtheMACHINE Unmanned Track 3 will yield insights for IAS and inform PEO IWS's use of models for systems design and acquisition. The Track will generate these engineering insights by focusing on the real-world problem of narcotics smuggling.

Each year, thousands of tons of illicit drugs are smuggled into the United States via maritime trafficking in the Caribbean and Eastern Pacific (the primary maritime portion of the western hemisphere transit zone, or WHTZ). To stop these drugs from entering the United States, the Navy and partner agencies under the Joint Interagency Task Force South (JIATFS) deploy a variety of maritime assets (a collection of assets working together is referred to as a "force package") to monitor, identify, and disrupt illicit maritime trafficking through the WHTZ. However, JIATFS has finite resources to combat the high volume of illicit maritime activity in the WHTZ. Over the past few decades, the number of illicit events in the WHTZ has exceeded the force packages by approximately 4:1. The situation is further complicated by the fact that the WHTZ represents an area larger than the continental United States, presenting a challenging wide area search problem. As a result, a significant and dangerous quantity of drugs destined for the United States successfully passes through the WHTZ.

To further disrupt drug trafficking operations in the WHTZ, JIATFS is looking for ways to optimize its use of currently available assets and resources. For example, suppose JIATFS could deploy a force package with air assets consisting of a helicopter and long-range patrol aircraft or three medium-range UAVs for the same cost in resources. Which of these would perform best, or is it a mixture of the two? At present, JIATFS measures the effectiveness of a particular set of assets by deploying them and measuring their effectiveness over time—the operational equivalent of "estimate and check". However, with a nearly unlimited combination of possible assets, finding the optimal approach using this estimate and check method is inefficient. Furthermore, JIATFS would like to support the development of entirely new assets by better defining the capabilities a new asset should have to maximize overall mission effectiveness. As more unmanned systems become available, how might JIATFS estimate and predict the performance of a force package when a new system is added?

Platforms the Navy acquires to support the JIATFS mission (and every other mission Navy performs around the world) are defined by a set of requirements. Over the last few years, the Navy has started to adopt model-based systems engineering (MBSE) in its acquisition decisions. These models allow traceability of system components to the requirement that drove the inclusion of a particular capability. At the same time, the Navy uses mission effectiveness models to determine how well a particular set of capabilities and operating patterns completes a mission. However, the link between MBSE and mission

[1] See the full strategy here: https://news.usni.org/2021/07/29/department-of-the-navy-strategy-for-intelligent-autonomous-systems

effectiveness modeling has not yet been clearly established. Without this link, it is difficult to translate a mission need into a set of requirements for a heterogenous collection of systems meant to complete that mission. As such, understanding how to link MBSE and mission effectiveness modeling is critical to establish a more efficient acquisition process and improve mission effectiveness. HACKtheMACHINE Track 3 is focused on discovering approaches to this modeling challenge for JIATFS, but there is a larger interest in understanding the interaction of MBSE approaches with mission evaluation across all Navy missions.

In this HACKtheMACHINE Track, you will help JIATFS combat drug trafficking by developing a quantitative model that can predict the mission effectiveness of different force package compositions—including compositions with theoretical assets. To get you started, we will give you access to a modeling tool called SIMDIS along with additional information relevant to this modeling challenge. Then, over the course of three Challenges, you will create a representation of drugs transiting the WHTZ environment, model the interaction between a force package and this environment, and then use your model to suggest a more effective force package. In this competition, we are looking for novel and creative approaches to this modeling problem.

You may choose to use SIMDIS as your starting point, or you may choose to utilize an entirely different approach. The competition will be judged by a panel of subject matter experts, so you should be able to describe both the "how" and the "why" of your modeling approach!

Terminology

For clarity, we will use the following terminology throughout the competition:

Mission Effectiveness Model: A model that predicts the effectiveness of a set of resources performing a given mission

Systems Engineering Model: A model that maps requirements defined by resource providers to a set of capabilities and the system elements that meet those capabilities and requirements.

Asset: A platform used to search for and disrupt drug traffickers (ships, small boats, helicopters, planes, unmanned vehicles, satellites, etc.)

Sensor: Sensors are deployed on assets. A sensor detects a phenomenology of a target (camera, radar, electronic support measure, etc.)

Target: A maritime drug smuggler platform used to carry illicit drugs (boats, semi-submersibles, etc.)

Force Package: A collection of assets deployed together to combat a drug trafficking in the WHTZ

Track: The spatial route of an asset or target

Illicit Event: The track of a target through the WHTZ

Drug Trafficking Environment: The flow of drugs trafficked by smugglers in the WHTZ. The totality of illicit events through the WTTZ over time.

Your Mission

Your mission is to create a quantitative model that can be used to predict the mission effectiveness of a force package for a particular drug trafficking environment. Your model should work over a timescale of approximately one month. Fundamentally, your model should take as inputs a representation of the drug trafficking behavior in the WHTZ and a representation of a force package and give as an output the mission effectiveness of that force package. For clarity, we will adopt the following shorthand to discuss these models:

X = A representation of drug trafficking behavior in the WHTZ

Y = A representation of a force package

Z = The mission effectiveness of the force package

Model: f(X,Y)=Z

Modeling Approach

In this competition, we are looking for a diverse set of novel approaches to a difficult problem. Therefore, you are given a relatively open-ended problem statement and the freedom to formulate a solution however you see fit. The only restriction is that your model must be of the form f(X,Y)=Z outlined above. This will ensure that your modeling solution addresses JIATFS' core problem and allow comparison across submissions. As such, your model should incorporate the following elements:

- A representation of the drug trafficking environment
- A force package representation for a variety of existing and proposed assets and sensors
- A quantitative metric for the mission effectiveness of a given force package over the course of ~1 month

As previously introduced, the Navy uses MBSE tools in acquisition. Tools in use now include Cameo and Rational Rhapsody among many other tools for system engineering models. Similarly, the Navy uses tools like SIMDIS, Gazebo, and CoppeliaSim among many others for mission effectiveness models. There has been initial work by the Office of Naval Research to explore linkages between these two types of modelling and insights at this intersection are useful for you to explore. There is a desire to see if video game development tools such as the Unreal Engine are applicable to this problem.

If you do not have a preferred modelling environment, you will be given access to a government owned modeling tool called SIMDIS[2] . SIMDIS is a software tool for generating 2D and 3D simulations and display of a tactical environment, both for "seen" data (e.g. the track of a boat) and "unseen" data (e.g. propagation of RF waves from radar equipment), and includes physics models that can be used to

[2] See the SIMDIS guide included in this packet. For more information, you may also want to look over the SIMDIS Wikipedia page: https://en.wikipedia.org/wiki/SIMDIS

simulate the behavior and interaction of assets and sensors. We will give you a guide to getting set up with SIMDIS along with starter code to generate a set of simple target tracks to get you familiar with building out scenarios in SIMDIS. Please note that SIMDIS does not have native support for macOS, and there may be performance issues using SIMDIS within virtual machines.

You may choose to build out every aspect of your solution in SIMDIS. Alternatively, you are free to build your representations and/or model in a different tool or use a purely mathematical approach of your own creation! Any mixture of these approaches and tools is acceptable (the world is your oyster, as they say), so long as your final formulation takes the form of f(X,Y)=Z.

The problem of creating a representation of the drug trafficking environment is a novel one and, as such, is open-ended regarding potential approaches. Here, you are asked to draw on your creativity—we are excited to see what you come up with! For your representation of a force package, there are two primary elements you must consider: assets and sensors. In JIATFS operations, assets act as platforms to carry sensors, and it is possible to mix and match what sensors are deployed on a given asset within the restrictions of size, weight, power consumption, etc. Creating a representation that allows for this mixing and matching will be useful for Challenge 3, where you will be asked to create a novel force package using your model. Keep in mind, your representation of the environment in Challenge 1 and the representation of assets and sensors in Challenge 2 will have to interact in your model for maximum score. Both the representation of the environment and your asset/sensor combinations will act as inputs to the same model (these are your X and Y). Therefore, you should consider how you will model their interactions as you create them.

When considering the mission effectiveness metric please focus on the wide area search problem. One example metric of effectiveness would be total illicit events detected by a given set of assets on a specific set of tracks with a specific set of sensors. Another mission effectiveness metric might be one that focuses search detections on targets with intelligence to indicate that they are moving large shipments of cocaine and results in a higher probability of detecting the largest amount of illicit cargo. HACKtheMACHINE Track 3 is the first step in a systematic effort to mathematically define an operational environment and the interactions of systems models that are working in the environment to achieve a defined mission objective. At this point, the exact metric to define success is not generally accepted and your insights can shape those metrics.

Finally, you will want to consider ways to demonstrate your approach and solution to the judges in addition to showcasing its theoretical backing and rigor. This is a relatively short event, and we don't expect you to have fully fleshed out solutions that are ready to be deployed by the end of the competition. However, we are looking for indications that an approach is feasible, effective, and worth further investment. You can demonstrate elements of your approach by showing simulation results, model constructions and outputs, etc. Where you don't have access to the necessary data or information, you could input synthetic data or estimated values to demonstrate feasibility knowing that the Navy would have access to real data and classified information. Overall, the Navy is looking for insights that are worth the investment to build out further and test in the physical world. What can you provide to convince the judges that your approach and solution fits the bill?

Modeling Considerations

Statistician George Box famously said, "All models are wrong, but some are useful." There are an almost unlimited number of factors you could consider when building your model for this competition. You will need to decide what factors to include in your model and at what level of abstraction. To get you started, the following subsections offer a non-exhaustive list of possible factors you may wish to include. Remember, though, that we are looking for creative approaches to this modeling challenge; what additional factors might you incorporate into your model that we didn't think of?

Geography and Weather

The geography and weather of the WHTZ constrain potential asset and target routes in both static (landmass distribution and seasonal weather patterns) and dynamic ways (acute weather like storms, fog, etc.).

Intelligence

JIATFS gets intelligence reports of varying accuracy on drug trafficking activity in the WHTZ. These reports can contain information on departure times, departure and arrival locations, vessel type, speed, drug load, and waypoints.

Target Characteristics

Target characteristics are a key factor in any wide area search problem. For this competition, some characteristics you may wish to consider are:

- # of targets
- Target types (fast boats, semi-submersibles, etc.)
- Target resolution (how big is it?)
- Target capabilities (speed, range, etc.)

Asset Characteristics:

Equally relevant to a wide area search problem are the characteristics of the assets being used to search. Important characteristics might include:

- # of assets
- Types of asset (ship, boat, helicopter, etc.)
- Asset capabilities (speed, range, endurance, etc.)
- Tending requirements (fuel, maintenance, basing, etc.)

Sensor Characteristics:

Important characteristics for sensors might include:

- Sensor capabilities (field of view, data, etc.)
- Required specifications for a platform asset (size, weight, power, communication, etc.)

Tactics

The tactics used by a force package will impact its effectiveness, and different force package compositions might benefit from different tactics. You may choose to factor in the tactics used to search for targets at varying levels of resolution in your model.

Adaptive Behavior

Drug trafficking behavior dynamically changes to adapt to JIATFS operations, which may include changing routes and tactics. In turn, JIATFS operations adapt to changes in drug trafficking behavior to form a behavioral feedback loop. These effects will show up over the course of a month, and you may wish to consider the dynamics of this feedback loop (see Magliocca *et al., 2019)* to improve your model's performance over longer timescales.

Competition

The competition will unfold over the course of a kickoff event and three Challenges described in the following sections. As we work with competitors throughout the next few weeks, we will synthesize the questions and answers then push consolidated feedback to each team at the start of each Challenge.

Competition Kickoff (16-19 November)

This Track begins with the Competition Kickoff event taking place from Tuesday, November 16th to Friday, November 19th. At the start of this event, you will research the problem, form teams, and brainstorm potential approaches. By midnight EST on Wednesday, you will fill out the "Team Approach" template answering a set of questions regarding your understanding of the problem and brainstorming on a solution. Thursday morning on Slack, you will answer a series of follow-up questions the judges have about your "Team Approach". Thursday afternoon, the judges will select teams to move into a live Q&A about their approach. Teams that are selected will put together a ten-minute presentation for the judges to further explain their understanding of the problem and outline their initial approach. These presentations will be given Thursday evening and Friday morning. Following these presentations, the judges will select the final set of teams to move onto the Challenge series of this competition.

The Competition Kickoff will be a summary of your overall approach to the problem. You will not have to implement your model for this phase of the contest. Points will be awarded based on:

- Your restatement of the problem with emphasis on key elements important to your team (10 points)
- Your planned approach for Challenge 1 (20 points)
- Your planned approach for Challenge 2 (20 points)
- Your planned approach for Challenge 3 (20 points)
- Creative insights (30 points)

Model based competitions are a new way the Navy is engaging industry and academia. So, in addition to the technical details of your approach the Judges are interested in questions such as:

- What was your thought process in creating the approach?
- What do you feel are your approaches strengths and weaknesses?
- What software/tools do you plan to use and why?
- What additional information did you find helpful for ideating your approach?
- What additional information would you like that could improve your approach?

Challenge 1 – Model the Environment (19 November – 1 December)

In the first Challenge of this competition, you will build out your representation of the drug trafficking environment using the information contained in this packet as well as supplementary material you will

receive at the start of the Challenge. In addition, you will likely want to supplement this information with your own research into the problem to create a competitive representation. Keep in mind that the representation you build in this Challenge will serve as one of the inputs to your model and be used for the rest of the competition. At the end of this Challenge, you will give a 20-minute presentation to the judges describing your representation and the approach you took to create it. In addition, you will fill out a written template to answer some additional questions about your approach.

The grading for Challenge 1 will be based on the representation's inclusion of the following categories:

- Geographic factors (20 points)
- Target characteristics (20 points)
- Dynamic scenario elements (20 points)
- Data requirements (20 points)
- Creative insights (20 points)

The supplemental information for Challenge 1 will provide examples for each of these categories and guidance on where to find more details to support your modelling effort. Your representation must include at least two elements of each category. For example, you may pick navigable waters and ocean currents as two elements of the geographic factors considered in your model. This will result in 100 points available based on inclusion of category elements.

The judges will also be able to award up to 20 points for insights related to:

- How systems engineering representations can feed or interact with your mission representation
- Can the representation be reparametrized to change the weighting of different elements
- Other cool ideas you bring forward

Challenge 2 – Add a Force Package and Show Effectiveness (2 – 8 December)

In this Challenge, you will need to model how a force package interacts with your environment developed in Challenge 1. The assets of a JIATFS force package may include:

- One Maritime Patrol Aircraft (MPA) like the P-8: https://en.wikipedia.org/wiki/Boeing_P-8_Poseidon
- Two Helicopter capable ships like the ARLEIGH BURKE class: https://en.wikipedia.org/wiki/Arleigh_Burke-class_destroyer
- Two helicopters with maritime sensors like the MH-60R: https://en.wikipedia.org/wiki/Sikorsky_SH-60_Seahawk#MH-60R
- A rigid hull inflatable boat (RHIB): https://en.wikipedia.org/wiki/Rigid_inflatable_boat

The assets in the force package carry sensors. You can use the Wikipedia pages above to determine sensors for each asset that make sense in this search challenge. We are curious about the distinction between sensor models and asset models so that packages in the future can composed from reconfigurable sets of assets and sensors.

Your Challenge 2 submission must create a representation of the force package to be used as an input to your model along with the drug trafficking environment representation from the previous Challenge.

Then, you will build your model to estimate the effectiveness of the force package against the drug trafficking environment.

The grading for your force package representation in Challenge 2 will be based on the representation's inclusion of the following categories:

- Asset characteristics factors (20 points)
- Sensor characteristics (20 points)
- Search tactics (20 points)
- Data requirements (20 points)
- Creative insights (20 points)

Challenge 2 is also the first time we will be asking about your ability to solve for the key equation f(X, Y) = Z. Therefore, we will also be awarding points for your modelling methodology in these categories:

- Implementation feasibility (20 points)
- Description of the technique (20 points)
- Multi-element interactions (20 points)
- Approach to creating an effectiveness metric (20 points)

The judges will also be able to award up to 20 points for insights related to:

- How systems engineering representations can feed or interact with your mission representation?
- Can the representation be parameterized to move between different force packages, assets, and sensors?
- Other cool ideas you bring forward

Challenge 3 – Adapt the Force Package (9 – 15 December)

In the final Challenge of this competition, you will use your representations and model to suggest a more effective force package to combat the drug trafficking environment from Challenge 1. The composition of this force package can consist entirely of existing US military assets, or it can include assets that you propose. Proposed assets need to be feasible using current technologies, and the force package should be comparable in cost to the given force packages from Challenge 2. No, you can't propose a UAV with a 1000-foot wingspan and unlimited range. And no, you can't have an aircraft carrier! You should use your model to show how your proposed force package would be more effective than existing force packages.

The grading for Challenge 3 will be based on:

- Feasibility of the proposed force package in terms of cost and technology (20 points)
- Model driven support for your force package's effectiveness (20 points)
- Modularity of your model to evaluate different combinations of assets, sensors, and tactics (20 points)
- Linkage of your mission effectiveness model to system engineering models (20 points)

- Creative insights (20 points)

This is the final phase of the competition so the judges will also be able to award up to 20 points for overall insights related to:

- Actionable ideas your modelling has suggested are worth the engineering cost of prototyping for in-water experiments
- Limitations to your approach realized late in the process
- Fundamental limitations of structuring wide area search as a model-based challenge
- Other cool ideas you bring forward

Useful Information

This section contains useful information to get you oriented to this Track's competition.

Statistics

In 2020, it is estimated that over 2000 metric tons of cocaine that made its way into the United States from South America. Over 70% of all cocaine trafficked went through the Eastern Pacific, with the remaining cocaine trafficked through the Caribbean[3].

[3] See U.S. Drug Enforcement Agency data at https://www.dea.gov/sites/default/files/2021-02/DIR-008-21%202020%20National%20Drug%20Threat%20Assessment_WEB.pdf

In the Eastern Pacific, there was a recent average of ~18 illicit events per day. Of those, there were an average of ~3 Force Packages sent to investigate. That is a rate of 1 Force Package to every 6 illicit events. The Eastern Pacific consists of several "traffic lanes" that are used by maritime vessels. About 1/3 of the traffic travels on short distances from the Northmost part of South America to the Southmost part of Central America. About half of the traffic travels between the Northmost part of South America, toward the Galapagos Islands, then north towards Central America and the southern coast of Mexico. 1/6 of the traffic travels the longest distance, from South America, past the Galapagos Islands, then to South Mexico.

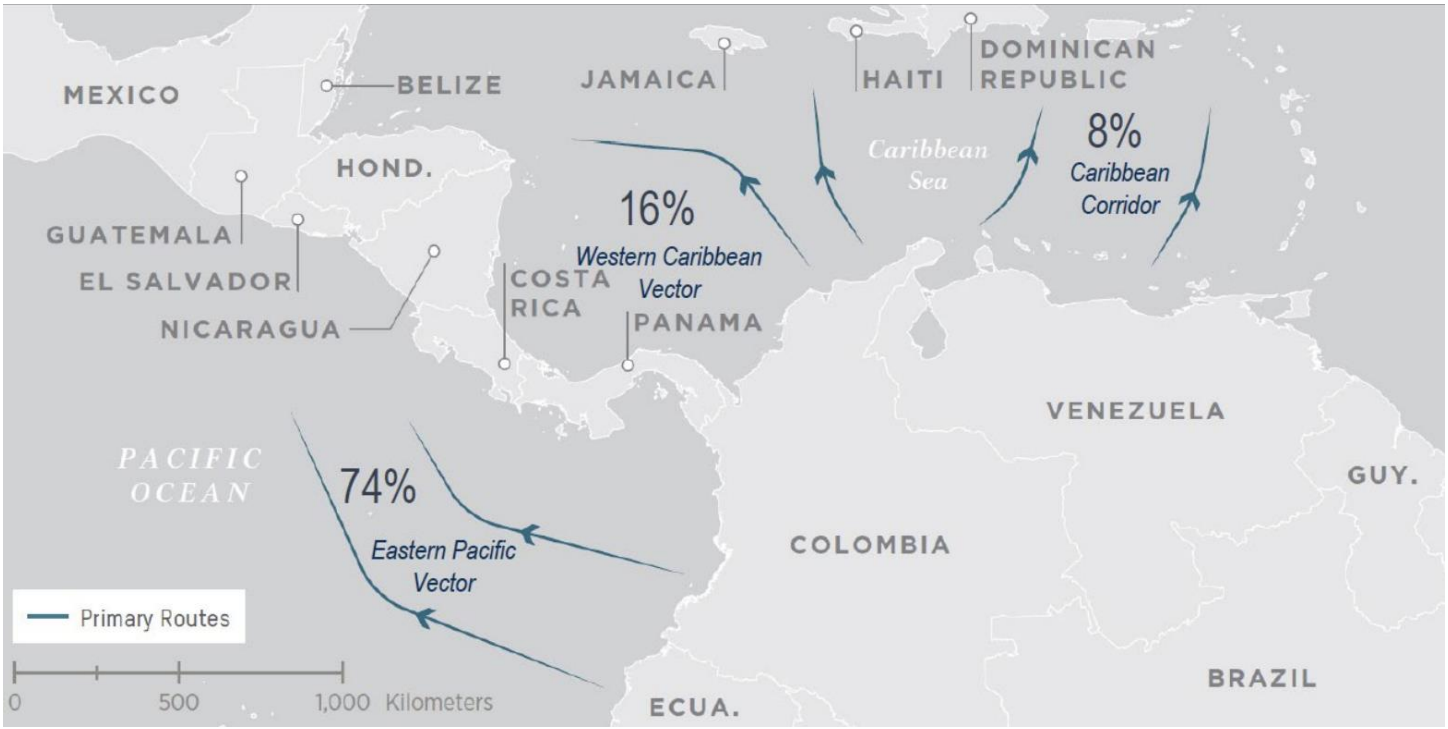

Figure 1. DEA depiction of drug routes in the WHTZ.

In the Caribbean, there is a recent average of 4 illicit events per day. Of those, there were an average of ~2 Force Packages sent to investigate. That is a rate of 1 Force Package to every 2 illicit events. The Caribbean consists of several "traffic lanes" that are used by maritime vessels. About 60% of the traffic travels from South America to the middle of Central America. ~30% of the traffic travels from South America to the Dominican Republic. ~10% of the traffic travels from South America to the islands in the Southeast part of the Caribbean Sea.

Figure 2: Map showing suspected drug trafficking tracks in the WHTZ in 2014. Image taken from https://adamisacson.com/trafficking-routes-over-time/

Multiple sources have identified "go-fast" vessels (bottom right of above image) as the primary means of illicit maritime transport in the WHTZ, accounting for ~85% of all illicit traffic. Most often these go-fast vessels are some type of Panga boat, usually between 19 and 28 feet in length and featuring an open design with large outboard engines. Traditional fishing vessels (top right of above image) and custom-made vessels (left side of above image), make up the remainder of this traffic. In this competition, you can focus entirely on identifying the go-fast vessels.

Previous Research

Before creating your model, you may wish to review existing research related to this modeling problem.

Though much research has published on topics related to optimal search planning under resource constraints, there is a much smaller body of research focusing on the nuances of applying these results to drug trafficking—a problem that has been coined the "smuggler search problem". Pietz and Royset (2015) is a good entry point into the existing literature researching the smuggler search problem. In addition, multiple theses have been published by students at the Naval Postgraduate School on this topic. The footnoted theses[4] are excellent introductions to the problem and existing approaches as they often include sections covering background context and literature reviews alongside discussion of the models they develop. In particular, Campos III (2014) is worth reviewing, especially the background and literature review sections. Additional research exists on related problems that share characteristics with the smuggler search problem. Many models have been developed to optimally deploy maritime assets for search and rescue (Pelot *et al.,* 2015), immigration flow monitoring (Skinner *et al.*, 2018), and counter-piracy operations (Hansen *et al.*, 2011). A full list of recommended reading, including works references in this section, is included in the *Useful References* section at the end of this document.

Please note, you are encouraged to use previous research to inform your approach and can include elements of this work to build upon in your own approach. Recreating previous research with an operating model for JIATFS and ONR will earn points, but the grading scale will favor novel and creative solutions to this problem.

Logistics

Track 3 is a virtual event that concludes on 15 December 2021. During the HACKtheMACHINE main event you will have staff members on-site and available for support over the course of the 4-day event. Winners will be announced on livestream broadcast announced on Friday, 17 December 2021. There are several announcements and speeches that will occur on the official HACKtheMACHINE live stream throughout the 4-day event. Any questions, comments, or concerns after 20 November 2021, should be communicated over the official HACKtheMACHINE Unmanned –Track 3 Slack channel.

The primary Slack channel for this Track is named #track-3-top-model.

Submission Schedule

The competition kickoff event during the HACKtheMACHINE livestream 16-19 November will have an interactive set of discussions and deliverables.

Submitting teams will present their finding during a video call with the judges on the following days:

- Challenge 1 – Wednesday, 1 December 2021
- Challenge 2 – Wednesday, 8 December 2021
- Challenge 3 – Wednesday, 15 December 2021

[4] Visit https://library.nps.edu/nps-theses to browse all publicly available NPS theses and dissertations, https://calhoun.nps.edu/ also contains additional research materials produced by NPS faculty and students

Winners will be announced in a livestream at 11am ET on Friday, 17 December.

Announcement Schedule

Nov 16th	TUESDAY - DAY ONE
1100-1130	Welcome RADM Selby, RADM Small, RDML Okano RDML Moton, RDML Nguyen
1200	Track 3 – Introduction to Game and Problem

Nov 17th	WEDNESDAY - DAY TWO
1155-1205	Track 3 – Top Model – MBSE Update & Lessons Learned Thus Far
1230	RADM Selby Keynote Speech

Nov 18th	THURSDAY - DAY THREE
1200-1215	Track 3 – Top Model – MBSE Update & Lessons Learned Thus Far

Nov 19th	FRIDAY - DAY FOUR
1230-1300	Track 3 – Top Model – MBSE Overview & Next Steps to Awards

Communication

All registered participants will receive a welcome email on Tuesday the 16th. Included in the email is a link to join the official HACKtheMACHINE Slack Workspace. Slack will have all the channels you need to view updates posted, relevant documents shared, and where you can ask any questions. If you have not received the link to join Slack, please first check your spam and junk inbox. Then, if you do not have the link, please reach out to hackthemachine@fathom5.co for assistance.

Prizes

Prizes will be awarded to teams that standout over the course of the three Challenges. Doing the best on one Challenge does not guarantee placement in the final standings. Prize money will be awarded to the top three teams:

- 1st Place - $15,000
- 2nd Place - $10,000
- 3rd Place - $5,000

Sportsmanship

This is a real problem, and the results could have real consequences. All teams are expected to abide by a code of honor that respects the rules and other competitors. Any attempt by a team to modify or falsify a scoring card will lead to the immediate disqualification of the entire team from the competition

and their score will be set to -1. Any concerns about cheating shall be immediately brought to the attention of the Track 3 Lead who has final decision on any penalties, warnings, or disqualifications.

Useful References

Allain, Richard J. *An evolving asymmetric game for modeling interdictor-smuggler problems*. NAVAL POSTGRADUATE SCHOOL MONTEREY CA, United States, 2016.

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