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Optimized Transit Tool & Easy Reference (OTTER) Improved Data Analysis

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OPTIMIZED TRANSIT TOOL & EASY REFERENCE (OTTER)

IMPROVED DATA ANALYSIS

by

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Distribution Statement A

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ABSTRACT

The Optimized Transit Tool & Easy Reference (OTTER) program is a simple Excel tool designed to help surface ships reduce their fuel consumption during transits while still adhering to mission and operational requirements. Past studies have attempted to pin a precise number to the expected fuel savings made possible through OTTER, but this is difficult to do because of the highly variable nature of OTTER's potential fuel savings. Possible fuel savings are a function of not only a ship's mission, but also the base case behaviors to which the optimized transit solution is being compared, and the operational constraints that limit the potential optimizations.

This effort expands on previous efforts by considering a wider range of possible transit scenarios for Cruisers and Destroyers. We modeled transits with an average speed ranging from 8 to 27 kts, with up to four hours per day dedicated to running drill sets, and both operational conditions where engine modes are unconstrained and where ships must maintain split plant at minimum. In all cases OTTER was shown to improve fuel efficiency compared to the bases case, but the improvements ranged from significant to negligible depending on specific operating and transit conditions.

This effort also solicited feedback from Navy Surface Warfare Officers (SWOs) at the Naval Postgraduate School to get their input on the tool's interfaces and training materials. Interviews with these SWOs led to revelations on how the OTTER interface can be improved to alleviate confusion and how the training materials can be made more effective. Their input will be used in future versions of OTTER and its related materials to improve the effectiveness of the tool and training materials once it reaches the users.

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I. INTRODUCTION

The objective of this study was to expand upon previous efforts to model the potential fuel savings of the Optimized Transit Tool & Easy Reference (OTTER) program on Cruiser and Destroyer transits. OTTER is an Excel-based tool where users can enter the parameters defining their transit and receive as output a transit plan optimized to meet mission needs while minimizing fuel consumption. Other tools have been used for similar purposes such as the Battlegroup Optimum Speed Calculator (BOSC) and Ship Energy Conservation Assistance Training (SECAT), but OTTER is unique in that it adapts to non-optimal mission parameters and uses the Mixed-Mode Fuel Minimization method [1] to find counterintuitive efficiency gains. In doing this research we hope to make the case that OTTER represents a potential for significant fuel savings under a wide variety of transit conditions, including conditions that restrict the optimization space due to operational engine mode constraints. It is our hope that this research will support the case for widespread adoption of the OTTER tool.

While this research effort evaluates OTTER's fuel saving potential for individual Cruisers and Destroyers, it does not address ships of other classes or the impacts that those fuel savings would have on greater fleet logistics, readiness, and sustainment. Prior studies have covered OTTER's potential fuel savings for other ship classes under ideal conditions, but further work remains in modeling transit conditions that impose operational limitations on ship engine configurations as is often encountered in the field.

A secondary objective of this study was to conduct limited user testing to identify ways in which OTTER and its training materials could be improved. Although we were unable to test OTTER on an actual ship, we were successful in recruiting a small number of Surface Warfare Officer (SWO) student volunteers to get their feedback. Their feedback lead to significant revelations on how the tool and training material could be improved, but those improvements could not be made to OTTER under this study because this study's funding did not cover further development of the tool.

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II. LITERATURE REVIEW

This study continues on the work done by prior NPS student theses and NRP studies that have aimed to promote the development of the OTTER tool and determine its potential fuel savings. The thesis by LCDR Blackburn [2] that introduced the original macro-based OTTER tool did a basic fuel saving analysis, but did not include factors such as time dedicated to drill sets or operational limitations on plant configuration. A later thesis attempted to use actual fleet transit records to evaluate the impact of OTTER, but much of their transit data was not able to be used due to inconsistencies and suspected errors in the records provided by the fleet. One example of such case that occurred often would be where the reported distance traveled would be less than the distance between the reported starting and ending locations. It is suspected that the cause of this apparent error is that different pieces of information were recorded at different times. The following year, a thesis team attempted to collect more transit data to conduct a more complete analysis of OTTER's potential savings. While this study was more comprehensive, it did not cover transit conditions that would impact engine configurations. NRP has also funded studies into OTTER's potential effectiveness [3] [4], but these studies were using an older version of OTTER and did not have access to actual ship transit data.

This study had hoped to use the data collect from past student thesis efforts, but the required data had since been purged from the classified servers at NPS. Attempts were made to get the same data from the original sources in the fleets, but the POCs had since rotated on to new positions. We were able to establish contact with other individuals within the fleet who had offered to gather ship transit data for us, but we did not receive the data in time to use it in this study.

Although we were not able to use actual transit data in our model, we did succeed in creating a notional dataset covering a wide variety of transit scenarios including and beyond what we would have encountered in the actual transit records. This dataset is discussed in further detail in the next section.

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III. ANALYSIS PROCEDURE

This study had originally proposed using transit records collected in prior studies to conduct a more in-depth analysis of OTTER's potential fuel savings, but as mentioned in the previous section, the records were no longer available and replacement data was not acquired in time. In order to forge ahead without actual transit data, the research team created a notional dataset of transits covering a wide array of transit conditions. Because the researchers were involved with the previous studies and student theses from which the original transit records would have been obtained, the researchers were already familiar with the type of transit conditions one might expect to find in actual records, were they available. The transit data set used in this study covers transits with prescribed average speeds ranging from 8 to 27 kts, with up to 4 hours per day dedicated to running drills or exercises that disrupt forward progress. The transits were modeled for both Cruisers and Destroyers, and in both cases where engine mode was unconstrained and where operational conditions prohibited the use of trail shaft. Transits requiring full plant configuration for their entire duration were not modeled because it OTTER's benefit comes from capitalizing on mixed engine mode efficiencies, thus it would yield no benefit in cases where mixed mode operation was not an option.

The macro-free version of the OTTER program was used to model these transits. Macro-free OTTER was chosen over the macro-enabled full version of OTTER because it is believed that the macro-free version of OTTER is more likely to see actual adoption and implementation since special permissions are not required to run spreadsheets without macros. Cruisers and Destroyers were modeled in both situations without engine mode restrictions, and in cases where trail shaft could not be used. The transits were modeled to start and end in the middle of the Plan of Intended Movement (PIM) moving window. Both the Cruisers and Destroyers were modeled to have a fuel capacity of 17500 barrels, and to start with 14500 barrels in the tank at the start of the transit. A fuel safety level of 60% was chosen for both the base case and OTTER optimized transit solution. In both cases, ships would refuel as many times as required to maintain the minimum fuel safety level.

In this analysis, the base case for comparing fuel savings assumes that the ship would otherwise engage in an inefficient behavior where they rush to the front of the PIM moving window at a high speed (27 kts or more) so as to not fall behind the middle of the moving window when pausing to conduct exercises. This assumption is based off of interviews with SWOs where they described the typical operations on the ships they've served on. In some cases the projected OTTER savings are overly optimistic, but this would occur primarily in cases where the ships are already operating in an efficient manor, and these would be a minority of cases based on our discussions with the SWOs.

Drill sets are modeled as occurring in blocks of four hours, at the lowest engine configuration (trail shaft), with a movement speed of 5 kts, and making no forward progress towards the transit destination. This combination was chosen as it was believed to reflect an "representative average" of possible drill sets in the absence of any data detailing the frequency of specific drill types or the impact they have on forward progress towards the transit destination. Because we modeled a wide variety of transits with exercise frequency ranging from only once in a ten day period, to once per day for the same ten day transit, our results should still capture the impact that specific drill sets would have, even if we didn't model those drill sets and exercises specifically.

IV. RESULTS

In our modeling, OTTER was shown to always improve fuel efficiency when compared against the base case, even in restricted engine mode transit scenarios. Typical fuel savings ranged from 3% to 15%, but could be as high as 20% in specific situations. Fuel savings tended to be higher in cases where ships were able to use trail shaft, and in cases where the average transit speed was close to a transition speed where a ship would need to change engine modes to reach higher speeds. Lower fuel savings occurred in cases with lower average transit speeds and fewer drill sets that minimized the impact of the inefficient base case behavior. In cases with no restriction on engine mode and at least one drill set every other day, fuel savings were typically 10% or higher compared to the base case. In cases that did not allow trail shaft and included at least one drill set every other day, fuel savings were typically 8% or higher compared to the base case.

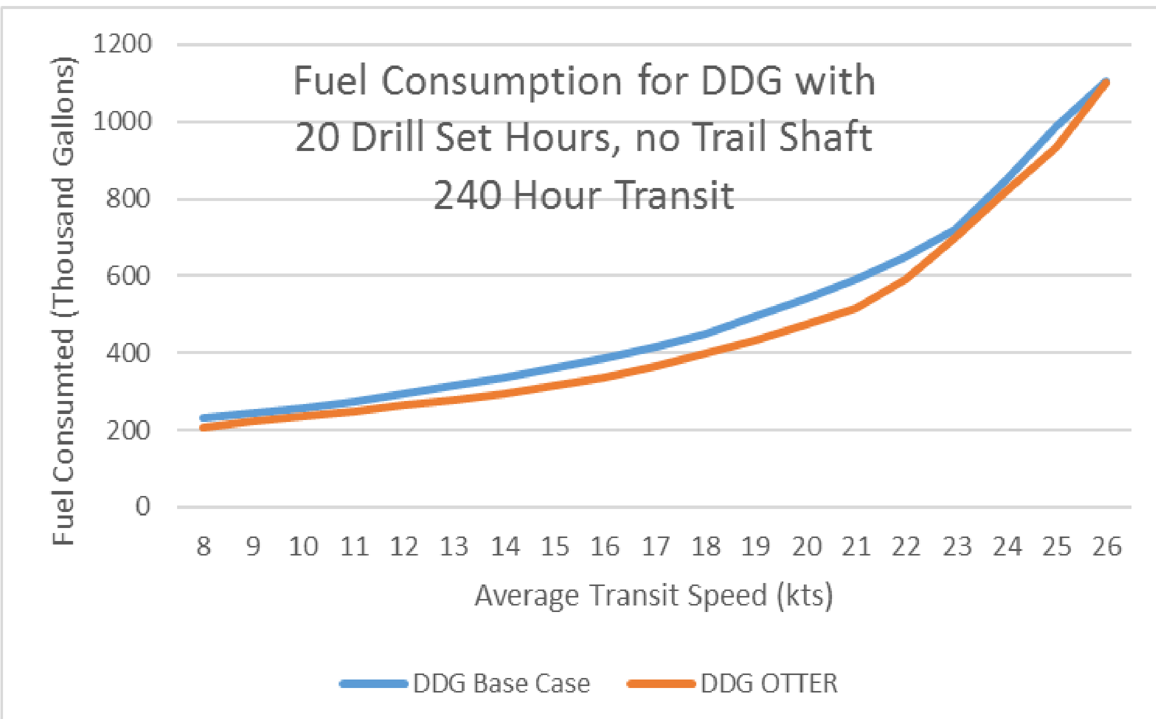

Figure 1: Base Case and OTTER Solution fuel consumption for a Destroyer under transit conditions preventing the use of trail shaft during 240 hour transits of various speeds with 20 hours of drill sets per transit.

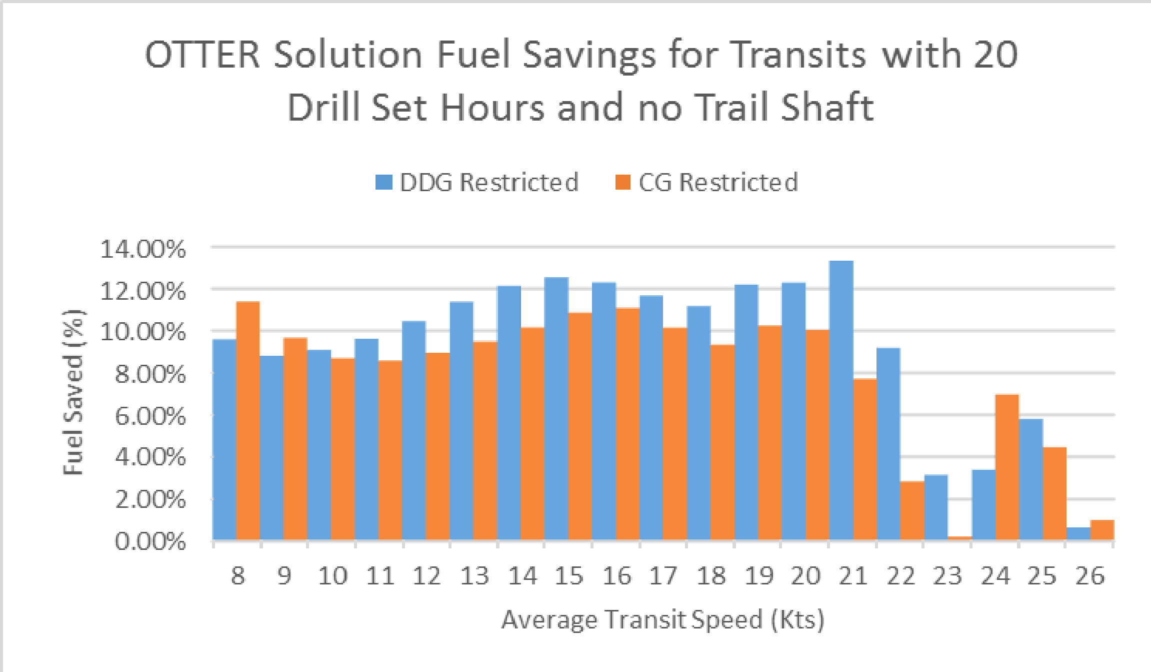

Figure 2: OTTER Solution fuel savings for a Destroyer and Cruiser under transit conditions preventing the use of trail shaft during 240 hour transits of various speeds with 20 hours of drill sets per transit.

This work supports the theory that OTTER would be expected to save significant amounts of fuel across a wide variety of transit conditions and would promote force sustainment efforts. The full transit model results are available in the Compiled Analysis file accompanying this report. Further work still remains to model the impact that OTTER would have on larger fleet logistics

V. USER TESTING AND FEEDBACK

In addition to gauging the potential fuel savings of OTTER, this study also sought to gauge the effectiveness of the OTTER training materials and see what improvements could be made to the interface to reduce the possibility of user error contributing to poor results from OTTER. SWO volunteers were recruited from NPS and asked to review the OTTER training materials and try to model some transits in OTTER. By observing the new users attempt to familiarize themselves with OTTER and gathering their feedback, we were able to learn of several improvements that could be made to the tool and training materials.

The biggest takeaway from the new user experimentation was that the training materials should be presented in a different format to increase their effectiveness. The current training materials are written as a set of instructions built into a sheet within the OTTER tool, but all of the SWO testers agreed that a slideshow-based training presentation would be more consistent with the types of training materials SWOs are used to receiving.

The SWO volunteers also offered suggestions on how the tool and interface could be improved to make it more user-friendly and cut out some of the unnecessary features. They suggested that the generator fuel consumption input on the main interface was unnecessary because users are unlikely to know their expected generator consumption; a fixed hidden value for generator fuel use would be more effective and reduce a potential source of user error. It was also requested that the transit could be specified through a set distance and duration rather than a duration and prescribed average speed as it is now. A bug was also discovered in the interface that allowed users to manually change a parameter that should only be able to update automatically based on input from another section of the interface. These desired improvements have been documented for later implementation.

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VI. SUMMARY

This study demonstrated that OTTER is expected to produce significant fuel savings during surface ship transits under a wider set of conditions than had been analyzed in prior studies, and uncovered ways in which the interface and training materials can be made more effective to promote future adoption. This study was unable to use data from ship logs taken during transits, but was able to model a wide variety of transit conditions including and beyond those that were encountered in previous studies. The study compared the expected fuel consumption of a ship running an OTTER optimized transit against a representative base case and found that OTTER transit solutions would typically produce fuel savings of 3-15% depending on transit conditions. Even in cases where ships could not use the efficient trail shaft engine configuration, OTTER was still able to produce significant fuel savings. While there does exist the possibility of OTTER generating non-optimal transit solutions due to user error, the feedback from test users will help guide future efforts to improve the OTTER interface and training materials to reduce the likelihood of this happening. The results of this study suggest that the Navy would see significant benefit in both operational costs and readiness by implementing OTTER across the fleet. Future work remains to be done in modeling how implementing OTTER would impact larger fleet logistics.

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[3] Howard, Alan, and Brandon Naylor. *Analysis and Improvement of Optimized Transit Tool & Easy Reference (OTTER) as an Improved Transit Fuel Planner*. 2017, *Analysis and Improvement of Optimized Transit Tool & Easy Reference (OTTER) as an Improved Transit Fuel Planner*.

[4] Howard, Alan, and Brandon Naylor. *Modeling the Impact of OTTER and Its Benefits to the Fleet*. 2017, *Modeling the Impact of OTTER and Its Benefits to the Fleet*.