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A cost estimation analysis of U.S. Navy fuel-saving techniques and technologies

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MONTEREY, CALIFORNIA

THESIS

A COST ESTIMATION ANALYSIS OF U.S. NAVY SHIP FUEL-SAVING TECHNIQUES AND TECHNOLOGIES

by

Samuel Vince A. Fonte

September 2009

Thesis Advisor: Daniel A. Nussbaum
Second Reader: Jeffrey E. Kline

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13. ABSTRACT (maximum 200 words)

The U.S. Department of Defense and Navy are placing a greater emphasis in energy efficiency. Though the surface fleet comprises only a small percentage of petroleum usage, seemingly small efficiencies gained could yield substantial fuel savings. This thesis follows a process of researching and collecting fuel-saving ideas, developing a method to estimate savings, subjecting calculations to sensitivity analyses by discount factor and cost of fuel, and creating prioritization listings of ideas based on predicted savings. Six technique and twelve technology-based initiatives are examined. Calculations are estimated for each idea using inputs from various sources. Sensitivity analysis is performed on the independent variables of fuel price and discount factor and rankings are computed. The prioritized listing of techniques and technologies are stable when subjected to these sensitivity analyses. And as expected, greater savings are realized when the cost of fuel is higher and/or when the discount factor is lower. For several of the practices in this study, fuel savings are shown to be substantial and worthy for consideration despite any involved risk. These findings may be used by decision makers to pursue further testing and evaluation of practices and subsequently confidently implement throughout the surface fleet, knowing that savings will remain robust despite fluctuations in fuel prices.

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A COST ESTIMATION ANALYSIS OF U.S. NAVY FUEL-SAVING TECHNIQUES AND TECHNOLOGIES

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Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

The U.S. Department of Defense and Navy are placing a greater emphasis in energy efficiency. Though the surface fleet comprises only a small percentage of petroleum usage, seemingly small efficiencies gained could yield substantial fuel savings. This thesis follows a process of researching and collecting fuel-saving ideas, developing a method to estimate savings, subjecting calculations to sensitivity analyses by discount factor and cost of fuel, and creating prioritization listings of ideas based on predicted savings. Six technique- and twelve technology-based initiatives are examined. Calculations are estimated for each idea using inputs from various sources. Sensitivity analysis is performed on the independent variables of fuel price and discount factor and rankings are computed. The prioritized listing of techniques and technologies are stable when subjected to these sensitivity analyses. And as expected, greater savings are realized when the cost of fuel is higher and/or when the discount factor is lower. For several of the practices in this study, fuel savings are shown to be substantial and worthy for consideration despite any involved risk. These findings may be used by decision makers to pursue further testing and evaluation of practices and subsequently confidently implement throughout the surface fleet, knowing that savings will remain robust despite fluctuations in fuel prices.

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EXECUTIVE SUMMARY

This thesis addresses a request from the Deputy Comptroller, Commander Naval Surface Forces, to conduct an analysis and prepare a brief on potential ship fuel efficiencies. This study's purpose is to collect and examine current technological initiatives and policy-based techniques for assessing fuel-saving practices in the U.S. Navy surface fleet.

The U.S. Department of Defense and Navy are placing a greater emphasis in energy efficiency. Though the surface fleet comprises only a small percentage of petroleum usage, seemingly small efficiencies gained could yield substantial fuel savings. This thesis follows a process of researching and collecting fuel-saving ideas, developing a method to estimate savings, subjecting calculations to sensitivity analyses by discount factor and cost of fuel, and creating prioritization listings of ideas based on predicted savings. Figure 1 is a flow chart of the process:

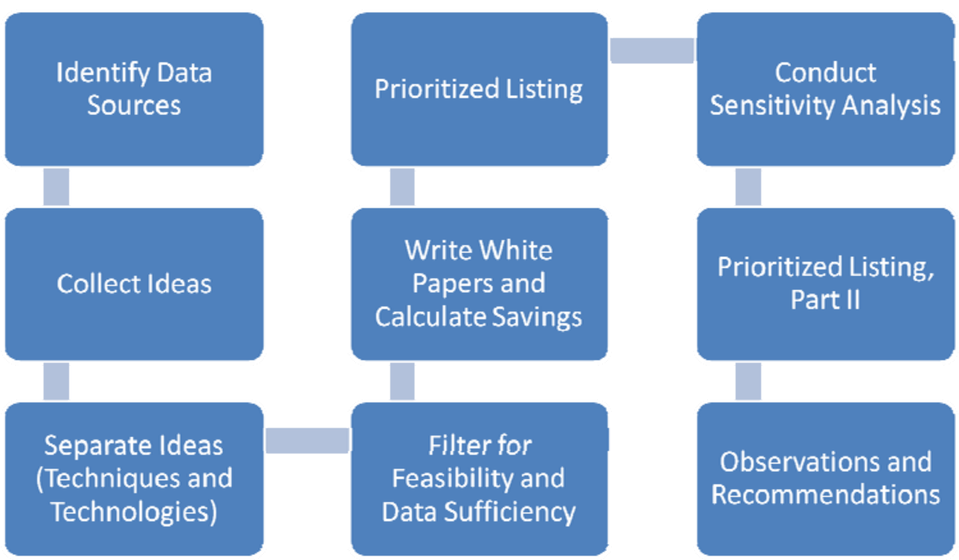

Figure 1. Thesis Flow Chart

Six technique-based and twelve technology-based initiatives are examined. Calculations are estimated for each idea using inputs from various sources. Sensitivity analysis is performed on the independent variables of fuel price and discount factor and rankings are computed. An example of the results are shown in Table 1.

At $50/barrel				
Technique	Savings/yr/ship ($K)	Savings/yr/SD Fleet ($K)	10-yr Savings at 0% disc ($K)	10-yr Savings at 5% disc ($K)
Single Generator Ops	440	4,845	48,448	37,410
Plant Status	22	460	4,600	3,552
Prairie Masker Air	19	394	3,943	3,045
Duty Radar	6	128	1,278	986
Flexible OPAREA	3	69	695	536
Auto-Pilot	3	43	430	332

Table 1. Technique Rankings at $50/barrel

10-yr ROI at 0%	10-yr ROI at 5%	10-yr Savings at 0%	10-yr Savings at 5%	Savings/yr/ship
D) Trim Loop	D) Trim Loop	G) Common Rail	G) Common Rail	G) Common Rail
A) Water Wash	A) Water Wash	B) Hull Coating	B) Hull Coating	J) Steering & Stability
C) Prop Coating	E) Hull Assessment	A) Water Wash	A) Water Wash	H) LHD Stern Flap
E) Hull Assessment	C) Prop Coating	K) Cooling Fan	K) Cooling Fan	F) Solid State Lighting
F) Solid State Lighting	F) Solid State Lighting	E) Hull Assessment	E) Hull Assessment	D) Trim Loop
H) LHD Stern Flap	H) LHD Stern Flap	F) Solid State Lighting	F) Solid State Lighting	I) LSD Stern Flap
B) Hull Coating	B) Hull Coating	J) Steering & Stability	J) Steering & Stability	C) Prop Coating
J) Steering & Stability	J) Steering & Stability	I) LSD Stern Flap	I) LSD Stern Flap	B) Hull Coating
I) LSD Stern Flap	I) LSD Stern Flap	H) LHD Stern Flap	H) LHD Stern Flap	K) Cooling Fan
G) Common Rail	G) Common Rail	D) Trim Loop	D) Trim Loop	E) Hull Assessment
K) Cooling Fan	K) Cooling Fan	C) Prop Coating	C) Prop Coating	A) Water Wash
L) Reverse Osmosis	L) Reverse Osmosis	L) Reverse Osmosis	L) Reverse Osmosis	L) Reverse Osmosis

Table 2. Technology Rankings at $200/barrel

The prioritized listing of techniques and technologies are stable when subjected to these sensitivity analyses. And, as expected, greater savings are realized when the cost of fuel is higher and/or when the discount factor is lower. For several of the practices in this study, fuel savings are shown to be substantial and worthy for consideration despite any involved risk.

These findings may be used by decision makers to pursue further testing and evaluation of practices and subsequently confidently implement throughout the surface fleet, knowing that savings will remain robust despite fluctuations in fuel prices.

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Much gratitude goes to CAPT(ret) Jeffrey E. Kline, USN, my second reader and who contributed great ideas to this study. His knowledge and experiences as a Surface Warfare Officer and Campaign Analyst lent valuable subject matter expertise.

This thesis would not have been possible if not for the effort and support from my sponsors at Commander Naval Surface Forces, Comptroller. This great team included CAPT Brian T. Drapp, SC, USN, CDR Robert K. DeGuzman, SC, USN, CAPT(ret) Julie E. Webb, SC, USN, and Mr. Albert F. Pena.

Without CDR(ret) Kevin J. Maher, SC, USN, a mentor and provider of encouragement, my time in the Operations Research program would have been short-lived.

I thank my NPS shipmates, whether they be fellow students or staff members. Your friendship during this challenging tour will never be forgotten.

Most importantly, I would like to thank my family and friends for their constant support and inspiration. You are the real reason why I proudly continue to serve. Thank you all very much.

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I. INTRODUCTION

A. OBJECTIVES

This study's purpose is to collect and examine current technological initiatives and policy-based techniques for assessing fuel-saving practices in the U.S. Navy surface fleet. The ability to analyze these ideas will benefit decision makers in several ways:

- Improved predictions of savings, leading to better budgeting and resource planning.
- Enhanced ability to rank each technology and technique against each other, allowing for quick identification of the most promising ideas for resourcing and implementing.
- Better knowledge of factors that drive fuel-saving estimates, giving managers more information in anticipating costs.

B. BACKGROUND AND MOTIVATION

During the Surface Navy Association's annual symposium in January 2009, Chief of Naval Operations (CNO) ADM Gary Roughead stressed the need for the Navy to put its maximum effort toward making its ships as efficient as possible, to get ahead of another potential spike in fuel costs and amidst the financial crisis which could bring about cuts on funding from Congress (Ewing, 2009).

The fuel spikes are illustrated in Figure 2 when the price per barrel of Diesel Fuel Marine (DFM) started at $35.28 in FY04, rose to $106.26 in FY06, and climbed to $170.53 in Quarter 1 of FY09.

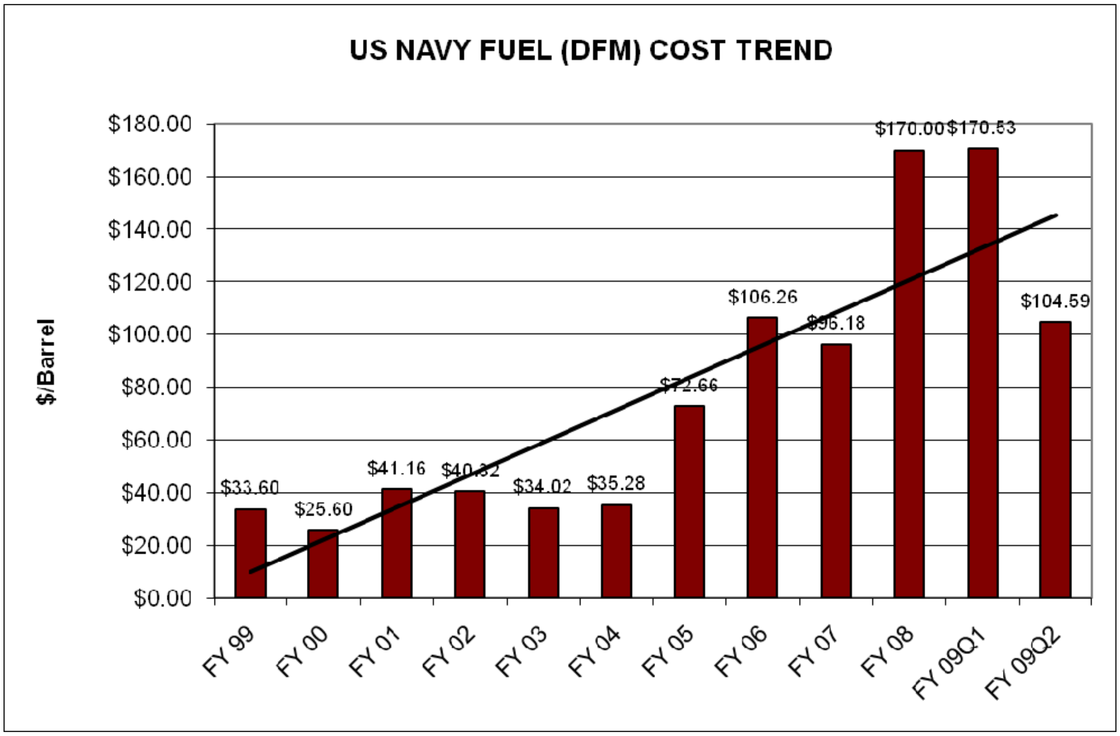

Figure 2. U.S. Navy Fuel Cost Trend [From Pehlivan, 2009].

In the CNO Guidance for 2010, released 3 September 2009, ADM Roughead outlines his vision, mission, principles, and intentions. In his top intention, "Continue to be the most dominant, ready, and influential naval force, globally and across all naval missions," he reemphasizes the commitment needed to meet the challenges the Navy faces in the future. The way ahead includes this focus: "We will increase our energy security by reducing our reliance on oil and improving the resilience of our shore energy sources. We will implement current technologies that increase our use of alternative fuels and spearhead new and innovative solutions to our future operational energy needs" (CNO, 2009, pp. 4-5).

The Department of Defense (DoD) recognized the need to conserve fuel years ago and directed various entities to conduct studies in order to better understand how to accomplish this task.

Dr. Amory Lovins, the director of the Rocky Mountain Institute (RMI), published an article called "All Energy Experts On Deck!" in the RMI Solutions

Newsletter in Fall 2001. It described the results of a study he conducted onboard USS PRINCETON (CG-59). He previously estimated that as much as 30% of the Navy's DFM fuel was used to generate power for the ship's non-propulsion energy systems such as lights, air conditioning, computers, water purifiers, etc. Naval Sea Systems Command's (NAVSEA's) engineers approximated that 19 percent could be saved on ships of this class. The results of his analysis indicated that hotel loads on Aegis cruisers could be substantially reduced. The RMI team found that retrofitting motors, pumps, fans, chillers, lights, and potable water systems could save an estimated 20–50 percent of the ship's electricity (with significant further opportunities still to be assessed). That could cut total fuel use by an estimated 10–25 percent. Additionally, many of the savings opportunities were purely operational, requiring little or no investment (Lovins, 2001).

The Under Secretary of Defense (Acquisition, Technology and Logistics), recognizing the crucial importance of weapons platform fuel usage to U.S. military capability, requested that the Defense Science Board (DSB) form a task force on Improving Fuel Efficiency of Weapons Platforms. Asked to consider existing or emerging technologies that could significantly improve platform efficiency, the task force also examined institutional barriers that exist and must be overcome to understand and capture the full advantages of more efficient military systems. According to this 2001 report:

> The United States uses more petroleum each year than the next five largest consuming nations combined. Military fuel consumption for aircraft, ships, ground vehicles and facilities makes the DoD the single largest consumer of petroleum in America, perhaps in the world.
>
> Considering this large and costly fuel usage, it would seem logical for the DoD to instinctively strive for continuous improvement in the fuel efficiency of all its platforms and forces. Similarly, a high and visible DoD priority would be to improve fuel efficiency to enhance platform performance, reduce the size of the fuel logistics system,

reduce the burden high fuel consumption places on agility, reduce operating costs, and dampen the budget impact from volatile oil prices.

To achieve these goals, future Science & Technology investments would focus more on fuel efficiency; cost-benefit decisions based on the true cost of fuel; and modern, near-real-time modeling tools concerning fuel efficiency choices would aid decision makers in the requirements determination, acquisition and war-gaming communities. Strong incentives would then encourage operators to reduce consumption while still maintaining readiness; the requirements process would demand fuel efficiency in platforms; the acquisition system would produce more efficient platforms and systems; and senior civilian and military leadership would trumpet the huge advantages of efficiency to combat capability.

Unfortunately, none of these priorities, tools or incentives are in evidence today. (DSB, 2001, p. ES-1)

Five years later, the DoD has made considerable progress. In May 2006, the Secretary of Defense commissioned the Director, Defense Research and Engineering to chair the Energy Security Task Force (ESTF) to define an actionable investment roadmap for lowering DoD’s fossil fuel requirements and developing alternate fuels for use. The ESTF is comprised of senior leaders from across the DoD with a stake in energy, including requirements development, technology, acquisition, logistics, installations and environment, policy, and the budget. The Secretary of Defense designated energy initiatives as one of the Department’s Top 25 Transformational Priorities, and military departments have established energy leads and task forces, responsible for overseeing all energy efforts (DoD Energy Security Task Force, 2009).

At the end of 2008, Naval Task Force Energy was stood up to be responsible for developing and implementing a comprehensive energy strategy for the Navy and Marine Corps. According to Public Affairs Officer LT Clayton Doss, the Navy is developing an energy strategy “that emphasizes energy security, energy efficiency and environmental stewardship" and "that recognizes energy transformation is a national priority and enables continued mission accomplishment." Furthermore, strategy aspects will include resource protection and conservation, increased efficiency and decreasing demand of non-renewable fossil fuels (Gordon, 2008).

Prior studies were reviewed, such as the Congressional Research Service (CRS) report in December 2006 which examined ship propulsion technologies and options for reducing oil use. Its basis is testimony prepared for a hearing on alternative Navy ship propulsion technologies held in April 2006, before the Projection Forces Subcommittee of the House Armed Services Committee, which granted permission for the testimony to be converted into the CRS report.

Notable excerpts from the CRS include the following:

- FY2007 Defense Authorization Act (H.R. 5122/P.L. 109-364). Section 128 of P.L. 109-364 (conference report H.Rept. 109-702 of September 29, 2006) expresses the sense of the Congress that the Navy should make greater use of alternative technologies, including expanded application of integrated power systems, fuel cells, and nuclear power, for propulsion of future major surface combatant ships. The report directs the Navy to include integrated power systems, fuel cells, and nuclear power as propulsion alternatives to be evaluated within the analysis of alternatives for future major surface combatant ships. Section 360 makes it Department of Defense (DoD) policy to improve the fuel efficiency of weapons platforms, consistent with mission requirements, and requires a report on DoD progress in implementing the policy (O’Rourke, 2006, Summary section).
- The Department of Defense (DoD) testified in September 2006 that its energy use represents about 1.2% of total U.S. energy use, and that DoD in FY2005 consumed roughly 125 million barrels of oil. Of total DoD energy use, DoD testified, mobility fuels for aircraft, ships, and vehicles account for about 74%. Jet fuel, used not only by aircraft, but also by tanks, other ground vehicles, and electrical generators,

accounts for 58% of DoD's consumption, DoD testified, while marine diesel fuel accounts for 13% (O'Rourke, 2006, p. CRS-1).

- The Navy stated in October 2006 that it uses about 41 million barrels of oil per year for all purposes (about 33% of the above-mentioned DoD figure of 125 million barrels in FY2005), and that in FY2005, the Navy spent $900 million for fuel for its ships and aircraft, or about 32% of the DoD total of $2.83 billion for that year (O'Rourke, 2006, p. CRS-2).

The figures and proportions listed in the 2001 DSB report and in the 2006 CRS report are consistent with more recent ones:

According to the DoD Annual Energy Report for FY06, the DoD consumed 1.2% of U.S. consumption, with marine diesel accounting for 12% of that figure.

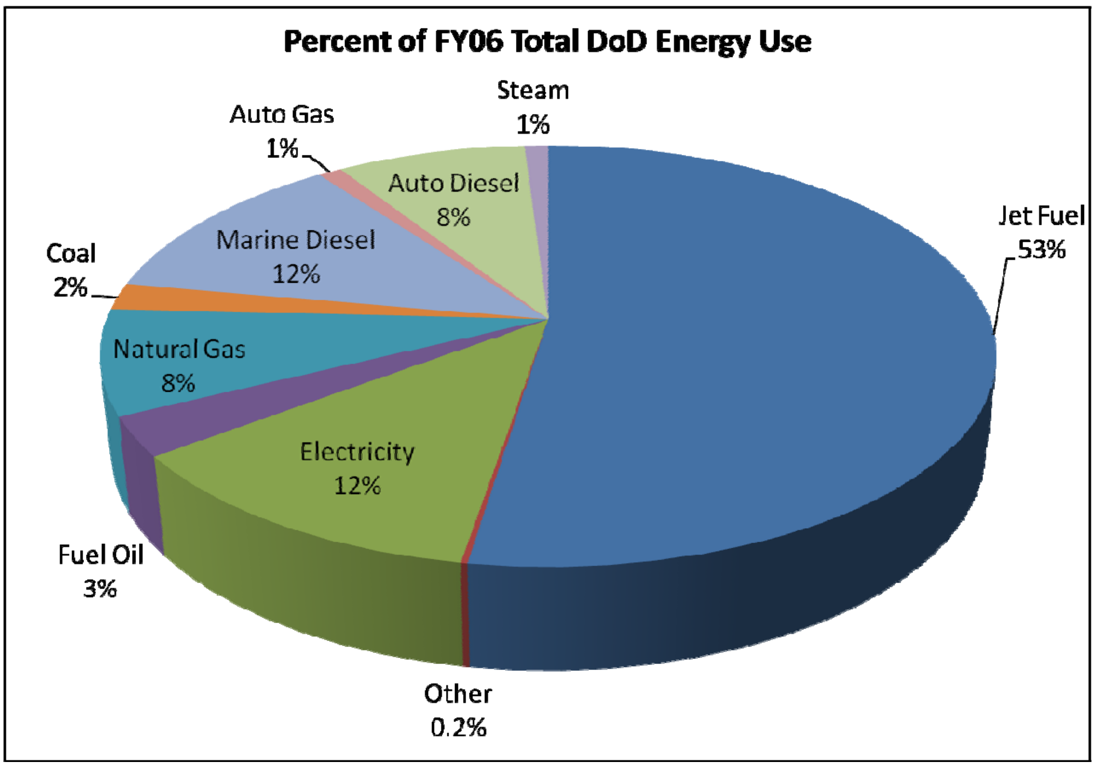

Figure 3. FY06 DoD Energy Consumption [After DSB Task Force, 2008].

The DoD Energy Security Task Force reported that for FY07, within DoD, marine diesel accounted for 11%.

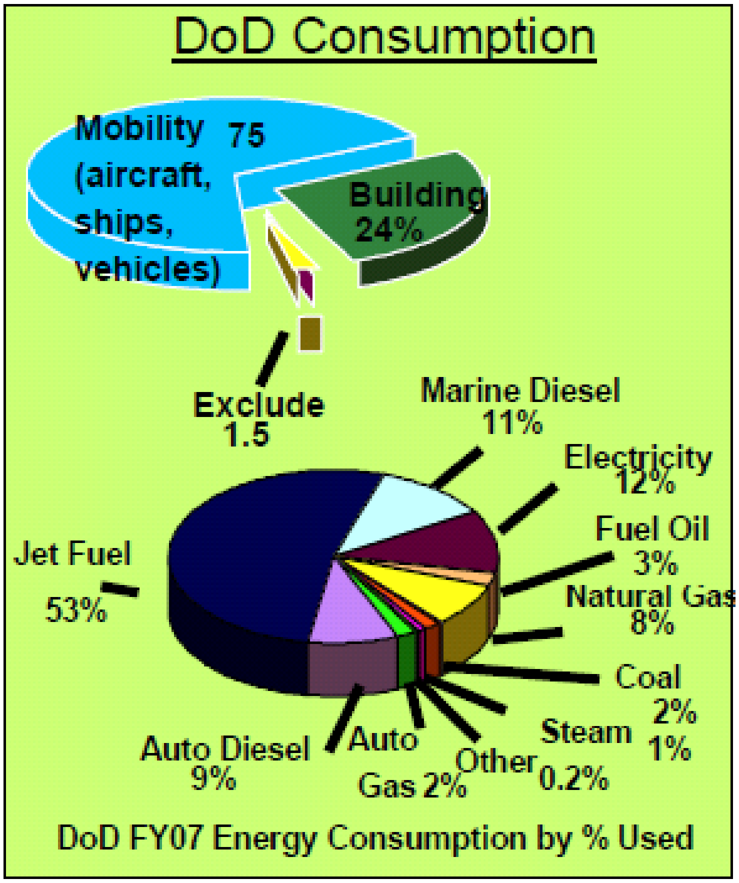

Figure 4. FY07 DoD Energy Consumption [From DoD Energy Security Task Force, retrieved 2009].

Navy Energy Perspectives Brief in June 2009 stated that in FY08, 34% of DoD Petroleum usage was attributed to the Navy, 40% of which was for maritime forces, with 54% of which was for surface combatants and 21% for amphibious ships.

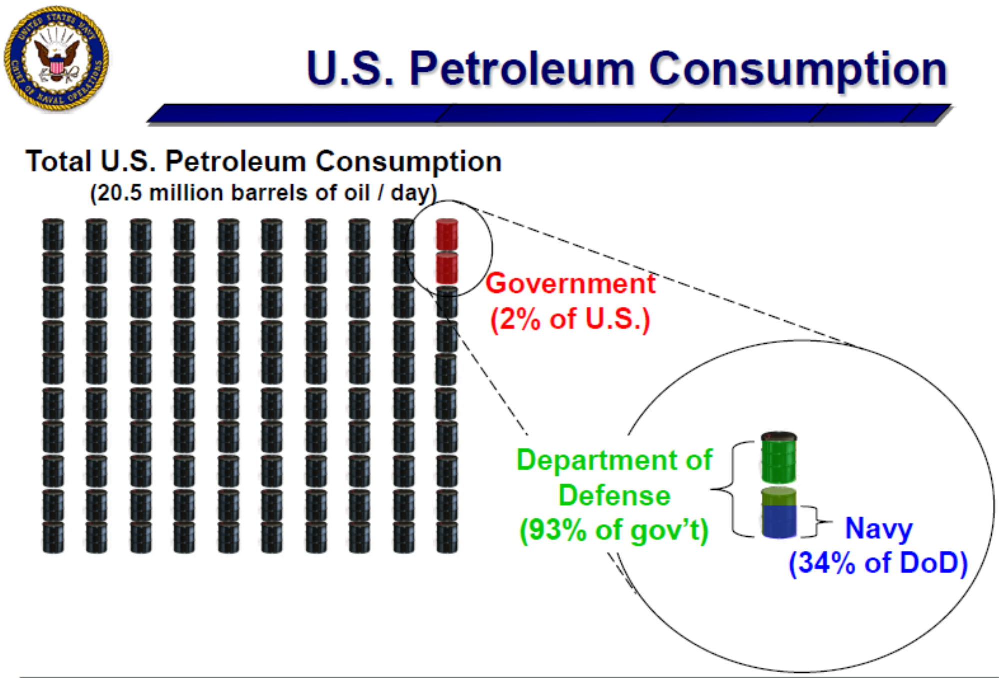

Figure 5. FY08 Navy Energy Sources and Consumption [From Navy Energy Perspectives, 2009].

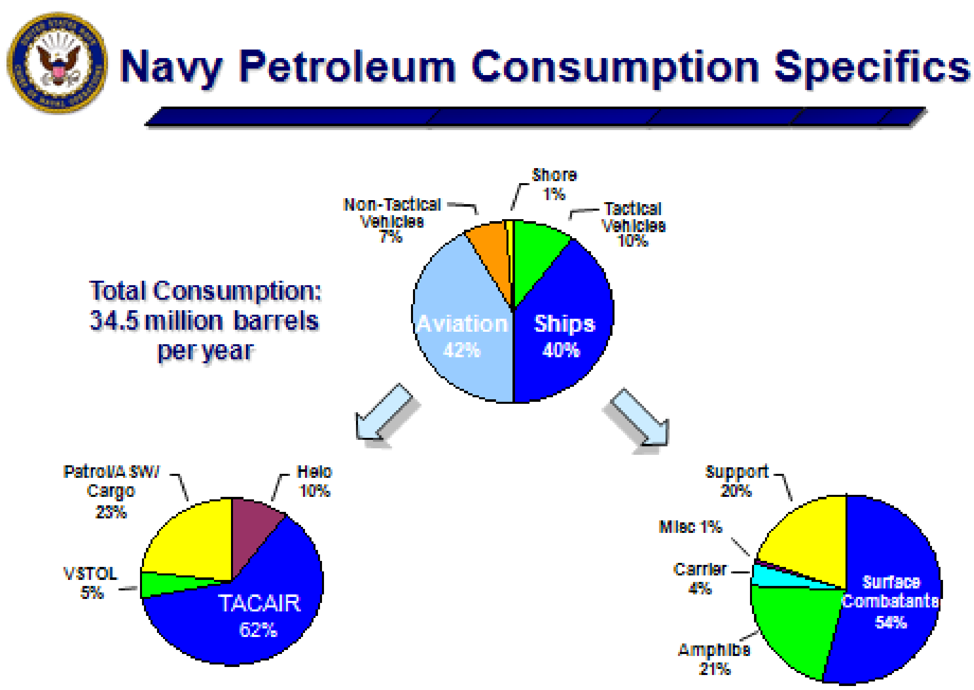

Figure 6. FY08 Navy Petroleum Consumption Specifics [From Navy Energy Perspectives, 2009].

A June 2009 Navy Energy Brief put out that FY07 Ship Fuel Usage accounted for 11.9 million barrels, guided missile cruisers and destroyers were responsible for 18% and 40%, respectively.

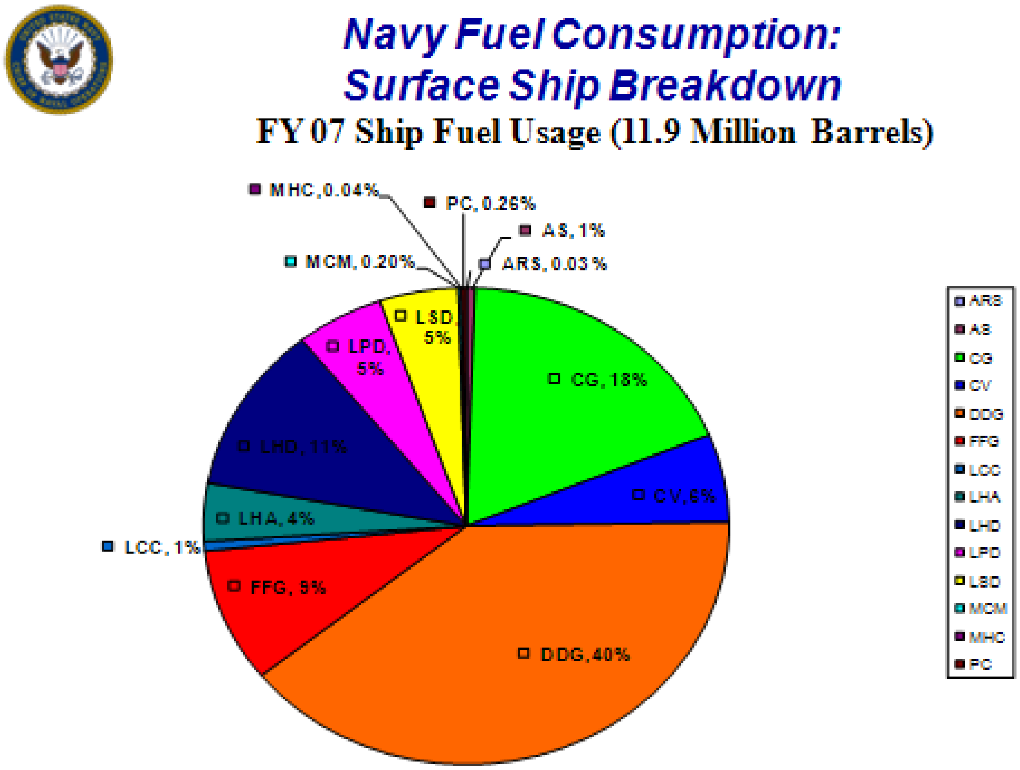

Figure 7. FY07 Navy Fuel Consumption: Surface Ship Breakdown [From Navy Energy Conservation, 2008].

A number of current practices, researched proposals, and general ideas could make a positive impact in the effort to save fuel. In July 2007, NPS Operations Research faculty published “Steaming on Convex Hulls,” a paper on optimizing ship’s fuel usage by mixing transit speeds and plant configurations during independent steaming operations (Brown, Kline, Rosenthal, & Washburn, 2007). Current and former Commanding Officers and Chief Engineers on ships, as well as experts in the field, have ideas waiting to be explored.

Initiatives such as Naval Sea Systems Command’s (NAVSEA) Incentivized Energy Conservation (i-ENCON) program, employ a number of specific fuel-saving procedures that the surface fleet can implement immediately. Representatives of the i-ENCON program routinely meet with ship operators to review specific fuel-saving operational procedures. Committed to reducing ships' energy consumption by 10 percent each year, i-ENCON provides ships' commanding officers and chief engineers energy-saving strategies and techniques along with consumption-reducing procedures and operations modifications. The i-ENCON team's training and awareness program includes videos, packet hooks and specialized software (NAVSEA, 2008). i-ENCON distributes quarterly fuel usage reports that detail the energy consumption of surface ships, and the leading fuel conservers among underway surface ships receive special recognition and cash incentives upwards of $90,000. On average, 100 ships qualify for cash awards each quarter, which go to commanding officers' discretionary funds (Pehlivan, 2009).

NAVSEA’s Fleet Readiness, Research and Development Program (FRR&DP) is designed to find long-term fuel reduction solutions to meet mission requirements despite fluctuating fuel prices. The FRR&DP program, initiated in October 2007, examines new technologies that may offer significantly reduced fuel consumption (Kristiansen, 2009).

As recently as January 2009, Commander, U.S. Pacific Fleet (COMPACFLT) took measures to decrease fuel usage of its units. The message stated: “Baseline and supplemental relief for FY09 will be significantly less than originally projected. As a result, fuel allocations for Feb thru Sep must be reduced by $30M, which has been applied to C7F and C3F ops” (COMPACFLT, 2009).

In order to plan for the reduced fuel allocations, numbered fleet commanders were instructed to submit fuel mitigation plans by the beginning of February 2009. Commander, Third Fleet (COMTHIRDFLT) felt the impact most, having to cut back on $23M of the $30M total. In a June 2009 e-mail message to the author from CAPT(ret) Julie Webb, SC, USN, COMTHIRDFLT calculated that approximately 400 days of underway time needed to be shaved from their fleet.

By canceling traditional public relations events, canceling non-transit port visits, reducing the number of ships or time involved in various evolutions, accounting for a 5% reduction in quarterly fuel allocation, and estimating a 10% reduction in the daily standard burn rate for all ships, COMTHIRDFLT planned for a total of 389 underway days saved. For the average guided missile destroyer (DDG) in this fleet, this meant it was allowed only 14 underway days a quarter, a large decrease from the 23 days previous to COMPACFLT orders.

Clearly, energy is a hot topic within the DoD, and especially fuel for Navy ships. It is so relevant that Commander, Naval Surface Forces (CNSF) is sponsoring this thesis to pull additional ideas together and analyze how we value our fuel-saving technologies and techniques.

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II. DATA COLLECTION AND METHODOLOGY

A. OVERALL FLOW

Figure 8 gives an overview of the thesis methodology.

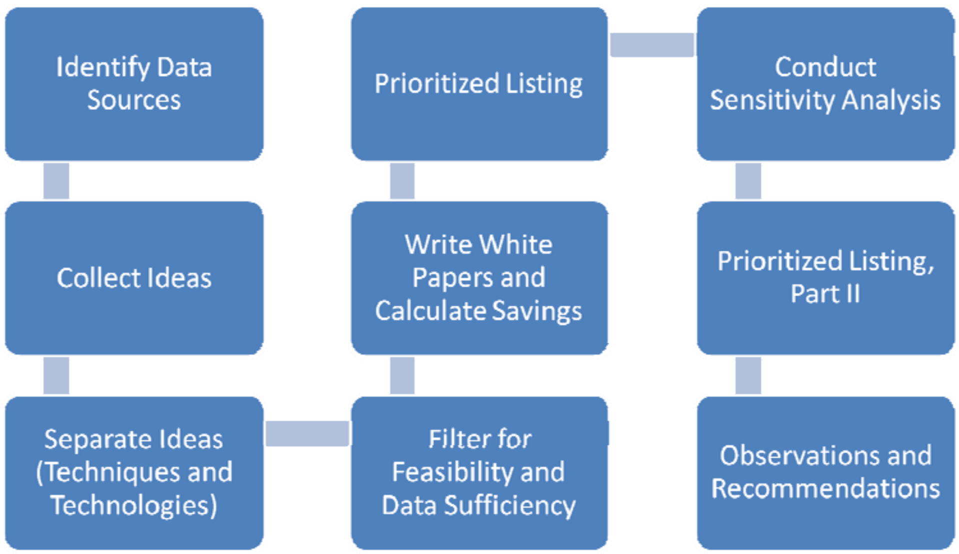

Figure 8. Thesis Flow Chart

The subsequent paragraphs provide detailed explanation of each step in the flow chart above.

B. DATA SOURCES

1. i-ENCON

The Incentivized Energy Conservation (i-ENCON) program was designed for all non-nuclear surface ships that routinely report monthly via Navy Energy Usage Reporting Systems (NEURS) messages. The program's purpose is for ships to operate in the most efficient manner while conducting their assigned mission. Some missions will demand ships over burn fuel allocation compared to their class average. However, there will be ships that have opportunities to apply i-ENCON strategies and practices to be efficient, i.e., those that are in the Fleet Response Training Plan (FRTP) cycle. When these ships under burn, the resulting fuel will offset ships that over burn. i-ENCON rewards under burning ships with cash incentives to their Operating Target (OPTAR).

From the NEURS reports, i-ENCON managers compile a vast amount of fuel data each year from each ship which measure hours underway (UW), hours auxiliary steaming, barrels consumed, barrel consumed per hour, class averages, and percentage of over burn and under burn compared to the class average. Those figures are inputted into a formula to calculate which ships performed most efficiently and deserve cash rewards. To compare ships of different classes and missions, the factors of displacement, shaft horsepower, and crew size are taken into consideration.

2. Fleet Readiness, Research and Development Program (FRR&DP)

Fleet Readiness, Research and Development Program examines near term technology system and components from the government, industry, and academia. All projects are designed where energy conservation and maintenance savings are the main goals, while not adversely impacting other ship systems. Project proposals are developed with known facts so that return on investment (ROI) calculations can be performed for both development and implementations costs.

The FY09 full program contains proposals on twelve initiatives, each of which contain project explanation, as well as the investment profiles with the cost calculations. These profiles made up the technology half of the data for this thesis. White papers and profiles are included in the appendices.

3. CNSF Fleet Interviews

As sponsors of this thesis, Commander, Naval Surface Forces (CNSF), Comptroller, organized interviews with Commanding Officers (COs) and Chief Engineers (CHENGs) of various San Diego-based surface ships. Through personal interaction with the current operators and war-fighters, the most up to date and accurate data and ideas were gained.

C. COLLECTION OF IDEAS

Over a span of three days in March 2009, CNSF Comptroller arranged for interviews with five different San Diego-based commands: USS JOHN PAUL JONES (DDG 53), USS PINCKNEY (DDG 91), USS RENTZ (FFG 46), CGRON HQ, and USS CURTS (FFG 38).

Among the questions asked to COs and CHENGs :

What are your top fuel-saving initiatives onboard? What factor limits fuel-savings most: technology, policy, orders, or other? How important is fuel efficiency to a ship CO or CHENG compared to drills/training? Is it something often taken into consideration during normal steaming? Is awareness of fuel efficiency written into the Night Orders? Are TYCOM-regulated ENCON awards enough to motivate better use of fuel?

All ships responded to being fuel-conscious whenever possible. However, it appeared that there were not many opportunities to save. Most expressed desire to have greater control of their fuel allocation, but the operational condition and general policy made that challenging. The general consensus was if more flexibility was allowed, more fuel could be saved.

Further complicating the situation was the recent policy change of decreasing underway days as directed by COMPACFLT and COMTHIRDFLT. With this plan in effect, COs will be giving less attention to fuel saving because the training and readiness of the crew was a greater priority.

However, several fuel-saving ideas were submitted for review. Many are already in practice but no studies have been conducted which estimate or measure the amount of fuel and money saved.

Concurrently, as a supplement to the Fleet interviews, e-mails and phone calls to various SMEs were sent to glean ideas. SMEs included former and future ship COs , Executive Officers, and CHENGs , and current engineers or program officers from NAVSEA and Military Sealift Command.

D. SEPARATE IDEAS

During the collection period, it became quite clear that the ideas were falling into two separate categories: techniques and technologies. In saving fuel, the Navy could either improve the equipment used or change the way it uses its current equipment. To be clear, the ideas are separated into the following characteristics:

Technique: Increased energy efficiency via adjustments of policy or direction of the methods or practices of existing ship system.

Technology: Increased energy efficiency (and maintenance savings) in the ship systems or components to include hull hydrodynamics, propulsion, thermal management, power generation and storage, underwater hull husbandry, electrical systems, and auxiliary systems.

By distinguishing the ideas, better comparisons are achieved based on their origin and implementation.

E. FILTER IDEAS

With the data sources identified, subsequent suggestions collected and sorted, the ideas are filtered for practicality and feasibility. In addition, an emphasis is put on a shorter range in order for reasonable development and implementation calculations. As such, legitimate but far from developed proposals such as sail or nuclear technology are not considered

Since each FRR&DP initiative had already been through a rigorous process of research and review by NAVSEA technical experts, none of these technologies are filtered. In order to qualify, project duration of each proposal could not exceed two years, meeting the near term criteria. In addition, extensive estimates were already available in the investment profiles.

With no previous study or research in regards to fuel estimates, each proposed technique is filtered to check if the practice is feasible and if data could be obtained. Some ideas are too complex to examine in this thesis, mainly due to time constraints and unavailability of subject matter experts to provide data and help formulate the calculations of approximating the fuel saved from each practice. However, if the proper support and data is available, the proposed idea is examined.

Technique ideas filtered out using the criteria above include the following:

- Allow DDGs and CGs to steam independently from the big deck during transit. Independent steaming allows for ships to sail at their best fuel speeds and removes the burden of fuel consuming plane-guard duties when transiting with a CVN or L-Deck.

- Add days to a transit for dedicated flight ops instead of flying during transit. Prevent unnecessary zig-zagging of a single plane-guard ship by spreading out DDGs and CGs in a square or triangle surrounding the big deck.

- Decrease the levels of re-supply trigger points. By lowering the required levels before a ship must refuel, ships can continue their transits further without having to alter course to meet with oilers for refueling.

- Allow COs to manage their own ship's fuel by giving the allotment in barrels vice underway days. By giving ownership to the CO, the ship has incentive to steam smarter in order in increase the number of underway days.

Technique ideas kept using the criteria above include the following:

- Use of Auto-Pilot During Long Transit
- Employ Duty Radar with 2 Aegis Ships
- Allow for a Flexible Third Fleet Operations Area (OPAREA)
- Modify Plant Status During Restricted Maneuvering Doctrine (RMD) Situations
- Reduce Use of Prairie/Masker Air (P/M)
- Practice Single Generator Operations (SGO)

F. WHITE PAPERS AND CALCULATIONS

After the filter process, six techniques and twelve technologies are left standing. A stand-alone paper—a White Paper—was written by the author, describing the background and concepts of each technique or technology, including a rough order of magnitude estimate of potential savings. White papers for techniques are created using knowledge gained from past experience or SME interviews, while white papers for technologies are condensed versions of the existing FRR&DP proposals. All white papers are in the Appendices A and B.

Costs and benefits are estimated for each technique and technology. No data existed for the proposed techniques, so estimates are developed. Inputs are used from fuel consumption tables/curves (see Appendices E and F), and subject matter expert estimations/assumptions of fuel savings percentages, average frequencies, average distances traveled, probability of various ship operations and system configurations. Since all technologies are taken from the existing FRR&DP proposals, those inputs are used in the initial calculations. Note that estimates of FRR&DP initiatives were conducted in either 2008 or 2009, when the price of fuel used was $96.16/barrel and $127.68/barrel, respectively. All data is normalized and adjusted for cost comparisons.

These calculations are located in Appendix C and D, and also are addressed in Chapter III. Assumptions for each calculation (e.g., number of ships affected, transit speeds, time in plant status) are listed in each spreadsheet.

G. PRIORITIZATION LISTING, SENSITIVITY ANALYSIS, AND PRIORITIZATION LISTING PART II

To compare the techniques to one another, or technologies to one another, a prioritization listing is created based on three criteria. An EXCEL-based model is constructed so that rankings could be sorted according to these criteria.

For techniques, the three rankings are

- Savings/year/ship
- Savings/year/SD Fleet
- 10-year savings

For technologies, the three rankings are

- 10-year ROI
- 10-year savings
- Savings/year/ship

Sensitivity analyses are performed to evaluate potential fuel saving for each alternative under varying fuel cost scenarios and to understand the robustness of the rankings. For techniques, a 5% discount factor is applied to 10-year savings and then the cost of fuel is adjusted (originally estimated at $100/barrel) to $50/barrel and $200/barrel. The results for techniques are in Chapter III.

Similarly, sensitivity analyses are performed for the technologies. A 5% discount factor is applied to the 10-year ROI, a 5% discount factor is applied to

10-year savings, and then the cost of fuel is adjusted (originally estimated at $100/barrel) to $50/barrel and $200/barrel. The results for technologies are in Chapter III.

Return on Investment (ROI) is a financial metric commonly used to evaluate the efficiency of an investment or to compare the efficiency of a number of different investments. It is a popular metric because of its simplicity, ease of use, and versatility. ROI works well in situations where both the benefits and costs of an investment are known and where they both clearly result from the proposed investment. Additionally, ROI blends all the ingredients of profitability – revenues, costs, and investment, into a single percentage. Note though that the metric itself does not speak to the magnitude of returns or the risks involved. To calculate ROI, the income from an investment is divided by the investment (Horngren, Datar, and Foster, 2006, p. 793). In this case, fuel savings are equivalent to income, and the Net Present Value (NPV) savings and NPV investment are used. The ROI formula according to Horngren, Datar, and Foster, 2006 (p. 793), where both Income and Investment are NPVs:

$$\mathbf{ROI} = \frac{\mathbf{Income}}{\mathbf{Investment}}$$

Figure 9. ROI Formula [From Horngren, Datar, and Foster, 2006]

The techniques under consideration have either no or negligible investment costs. Therefore, ROI rankings are applied only to technologies.

From the formula in Figure 9, one can improve ROI by reducing costs, increasing gains, or accelerating benefits. Longer or shorter time periods may produce different ROI results for the same investment.

In this thesis, a ten-year timeframe, with NPVs, is examined. To do this, a discount factor is applied to each year’s predicted cost (investment and savings). According to Gibson, Scherer, and Gibson (2007), the future value of an investment is found using this equation,

$$F = P[(1+i)^n]$$

Figure 10. Future Value Formula [From Gibson, Scherer, and Gibson, 2007]

where F represents future value, P represents present value, i represents interest rate per period, and n represents number of periods (pp. 96-97). If one knows the future value, the present value is derived using the following equation:

$$P = \frac{F}{(1+i)^n}$$

Figure 11. Present Value Formula

As stated earlier, the interest rate period or discount factor is adjusted during sensitivity analysis to learn if it makes an impact on the prioritization of ideas.

H. OBSERVATIONS AND RECOMMENDATIONS

Observations are made after the first set of prioritization results and then the second time around after conducting sensitivity analysis. The outcome and explanation of the analysis then lead to conclusions and recommendations regarding fuel-savings ideas.

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III. ANALYSIS

A. PRIORITIZATION LISTING

1. Initial Results for Techniques

Initial calculations are estimated for every technique. For the full set, see Appendix C.

Based on the calculations, prioritization listings are developed for three initial metrics at the base cost of $100/barrel:

- Savings/year/ship
- Savings/year/SD Fleet
- 10-Year Savings at 0% discount

The results are in Table 3. Note that prioritization remained the same each time. For background info on the techniques, Appendix A contains white papers with more detailed explanations.

At $100/barrel			
Technique	Savings/yr/ship ($K)	Savings/yr/SD Fleet ($K)	10-yr Savings at 0% disc ($K)
Practice Single Generator Ops	881	9,690	96,895
Modify Plant Status During RMD	44	920	9,200
Reduce Use of Prairie/Masker Air	38	789	7,886
Employ Duty Radar w/ 2 Aegis Ships	12	256	2,555
Allow for a Flexible C3F OPAREA	7	139	1,389
Use Auto-Pilot During Long Transit	6	86	860

Table 3. Initial Results for Techniques

2. Initial Results for Technologies

Initial calculations are estimated for each technology. For the full set, see Appendix D.

Based on the calculations, prioritization listings are developed for three initial metrics at the base cost of $100/barrel:

- 10-Year ROI at 0% discount
- 10-Year Savings at 0% discount
- Savings/year/ship

The results are in Table 4. For background info on the technologies, the Appendix contains white papers with detailed explanations.

10-yr ROI at 0%	10-yr Savings at 0%	Savings/yr/ship
D) Trim Loop	G) Common Rail	G) Common Rail
A) Water Wash	B) Hull Coating	J) Steering & Stability
C) Prop Coating	A) Water Wash	H) LHD Stern Flap
E) Hull Assessment	K) Cooling Fan	F) Solid State Lighting
F) Solid State Lighting	E) Hull Assessment	D) Trim Loop
H) LHD Stern Flap	F) Solid State Lighting	I) LSD Stern Flap
B) Hull Coating	J) Steering & Stability	C) Prop Coating
J) Steering & Stability	I) LSD Stern Flap	B) Hull Coating
I) LSD Stern Flap	H) LHD Stern Flap	K) Cooling Fan
G) Common Rail	D) Trim Loop	E) Hull Assessment
K) Cooling Fan	C) Prop Coating	A) Water Wash
L) Reverse Osmosis	L) Reverse Osmosis	L) Reverse Osmosis

Table 4. Initial Results for Technologies

B. SENSITIVITY ANALYSIS

In order to test sensitivities of savings metrics to the input parameters, Table 5 shows the range of values used.

Variable	Low Value	Base Case	High Value
Discount Factor	0%	0%	5%
$/barrel	$50	$100	$200

Table 5. Variables and Range of Sensitivity Analysis

C. PRIORITIZATION LISTING, PART II

1. New Results for Techniques

Using the Sensitivity Analysis table, new calculations are estimated for all the techniques:

- 10-Year Savings at 5% discount
- Cost of fuel at $50/barrel
- Cost of fuel at $200/barrel

Despite these changes, the rankings did not change at all for any combination of conditions. As an example, the results for 10-Year Savings at 5% discount at $50/barrel are shown in the last column of Table 6:

At $50/barrel				
Technique	Savings/yr/ship ($K)	Savings/yr/SD Fleet ($K)	10-yr Savings at 0% disc ($K)	10-yr Savings at 5% disc ($K)
Single Generator Ops	440	4,845	48,448	37,410
Plant Status	22	460	4,600	3,552
Prairie Masker Air	19	394	3,943	3,045
Duty Radar	6	128	1,278	986
Flexible OPAREA	3	69	695	536
Auto-Pilot	3	43	430	332

Table 6. Technique Rankings at $50/barrel

2. New Results for Technologies

Using the Sensitivity Analysis table, new calculations are estimated for all the technologies:

- 10-Year ROI at 5% discount
- 10-Year Savings at 5% discount
- Cost of fuel at $50/barrel
- Cost of fuel at $200/barrel

In Table 7, the initial results (at 0% discount) are listed before the new results for ease of comparison:

10-yr ROI at 0%	10-yr ROI at 5%	10-yr Savings at 0%	10-yr Savings at 5%
D) Trim Loop	D) Trim Loop	G) Common Rail	G) Common Rail
A) Water Wash	A) Water Wash	B) Hull Coating	B) Hull Coating
C) Prop Coating	E) Hull Assessment	A) Water Wash	A) Water Wash
E) Hull Assessment	C) Prop Coating	K) Cooling Fan	K) Cooling Fan
F) Solid State Lighting	F) Solid State Lighting	E) Hull Assessment	E) Hull Assessment
H) LHD Stern Flap	H) LHD Stern Flap	F) Solid State Lighting	F) Solid State Lighting
B) Hull Coating	B) Hull Coating	J) Steering & Stability	J) Steering & Stability
J) Steering & Stability	J) Steering & Stability	I) LSD Stern Flap	I) LSD Stern Flap
I) LSD Stern Flap	I) LSD Stern Flap	H) LHD Stern Flap	H) LHD Stern Flap
G) Common Rail	G) Common Rail	D) Trim Loop	D) Trim Loop
K) Cooling Fan	K) Cooling Fan	C) Prop Coating	C) Prop Coating
L) Reverse Osmosis	L) Reverse Osmosis	L) Reverse Osmosis	L) Reverse Osmosis

Table 7. Results for Technologies after 5% Discount Factor

A slight re-ordering of the rankings occurs for 10-Year ROI when the discount factor increases to 5%. Propeller Coating and Hull Assessment Tool swap positions at third and fourth place.

When recalculating cost of fuel at $50/barrel and $200/barrel, prioritization remained the same. As an example, Table 8 lists the rankings for each condition at $200/barrel (same as for $100/barrel and $50/barrel):

10-yr ROI at 0%	10-yr ROI at 5%	10-yr Savings at 0%	10-yr Savings at 5%	Savings/yr/ship
D) Trim Loop	D) Trim Loop	G) Common Rail	G) Common Rail	G) Common Rail
A) Water Wash	A) Water Wash	B) Hull Coating	B) Hull Coating	J) Steering & Stability
C) Prop Coating	E) Hull Assessment	A) Water Wash	A) Water Wash	H) LHD Stern Flap
E) Hull Assessment	C) Prop Coating	K) Cooling Fan	K) Cooling Fan	F) Solid State Lighting
F) Solid State Lighting	F) Solid State Lighting	E) Hull Assessment	E) Hull Assessment	D) Trim Loop
H) LHD Stern Flap	H) LHD Stern Flap	F) Solid State Lighting	F) Solid State Lighting	I) LSD Stern Flap
B) Hull Coating	B) Hull Coating	J) Steering & Stability	J) Steering & Stability	C) Prop Coating
J) Steering & Stability	J) Steering & Stability	I) LSD Stern Flap	I) LSD Stern Flap	B) Hull Coating
I) LSD Stern Flap	I) LSD Stern Flap	H) LHD Stern Flap	H) LHD Stern Flap	K) Cooling Fan
G) Common Rail	G) Common Rail	D) Trim Loop	D) Trim Loop	E) Hull Assessment
K) Cooling Fan	K) Cooling Fan	C) Prop Coating	C) Prop Coating	A) Water Wash
L) Reverse Osmosis	L) Reverse Osmosis	L) Reverse Osmosis	L) Reverse Osmosis	L) Reverse Osmosis

Table 8. Results for Technologies at $200/barrel

As an example, the following four figures (2 figures for a technique, 2 for a technology) provide graphical displays of the ranges used in Table 3, Variables and Range of Sensitivity Analysis. All other sensitivity analysis graphs can be located in Appendices C and D, Calculations for Techniques and Calculations for Technologies, respectively.

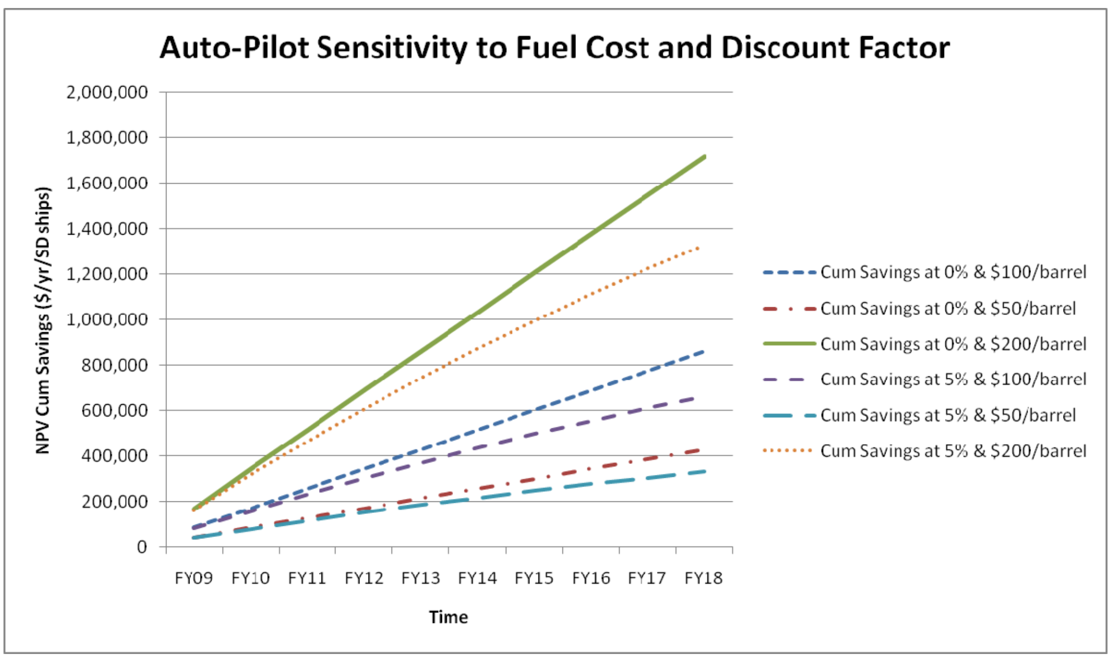

Figure 12. Auto-Pilot Sensitivity to Fuel Cost and Discount Factor

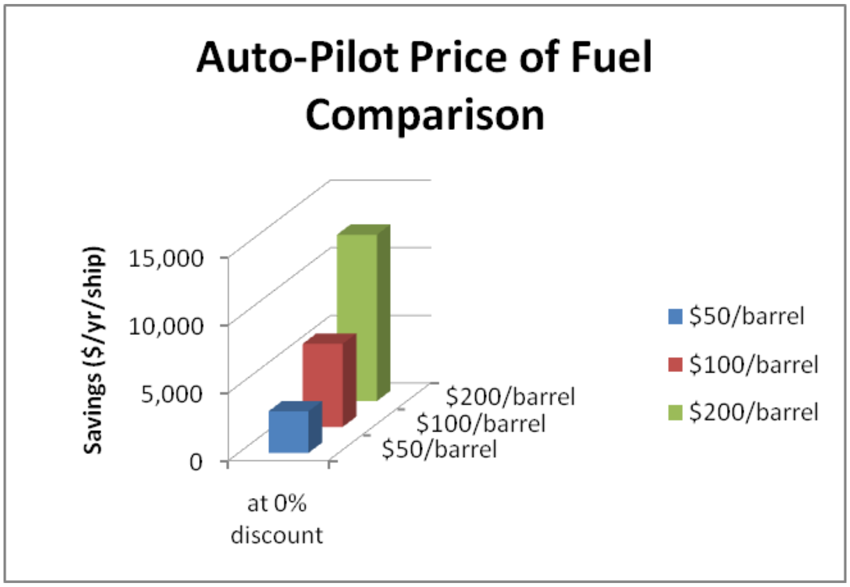

Figure 13. Auto-Pilot Price of Fuel Comparison

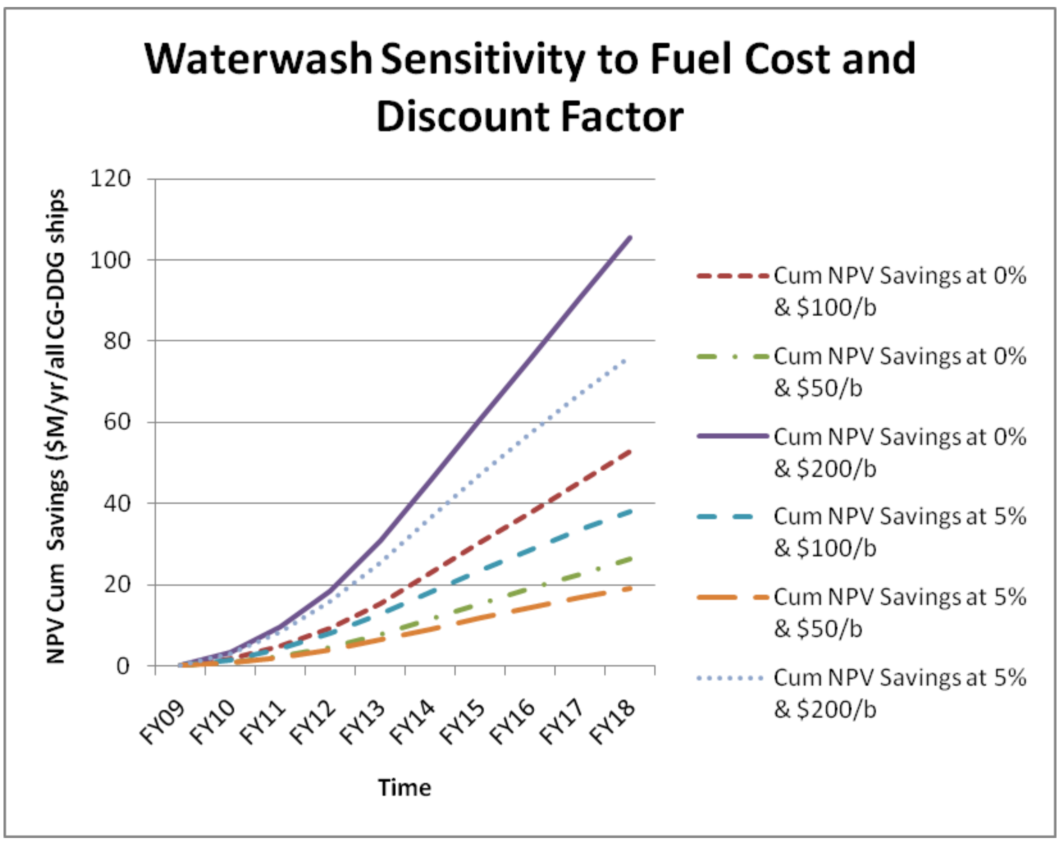

Figure 14. Waterwash Sensitivity to Fuel Cost and Discount Factor

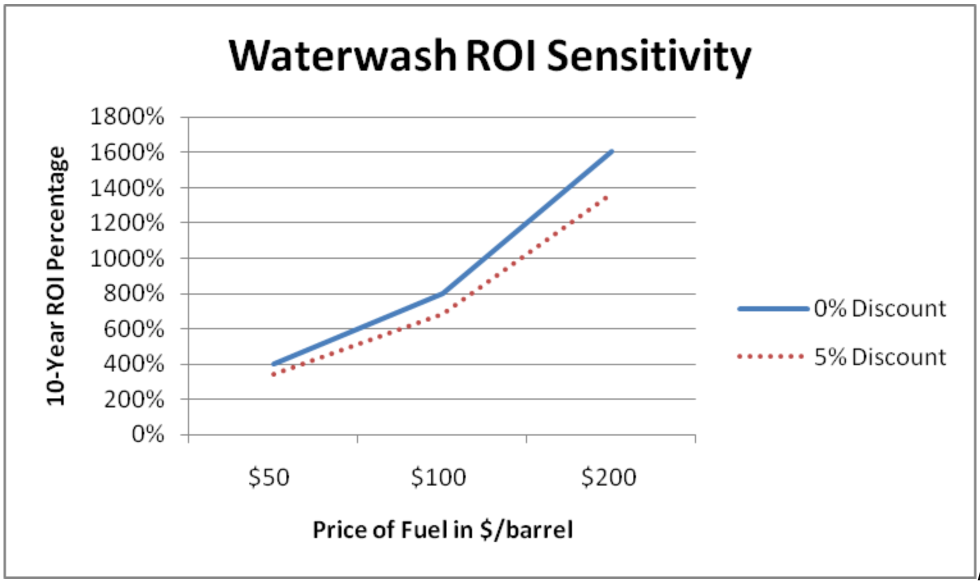

Figure 15. Waterwash ROI Sensitivity

D. OBSERVATIONS

1. Techniques

Summarizing the findings, despite increases in savings discount factor and fluctuations in the cost of fuel, the techniques rankings remained unchanged, although fuel savings naturally vary.

In Figure 12, Auto-Pilot Sensitivity to Fuel Cost and Discount Factor, the picture further verifies what one would expect: when the price of fuel increases, more savings are realized, and when the discount factor increases, savings decrease. In comparing the Cost of Fuel Net Present Value Cumulative Savings at the same cost of fuel, savings were less when the techniques are discounted to 5%. Similar graphs were plotted for each technique ending with the same conclusions as this Auto-Pilot example.

In Figure 13, Auto-Pilot Price of Fuel Comparison, the picture visually confirms what one would expect analytically: when the price of fuel increases, more savings are realized. At $50/barrel, approximately $3,070 is saved per year per ship. When the price quadruples to $200/barrel, the savings also quadruple, to approximately $12,300 per year per ship. Similar graphs were plotted for each technique ending with the same conclusions as this Auto-Pilot example.

2. Technologies

Similar to techniques' insensitivity to the discount factor, despite fluctuations in the cost of fuel, the technologies rankings remain unchanged. Increases in discount factor yielded miniscule rankings change in ROI (swap of Propeller Coating and Hull Assessment Tool), but no deviation in 10-Year Savings.

Similar to Figure 12, Figure 14 shows the Waterwash Sensitivity to Fuel Cost and Discount Factor. The picture visually confirms what one would expect analytically: when the price of fuel increases, more savings are realized. In addition, savings decreased when a higher discount factor is applied to the Cumulative Net Present Value calculations. Similar graphs were plotted for each technology ending with the same conclusions as this Waterwash example.

In Figure 15, Waterwash ROI Sensitivity, the graph visually verifies that ROI percentage increases as the cost of fuel increases, and a higher ROI percentage is realized at the lowest discount factor. Similar graphs were plotted for each technology ending with the same conclusions as this Waterwash example.

Lastly, in referring to Table 8, Results for Technologies at $200/barrel, when comparing 10-Year Savings at the different discount factors, no change was apparent. However, when comparing the 10-Year Savings to Savings/Year/Ship, all rankings changed except for first place (Common Rail) and last place (Reverse Osmosis). A closer look at the calculations reveals that the number of ships impacted determines those winners. In the case of Common

Rail, the first place winner in either situation, having the highest 10-Year Savings along with only a few ships impacted explains why this technology also wins out in Savings/Year/Ship.

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IV. CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

As described in Chapter I, the Department of Defense accounts for only 1.2% of energy consumption in the United States, with the Navy surface fleet representing only 13% of that usage. As recently as FY07, ship fuel usage accounted for 11.9 million barrels, which translates into large amount of fuel and money spent. The Navy has recognized the need to improve its energy efficiency and has implemented a task force as well as several programs to meet those goals. Initiatives that save even a small percentage of fuel onboard a ship could make a great impact over the years, and especially if applied to similar platform types across the Fleet.

This thesis followed the subsequent process:

- Identification of data sources
- Collection of ideas
- Separation of ideas
- Filtering of ideas
- Creation of white papers and calculations
- Prioritization of ideas
- Conducting of sensitivity analysis
- Re-prioritization of ideas
- Conclusions

The analysis showed that the rankings of the ideas are generally unaffected by changes in discount factor and price of fuel. The resulting calculations and graphs verify initial expectations that savings are greatest when the cost of fuel is higher and/or the discount factor is lower. When comparing technologies, the ranking categories (ROI, 10-Year Savings, and Savings/Year/Ship) produced different results. In an ideal situation, the best initiatives will remain near the top of the rankings under each category.

Several attractive fuel savings options currently exist as evidenced by the amount of technologies and techniques examined. The techniques mentioned but not studied in this thesis could prove to yield fuel efficiencies as well. Furthermore, once the ideas are researched and calculations estimated, a process is available to assess and rank order them by a few different categories, all of which are legitimate and recognized methods.

B. STUDY LIMITATIONS

Due to time or data restrictions, the following limitations are listed here:

- Only a 10-year time-frame is examined for the various ideas. Perhaps over a longer period, savings, ROI, and rankings would change.
- Inputs used in the initial calculations for all technologies were based on FRR&DP proposals and investment profiles. FRR&DP data is assumed to be accurate.
- Technique inputs are based on SME opinion. Detailed testing and evaluation would yield more accurate estimates of savings.
- Implementation of some techniques may incur more risk than a ship is willing to assume. No risk analysis is conducted.
- Techniques are limited to CGs and DDGs only. Further savings may be realized if ideas were expanded to other classes of ships.

C. RECOMMENDATIONS

This thesis showed that fuel-saving ideas are robustly attractive and remain so under varying fuel cost scenarios and ROI assumptions. Implement them with confidence. All technologies except for the Cooling Fan and Reverse Osmosis initiatives are already being developed and/or implemented. Continue implementation. There are no (or negligible) investment costs for techniques, but there is inherent risk in all initiatives. Recommend:

- Dedicated research and testing for the top four techniques (Single Generator Operations, Relaxing Plant Status, Reducing use of Prairie/Masker Air, and Duty Radar) to determine more detailed calculations. Conduct risk analysis. Given acceptable risk assumption and further examination still indicates substantial fuel savings, Fleet implementation should follow.
- Study the four filtered ideas (ship fuel allocation, additional days to big deck flight ops transit, allow CRUDES to independently steam from the big deck, and adjustment of re-supply trigger points) to determine detailed calculations of fuel savings. Possible risk analysis and implementation to follow.

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APPENDIX A: WHITE PAPERS FOR TECHNIQUES

SHORT TITLE:

Auto-Pilot for DDGs on Long Transits

DESCRIPTION (by the author)**:**

No information is provided by SMEs . Comparable to “cruise control” for cars. Bridge team enters in course and speed. Engines and rudders self correct based on set and drift of the environment.

A claim was made that fuel could be saved by DDGs if the auto-pilot was utilized. Few ships have put it in use citing training needs, surrounding conditions (traffic), little to no opportunity, and negligible fuel savings.

ESTIMATED SAVINGS:

Unknown.

SHORT TITLE:

Duty Radar Ship

DESCRIPTION (by the author)**:**

The Aegis Combat System is controlled by an advanced, automatic detect-and-track, multi-function three-dimensional passive electronically scanned array radar, the AN/SPY-1. Known as "the Shield of the Fleet", the SPY high-powered (four megawatt) radar is able to perform search, tracking, and missile guidance functions simultaneously with a track capacity of well over 100 targets at more than 100 nautical miles (190 km).

The use of the Aegis system uses more power, and thus more fuel, when in operation than when secured. If two or more Aegis ships are transiting or working together in close proximity, a simple idea to save more fuel would be the assignment of a duty radar ship. So long as the ships are not in a war-time environment, little risk as taken if one ship is responsible for tracking the airspace around the group. This thesis examines the case where only two Aegis ships are transiting together.

ESTIMATED SAVINGS:

Unknown.

SHORT TITLE:

Flexible C3F OPAREAs

DESCRIPTION (by the author)**:**

Currently, ships stationed in San Diego are sent up the California coast to the waters surrounding San Clemente Island as the operational area (OPAREA) to conduct various drills, exercises, qualifications, etc. Within the OPAREA, rectangular or trapezoidal sectors are assigned to various events or evolutions. Ships must transit to those sectors in order to perform that particular event.

The claim has been made that if 3rd Fleet would allow ships to conduct all their required evolutions in the same sector, significant fuel savings could be realized. This would prevent ships from having to transit throughout the OPAREA in order to complete tasking.

SMEs have not been favorable to this proposed idea. Sectors were developed so that all in the area are aware of ongoing operations in each sector and can steer clear appropriately, for example UNREP/CONREP, PACFIRE, and streaming TACTAS. Additionally, 3rd FLT does not have the proper manning to manage all ships and their events in the OPAREA. Finally, it has been noted that ship training would decrease as this does not mimic real life operations.

ESTIMATED SAVINGS:

Unknown.

SHORT TITLE:

Relaxing Plant Status

DESCRIPTION (by the author)**:**

Ships generally are at full plant status during certain evolutions. The claim has been made that ships could easily save if COs were more fuel-focused during these time periods.

- Starting engines prior to getting underway (CGs and DDGs): SMEs recommend starting engines only 10-15 minutes prior. Estimate that average gas turbine ship starts engines 45 minutes beforehand. Assume a 30 minute savings of secured vs full plant.

- Sea & Anchor Detail: Full plant is not necessarily required during the whole evolution. Depends on the port and surrounding area. Assume a 30 minute savings of split vs full plant.

- Before and after UNREP/CONREP: No need to go to full plant more than 10 minutes beforehand. No need to break away at “all ahead full” and maintain speed during transit to next OPAREA. Assume a 30 minute savings of split vs full plant.

- Auxiliary steaming: Reduce auxiliary steaming time through better planning by Port Ops, use of portable diesel generators, use of molded plugs for quicker shore power hook-up. Assume a 30 minute savings of secured vs full plant.

ESTIMATED SAVINGS:

Using fuel curves, savings could be calculated based on time in each plant configuration in each situation. Estimates will also be dependent on frequency of events.

SHORT TITLE:

Reduced Use of Prairie/Masker Air (P/M)

DESCRIPTION (by the author)**:**

P/M is a radiated noise reduction system fitted on DDG-51 and CG-47 class ships. The Masker portion consists of two bands fitted to the outside of the hull adjacent the vessels engine rooms, compressed air is then forced into the bands and escapes through machined perforations to create a barrier of air bubbles in the sea about the hull, thus trapping machinery noise. Prairie works via the same principles but is fitted either near to or on the ships propellers. The systems are designed to prevent classification/identification by radiated noise of the warship in question by acoustical analysis, i.e. by a hostile submarine. Instead of hearing machinery, the ship sounds similar to rain to passive sonar. Originally classified, these systems are now used by several countries as part of their anti-submarine warfare solutions.

P/M takes away compressed air and gas from GTGs and GTMs , forcing these engines to work harder and to burn more fuel in order to make the same amount of horsepower. Currently, the Navy Engineering Operational Sequencing System (EOSS) calls for P/M to be operated at all times unless the ship traveling below 5 kts. Engineering Operational Procedure calls for P/M to be secured at 5 kts.

The claim has been made that unless the ship is in an anti-submarine environment, use of P/M puts undue strain on engines and unnecessarily burns more fuel. SMEs concur that securing of P/M definitely saves fuel, but the amount is unknown.

ESTIMATED SAVINGS:

Unknown.

SHORT TITLE:

Single Generator Operations (SGO) for DDG-51 Class Ships

DESCRIPTION (by the author)**:**

DDG-51 class ships generally operate with 2 of 3 gas turbine generators (GTGs) online. For a DDG Flt I the maximum load for 1 GTG is about 2500 KW. For a DDG Flt IIA, the capacity increases to 3000 KW. A few ships in the Fleet have been operating almost exclusively on single generator operations. One of the pioneers of this concept is USS HALSEY (DDG-97), a Flt IIA ship.

A phone interview on 17 June 2009 with GSCS Odelon Malig, GS LCPO on HALSEY, is the source of the following information. HALSEY first started experimenting with SGO midway through her summer 2008 deployment. Originally the Commanding Officer's idea, the motivation was to save fuel. Some basic research showed that while on deployment, the ship typically required 2200-2300 KW during the day, and about 2000 KW at night. The ship took a conservative approach to using SGO, initially implementing for four hours at night when the least amount of power was required. Slowly, they increased the time in SGO to six hours, and later to eight. It was estimated that 90-100 gal/hr were saved during night SGO. (Their tests showed that running on 2 GTGs at about 2100-2200 KW vs 1 GTG at about 2100-2200 KW yielded a savings of 94 gal/hr.) Eventually, the ship felt comfortable enough to operate exclusively on SGO, unless ship operations required a greater load. (GSCS Malig recalls that on 2 GTGs, about 9600 gal/day were consumed. In June 2008 when SGO became the standard U/W plant figuration, 5200 gal/day were consumed.) Should another GTG or GTM need to come online, the OOD and EOOW had a pre-planned response ready which would bring the 2nd GTG online in 1 minute 10 seconds, achieve split plant status in 2 min 30 sec, and achieve full plant in 3 min 36 sec.

It is important to note that while in SGO, HALSEY was in a trail shaft plant status, Prairie/Masker Air was secured, space ventilation cooling fans were being run at low speeds, and Aegis radar power settings were set to "low." Additionally, the ship could not operate sonar or any other equipment which would overload the single generator. Split plant status could be run during SGO, but could not be transitioned to from SGO. Additionally, HALSEY adjusted her drills and responses so that the crew was accustomed to respond to any associated risks from being in SGO.

Other notable opinions from GSCS Malig:

- If stationed on a DDG Flt I ship, he would be comfortable operating at SGO if the load was at 2000 KW.
- GTGs on DDGs are more efficient when operating closer to maximum load (also echoed by other SMEs).

- It requires an additional 200-300 KW to operate Aegis system at high power.
- 25-45 KW savings per fan if operating at low.
- 120 KW savings per fire-pump not online.
- Securing P/M saves approx 5% of fuel.

ESTIMATED SAVINGS:

Based on GSCS Malig’s memory, I will use 100 gal/hr as the estimated savings between 2 GTG and SGO.

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APPENDIX B: WHITE PAPERS FOR TECHNOLOGIES

TITLE:

Online Water Wash for GTM and GTG Engines on DDG-51 and CG-47 Class Ships

DESCRIPTION (condensed from FRR&DP proposal)**:**

DDG-51 and CG-47 class US Navy ships currently perform gas turbine crank wash maintenance on a periodic basis. This periodicity results in maintenance which is either too frequent (resulting in unnecessary costs) or too infrequent (resulting in future costs to correct the lack of maintenance). Crank wash maintenance is performed on both the Ship Service Gas Turbine Generators and Gas Turbine Main engines. Each time a crank wash is performed, the engine starter undergoes wear and tear, and hazmat is generated and needs to be stored and subsequently offloaded. An Online Wash System would reduce these maintenance costs and improve fuel efficiency of these engines by keeping the engines cleaner for a longer period of time and by extending the period between scheduled crank washes.

Fuel efficiency, starter life expectancy, and hazmat levels can all be improved by the installation of an online wash system. Online wash systems have been designed and tested for SSGTG and GTM engines on USS LABOON (DDG-58). These systems were stand-alone. A new, much more cost effective system has been proposed. The new system design would take advantage of the already existing crank wash piping arrangement and would allow for quick, reliable online washing for both SSGTG and GTM gas turbine engines.

ESTIMATED SAVINGS:

Previous online wash test results indicated a 1% fuel savings. Using fuel consumption data from Avg. Yearly Total Fuel Consumption Data NEURS (2004/2005/2006), approximately 5,922,000 BBLs (3,651,000 BBLs across 51 DDG-51 Class hulls and 2,271,000 BBLs across 22 CG-47 class hulls) were consumed. At the FY-07 fuel cost of $96.16/bbl, the savings realized is approximately $78,014 per year/ship. (Or 811 BBLs Saved/Ship)

PROPOSED R&D DEVELOPMENT AND SHIP EVALUATION COSTS ($K)

FY-08 - $ 530K

FY-09 - $ 300K

TOTAL: $ 830K

TITLE:

DDG-51 Advanced Fouling Release Coatings

DESCRIPTION (condensed from FRR&DP proposal)**:**

The Navy has instituted an effective hull husbandry strategy which includes in-water hull cleaning in order to remove accumulations of biofouling and reactivate the coating system, thereby extending its overall service life. However, the system is not perfect and ships operate at least some percentage of the time with fouled hulls. When they do, they pay a fuel penalty.

Recently improved non-toxic fouling release (FR) coating systems may provide such a solution for the US Navy fleet. FR coatings represent a shift from the standard biocide-based coating technology. FR coatings function by minimizing the adhesion strength between the "glue" of biofouling organisms and the coating surface. Therefore, during underway periods, hydrodynamic forces work to dislodge the biofouling and return the hull to a smooth condition.

ESTIMATED SAVINGS:

Last year the U.S. Navy's 51 active DDG 51 platforms consumed approximately 2.7 M BBLs of fuel (propulsion only) for a total cost of $339.6 M (assuming price per barrel of fuel at $127.68 and rising). With fuel demand expected to maintain current rates for the near future, but prices expected to rise, implementation of a hull coating system that ensures continuous hard-fouling-free operation (smooth hull, no hard fouling) will significantly reduce fuel consumption while maintaining mission capabilities. For this proposal, a conservative estimate of 3% fuel savings will be used. A 3% reduction in the Navy's 51-ship DDG 51 fleet yearly fuel bill would total $10.2M.

PROPOSED R&D DEVELOPMENT AND SHIP EVALUATION COSTS ($K)

FY -08 - $572

FY- 09 - $247

FY- 10 - $665

FY- 11 - <u>$484</u>

TOTAL- $1,968

Assumed fuel savings is 3% based on the benefit of operating continuously with an unfouled, smooth hull. Using fuel consumption data from Avg. Yearly Total Fuel Consumption Data NEURS (2004/2005/2006), approximately 51,543 BBLs/Ship/underway (51 ships at 72% usage underway), and at the FY-08 fuel cost of $127.68/BBL, the 3% savings realized is approximately $189,863 per year/ship. (or 1,486 BBLs Saved/Ship)

SHORT TITLE:

Propeller Coatings on LHA-1, LHD-1 & LPD-4 Class Ships

DESCRIPTION (condensed from FRR&DP proposal)**:**

Currently, propellers on Navy surface ships (excluding MCMs) and other DoD vessels are not coated. Uncoated propellers are subject to biofouling which increases the surface roughness and adversely affects ship fuel efficiency.

Intersleek® is a commercially available, multi-coat, silicone-based elastomeric coating system. It does not prevent biofouling settlement. Instead it controls fouling accumulation by minimizing adhesion strength between the biofouling organism and the coating surface. This is achieved through the combination of low surface energy silicone elastomeric polymer and unique material properties including a very smooth surface and compliant texture. This type of coating is often referred to as fouling release (FR) since biofouling that settles and grows under static conditions is later released during underway periods due to hydrodynamic forces. Its performance has been proven as a hull coating system and it is on the Navy ship hull coating system Qualified Products List (QPL), MIL-PRF-24647D, for limited ship classes.

ESTIMATED SAVINGS:

Assumed fuel savings is 2% based on the benefit of operating continuously with an unfouled coated propeller.

PROPOSED R&D DEVELOPMENT AND SHIP EVAL COST ($K)

FY-08 - 546

FY-09 - 345

FY-10 - 402

TOTAL: 1,293

Using fuel consumption data from Avg. Yearly Total Fuel Consumption Data NEURS (2004/2005/2006), approximately 1,304,000 BBLs/underway (222,000 BBLs across 2 LHA-1 Class hulls, 769,000 BBLs across 7 LHD-1 class hulls, and 313,000 BBLs across 5 LPD-4 Class Hulls) utilizing a 72% factor underway were consumed. At the FY-07 fuel cost of $96.16/BBL, the savings realized is approximately $179,132 per year/ship. (Or 1,863 BBLs Saved/Ship)

SHORT TITLE:

Class Combustion Trip Loop for LHA-1 and LHD-1 Class Ships

DESCRIPTION (condensed from FRR&DP proposal)**:**

The LHA-1 and LHD-1 Class Ships use forced draft blowers to supply air for combustion in the main boilers. Excess air, particularly at lower steaming rates, result in decreased gas temperatures and boiler efficiency.

Two phase implementation:

First phase involves replacing the existing Stack Gas Analyzer (SGA) system with one that will provide signal outputs for future incorporation into an existing boiler control system. The SGA detects the excess oxygen in the combustion gases as they exit the boiler. The existing obsolete SGA system is no longer supported by the manufacturer and only displays an oxygen reading to the boiler operator at the control console. A ship change document (SCD) in shipmain exists (SCD # 4054) and has been approved for Phase IV implementation. Initial seed money for testing of possible SGA replacements has been received and allows for testing of one unit in house and on board one ship on one boiler. Once testing is complete the system will be installed throughout the fleet.

The second phase involves incorporating the new SGA system output signals into the existing boiler controls. A programmable logic controller will be installed to incorporate the SGA readings, send signals to the existing boiler controls for trimming excess air, and display both oxygen and boiler efficiency readings to the boiler operator. The PLC will provide constant automatic trimming of the excess oxygen based upon real time SGA readings. An SCD also exists for this effort (SCD # 985) and is currently in Phase 1. It has been approved at the O6 review board for fleet implementation once the first ship install validates the projected 2% fuel savings. RDT&E funds are needed to install the trim loop system on the first ship.

ESTIMATED SAVINGS:

Preliminary calculations based upon fuel curve and LHD-2 fuel numbers indicated a 1.8%-2.5% fuel savings (2% will be used).

PROPOSED R&D DEVELOPMENT AND SHIP EVAL COST FOR TRIM LOOP SYSTEM

FY-08 - $ 328K

FY-09 - $ 85K

Total: $ 435K

Using fuel consumption data from Avg. Yearly Total Fuel Consumption Data NEURS (2004/2005/2006), approximately 1,380,000 BBLs (312,000 BBLs across 2 LHA-1 Class hulls and 1,068,000 BBLs across 7 LHD-1 class hulls) were consumed. At the FY-07 fuel cost of $96.16/BBL, the savings realized is approximately $294,889 per year/ship. (Or 811 BBLs Saved/Ship).

SHORT TITLE:

Hull Condition Assessment Tool for DDG-51 Class Ships

DESCRIPTION (condensed from FRR&DP proposal)**:**

The Fleet Readiness R&D (FRR&DP) Program is designed to test and validate energy and maintenance savings through research and development. Examination and measurement of these savings is extremely difficult for underwater hull coating system evaluations, and requires subjective divers' observations to assess the condition of the underwater hull and appendages, and estimate the "fouling penalty" with respect to hull drag. The current Navy practice is to schedule periodic hull and propeller inspections (observations) and recommend cleanings based on the results of the inspections. Numerous programs are in progress to realize fuel savings by reducing the fouling that accumulates on Navy ships, and these require some means of monitoring the hull condition over time, and their relationship to ship powering.

It is proposed to develop a shipboard underwater hull assessment tool, coupled with data acquisition, a tie-in to the ship's powering data, and the necessary algorithms to determine the fuel penalty and inform ship's force that the underwater hull needs attention.

ESTIMATED SAVINGS:

Assumed fuel savings is 2%.

PROPOSED R&D DEVELOPMENT AND SHIP EVAL COST

FY-09 - $ 286K

FY-10 - $ 242K

<u>FY-11- $121K</u>

TOTAL: $ 649K

Using fuel consumption data from Avg. Yearly Total Fuel Consumption Data NEURS (2004/2005/2006), approximately 51,543 BBLs/Ship/underway (51 ships at 72% usage underway), and at the FY-08 fuel cost of $127.68/BBL, the 2% savings realized is approximately $126,588 per year/ship. (or 992 BBLs Saved/Ship).

SHORT TITLE:

Solid State Lighting Initiative on LSD-41/49 Class Ships

DESCRIPTION(condensed from FRR&DP proposal)**:**

Current shipboard illumination of racks/bunks is provided by fluorescent lamps (with starters) with an exhibited lamp life of approximately 6K hours. General illumination of walk ways and passages is provided by incandescent lamps with a rated life of approximately 1K hours. With approximately 930 fluorescent bunk fixtures and 360 incandescent fixtures on an LSD-49 class ship, the maintenance associated with maintaining the lighting system is extensive. In addition, cumbersome and fragile spare lamps must be stored onboard during deployment and used/damaged lamps must be stored as hazmat.

A complete shipset of solid state variant replacements for legacy fluorescent berth light fixtures (sym 232.1) and incandescent general illumination fixtures (sym 92, sym 112) is considered in this proposal. Solid state luminaires such as Light Emitting Diodes (LEDs) are currently experiencing a rated life of approximately 50K hours in the commercial industry. This rated life would translate to a LED array and driver replacement interval at most once every 5.7 years, and a considerable decrease in maintenance and spares associated with upkeep of the lighting system.

ESTIMATED SAVINGS:

Efficiency improvement on the order of 80% can be realized through the use of discreet HBLEDs for colored lighting applications and on the order of 30% is expected when using white HBLEDs.

<u>Documentation of Assumptions:</u>

- Project costs in FY09 are for development, testing and installation of solid state lighting system
- Implementation costs include ILS, Contract Development, Training
- 1,290 general illumination incandescent / detail illumination fluorescent fixtures to be replaced by solid state variation at an average cost of $294/ea to procure and an average of $130/ea to install. Total installation cost is $546,960.
- Also supported are NDE Drawings, COSAL support, MRCs, Shipcheck and control interface determination. Mil Qualification Testing will be accomplished on 3 Fixture Types.
- Total in FY09/10 of $924,000.

Laboratory test results indicated a 75% electrical savings over the present lighting system. Using fuel consumption data from Avg. Yearly Total Fuel Consumption Data NEURS (2004/2005/2006), approximately 1,167 BBLs/Ship

(12 LSD 41/49 Class Ships), and at the FY-08 fuel cost of $127.68/BBLs, the 75% savings realized is approximately $112,667 per year/ship. (or 883 BBLs Saved/Ship).

SHORT TITLE:

Service Diesel Engine Life Extension Upgrade on LSD-41/49 Class Ships

DESCRIPTION (condensed from FRR&DP proposal)**:**

Currently on LSD 41/49 Class vessels, the Opposed Piston 38ND8-1/8 Ship Service Diesel Generators (SSDG) operate for extended periods of time at partial loads. These engines were commissioned in the late 1970s and have a fuel injection system that is highly reliant on mechanical components such as the timing chain, timing chain sprockets, camshafts, fuel tappets, mechanical fuel pumps, mechanical governor and mechanical rack linkage. This mechanical fuel injection system has experienced low reliability, which has resulted in high annual maintenance costs. Additionally, the LSD SSDGs are not providing optimized performance when compared to today's electronic fuel injection technology, achieving only 36.5% thermal efficiency, whereas current Best in Class engines are operating above 40% thermal efficiency. This results in higher fuel oil and lube oil consumption.

The LSD 41/49 Class vessels are currently undergoing Low Load Package installations in order to improve engine performance while operating at low load conditions for extended periods of time. While the Low Load Package improves engine combustion performance using the current mechanical fuel injection system, significant reductions in fuel consumption, lube oil consumption, internal engine maintenance costs and exhaust emissions could be realized through the development and implementation of a Common Rail Electronic Fuel Injection (EFI) system.

The proposed solution is to replace the existing mechanical fuel injection system on the LSD SSDGs with a Life Extension Upgrade (LE) consisting of a Common Rail Electronic Fuel Injection (EFI) System, a new chromeless liner and improved piston ring pack.

ESTIMATED SAVINGS:

Converting the existing LSD 41/49 Ship Service Diesel Generators to EFI technology will yield a projected reduction in annual fuel consumption of 10% and a projected annual savings in SSDG maintenance costs of $1.94M.

PROPOSED DEVELOPMENT AND SHIP EVALUATION COST

FY-09 -	$1,318K
FY-10 -	$3,072K
FY-11 -	$561K
TOTAL:	$4,951K

Previous results on similar diesel engines indicated a 10% fuel savings realized. Using fuel consumption data from Avg. Yearly Total Fuel Consumption Data NEURS (2004/2005/2006), approximately 25,925 BBLs/Ship (12 ships at

30% usage underway), and at the FY-08 fuel cost of $127.68/BBLs, the 10% savings realized is approximately $330,917 per year/ship. (or 2,592 BBLs Saved/Ship).

Documentation of Assumptions:

- Project costs are for development, design, environmental qualification and prototype testing of two 12 cylinder prototype Life Extension upgrade packages and one additional set for shock qualification testing.

- Forty eight (48) SSDGs, four (4) each on all twelve (12) LSD 41/49 Class vessels, are to be modified.

- Estimated material costs per engine = $338K

- Estimated installation costs per engine = $250K

- Estimated maintenance savings is 14.5% of $13.4M

SHORT TITLE:

Stern Flap for LHD-1 Class Ships

DESCRIPTION (condensed from FRR&DP proposal)**:**

The LHD 1 thru 7 Class Ships have a stern gate and associated external stern gate support appendages. These support arms cause hull drag (resistance) lowering fuel efficiency.

Drag and fuel efficiency can be improved by the application of a stern flap. A stern flap for the LHD class was designed and model tested in the course of the LHD 8 design program. The LHD 8 has controllable pitch propellers with gas turbines. LHD 1 thru 7 has fixed pitch propellers. Nevertheless, the basic LHD 8 flap design is directly applicable to the LHD 1 thru 7.

ESTIMATED SAVINGS:

PROPOSED R&D DEVELOPMENT AND SHIP EVAL COST

FY-08 - $ 600K

FY-09 - $ 688K

FY-10- $ 150k

TOTAL: $1,438K

Previous model test results indicated a 5.00% fuel savings. Using fuel consumption data from Avg. Yearly Total Fuel Consumption Data NEURS (2004/2005/2006), approximately 109,800 BBLs/Ship/underway (7 ships at 72% usage underway), and at the FY-07 fuel cost of $96.16/bbl, the 5% savings realized is approximately $528,143 per year/ship (or 5,492 BBLs Saved/Ship).

DOCUMENTATION OF ASSUMPTIONS:

- Note that these ships all have a long remaining service life on the order of 25 years and once installed the new flap will keep on saving fuel.
- LHD 8 has a stern flap. Because of the nature of the LHD 8 acquisition the stern flap cost cannot be identified. A better acquisition strategy for flap retrofits needs to be adopted

SHORT TITLE:

Stern Flap for LSD-41/49 Class Ships

DESCRIPTION (condensed from FRR&DP proposal)**:**

The LSD 41/49 Class Ships (12 total) share the same hull form and were launched between 1989 and 1996. They all have a stern gate with external support arms that produce drag and lower fuel efficiency. In addition, their large transom hurts low speed performance.

Drag and fuel efficiencies can be improved by the application of a stern flap.

ESTIMATED SAVINGS:

PROPOSED R&D DEVELOPMENT AND SHIP EVAL COST

FY-08 - $ 500K

FY-09 - $ 792K

FY-09 - $ 245K

TOTAL: $ 1,537K

Previous model test results indicated a 5.62% . Using fuel consumption data from Avg. Yearly Total Fuel Consumption Data NEURS (2004/2005/2006), approximately 62,238 BBLs/Ship/underway (12 ships at 72% usage underway), and at the FY-07 fuel cost of $96.16/bbl, the 5.62% savings realized is approximately $336,417 per year/ship. (or 3,499 BBLs Saved/Ship).

DOCUMENTATION OF ASSUMPTIONS:

Note that these ships all have a long remaining service life on the order of 25 years and once installed the new flap will keep on saving fuel.

SHORT TITLE:

Energy Savings By Better Steering (ESBBS) for Amphibious Ships

DESCRIPTION (condensed from FRR&DP proposal)**:**

The LHA 1, LHD 1, and LPD 17 Class Ships have directional stability and steering controllability issues. Tests with other types of ships have shown that appendages installed to eliminate these maneuvering issues reduce total energy costs by improving the steering. These savings are due to reductions in a combination of fuel consumption, energy demands of steering gear activity, and steering gear maintenance costs. The savings can be magnified when the ships transit at higher speeds or operate ballasted down to a heavier displacement.

Determine the appendage configuration that provides the best compromise between directional stability, steering controllability, and resistance. Fuel consumption can be reduced by adding appendages to improve the steering of the ship provided that the appendages do not overly increase the resistance. Optimizing the trim and autopilot algorithms may also provide further fuel consumption reductions.

ESTIMATED SAVINGS:

PROPOSED R&D DEVELOPMENT AND SHIP EVAL COST

FY09 - $ 605K

FY10 - $ 1,485K

FY11 - $ 440K

TOTAL: $ 2,530K

It is assumed that a 4.00% fuel savings will be realized on auxiliary ships with the improved steering and stability. Using fuel consumption data from Average Yearly Total Fuel Consumption Data NEURS (2004/2005/2006), approximately 109,800 BBLs/Ship/underway (7 LHD-1 Class Ships at 72% usage underway), and at the FY-08 fuel cost of $127.68/BBLs, the 4% savings realized is approximately $561,000 per year/ship. (or 4,400 BBLs Saved/Ship)

DOCUMENTATION OF ASSUMPTIONS:

Note that LHD-1 Class ships have a long remaining service life on the order of 25+ years and once installed the new flap will keep on saving fuel.

SHORT TITLE:

Variable Speed Drives for Gas Turbine Module Cooling Fans for DDG-51 Class Ships

DESCRIPTION (condensed from FRR&DP proposal)**:**

The cooling system for the Main Propulsion Gas Turbine on DDG Class vessels is designed to provide enough cooling of the gas turbine when the gas turbine is operating at full power. The issue is that the DDG Class vessels do not operate at or near full power most of the time. Thus, the module cooling fans are expending significant amounts of energy providing cooling that is not required. This method of operation increases operational costs by using excessive energy and increases wear on module cooling fan motors.

The Module Cooling Fan is designed to provide maximum cooling for the propulsion gas turbine even when the gas turbine is not operating at full power. By operating in this fashion, energy is being wasted and the module cooling fan motors are exposed to excessive wear. By operating with Variable Speed Drives, the energy presently being wasted is saved and the module fan motor life will increase.

ESTIMATED SAVINGS:

PROPOSED R&D DEVELOPMENT AND SHIP EVAL COST

FY-09 - $ 583

FY-10 - $ 427

TOTAL: $ 1,010

The conclusions to be drawn from this energy analysis are as follows:

- Without VSDs , Module Cooling Fans consume 490,000 KW-HRS
- With VSDs , Module Cooling Fans consume 296,000 KW-HRS
- Using VSDs saves 194,000 KW-HRS per year per ship
- At $.58/KW-HR yields savings of $112,520/yr-Ship (Based on
- $127.68/BBL fuel cost and an approx. fuel savings of 40%).

SHORT TITLE:

Reverse Osmosis System Update for DDG-51 Class Ships

DESCRIPTION (condensed from FRR&DP proposal)**:**

Reverse Osmosis (RO) desalination plants used on DDG51 Class and other ships in the Fleet were designed in the mid-1980s. Although these RO plants, known as the Navy Standard RO (NSRO) plants have proven themselves over the distillation plants of the past, technologies developed since their introduction to the Fleet in 1991 can be used to significantly reduce maintenance, operating cost and fuel usage. Ships operating in littoral and coastal waters during the present conflict in Iraq have experienced excessive filter usage rates and premature RO membrane failures.

New microfiltration (MF) technology can provide a superior level of filtration in most waters and can be renewed by backflushing techniques developed under an ONR program. MF can facilitate operation in coastal and littoral waters and will also allow operating the RO plant at higher membrane recoveries saving as much as 60% of the input energy. Other energy recovery technologies when applied can enable additional energy savings on these plants.

ESTIMATED SAVINGS:

PROPOSED R&D DEVELOPMENT AND SHIP EVAL COST

FY-09 - $1,540K

<u>FY-10 - $ 550K</u>

TOTAL: $2,090K

Calculations indicate a fuel savings <u>per ship</u> (DDG-51 Class) of 230 BBLs/ship with a cost savings of $29.4K. For the 51 ships of the DDG-51 Class, this would result in an annual Fleet-Wide savings of approximately 11,730 barrels of oil and a savings of $1.5 M. An additional maintenance (filter and RO maintenance) cost savings of $17.0 K/ship would also be realized.

Follow-on savings and improvements could be realized on other ship classes such as the DDG-1000 Class.

DOCUMENTATION OF ASSUMPTIONS:

· Note that the proposed ship class has a long remaining service life on the order of 25 additional years. It was assumed and the calculations were based upon a total ship class consisting of 62 ships. The proposed savings would also be extended to other ships, including the DDG1000 Class and other new classes which would use the NSRO plant and its derivatives such as the RO plants for the LPD17 and LSD41/49 Classes.

· Cost of fuel is based on $127.68/BBL.

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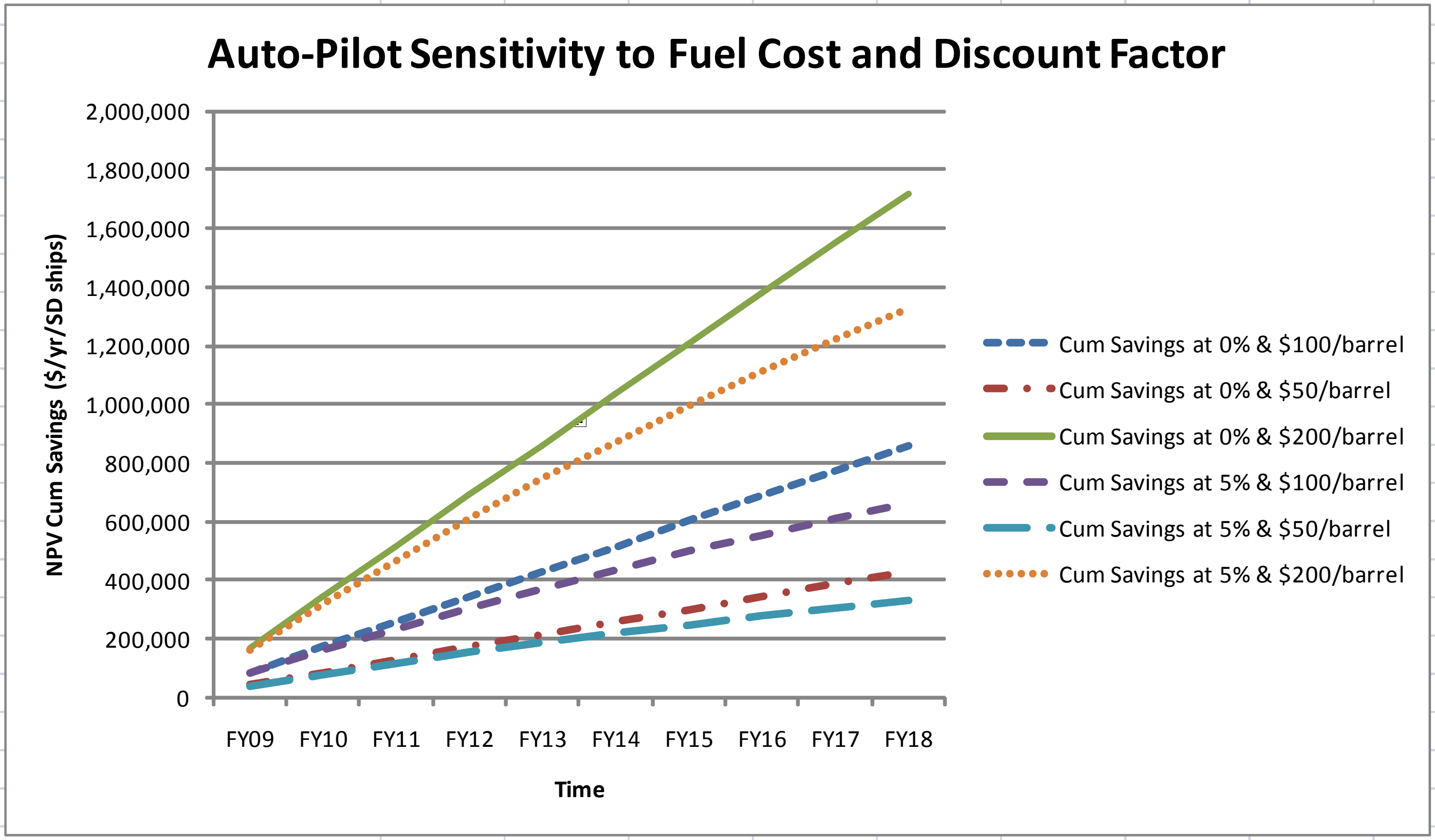
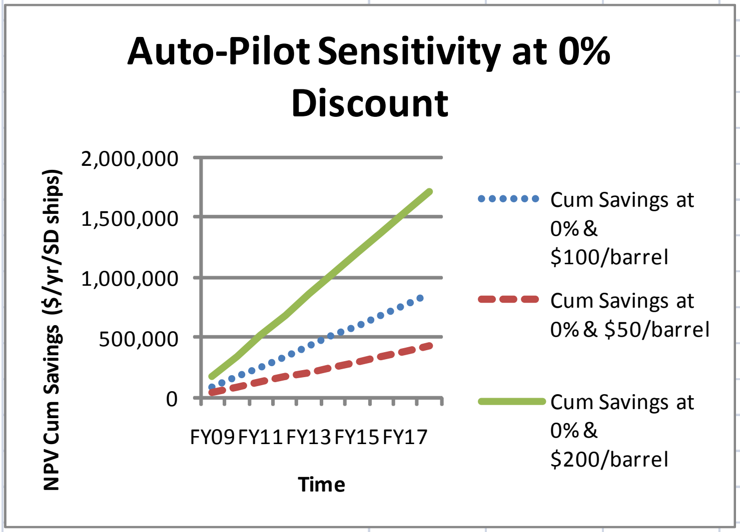
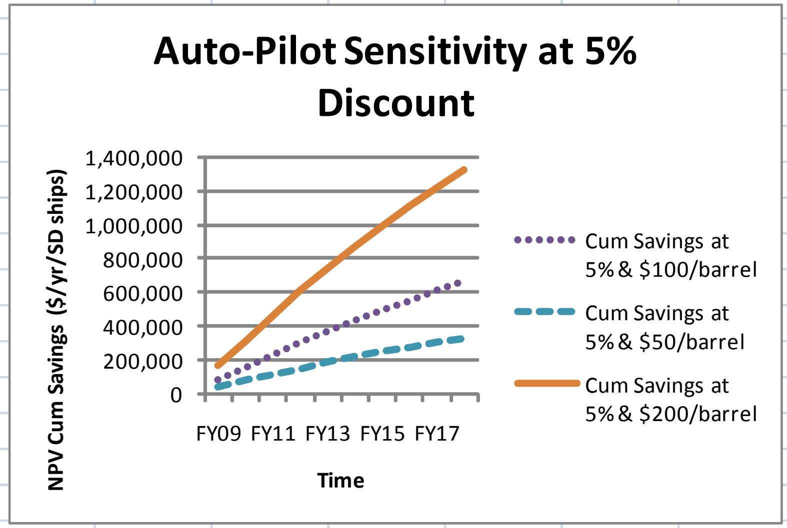
APPENDIX C: CALCULATIONS FOR TECHNIQUES

Auto-Pilot										
	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18
R/D, Proc, & Impl	0	0	0	0	0	0	0	0	0	0
Savings at 0% & $100/barrel	86,000	86,000	86,000	86,000	86,000	86,000	86,000	86,000	86,000	86,000
Cum Savings at 0% & $100/barrel	86,000	172,000	258,000	344,000	430,000	516,000	602,000	688,000	774,000	860,000
Savings at 5% & $100/barrel	81,905	78,005	74,290	70,752	67,383	64,175	61,119	58,208	55,436	52,797
Cum Savings at 5% & $100/barrel	81,905	159,909	234,199	304,952	372,335	436,510	497,628	555,836	611,273	664,069
Savings at 0% & $50/barrel	43,000	43,000	43,000	43,000	43,000	43,000	43,000	43,000	43,000	43,000
Cum Savings at 0% & $50/barrel	43,000	86,000	129,000	172,000	215,000	258,000	301,000	344,000	387,000	430,000
Savings at 5% & $50/barrel	40,952	39,002	37,145	35,376	33,692	32,087	30,559	29,104	27,718	26,398
Cum Savings at 5% & $50/barrel	40,952	79,955	117,100	152,476	186,167	218,255	248,814	277,918	305,636	332,035
Savings at 0% & $200/barrel	172,000	172,000	172,000	172,000	172,000	172,000	172,000	172,000	172,000	172,000
Cum Savings at 0% & $200/barrel	172,000	344,000	516,000	688,000	860,000	1,032,000	1,204,000	1,376,000	1,548,000	1,720,000
Savings at 5% & $200/barrel	163,810	156,009	148,580	141,505	134,767	128,349	122,237	116,416	110,873	105,593
Cum Savings at 5% & $200/barrel	163,810	319,819	468,399	609,903	744,670	873,019	995,256	1,111,673	1,222,545	1,328,138
Assume:	2%	Auto-pilot yields this percentage of fuel savings during a long, straight-line transit.								
	1	# of times times transit occurs in a year								
	2600	Distance in NM from SD to Pearl Harbor								
	13	kts or NM/hr, proposed speed during transit								
	645	avg rate of consumption in gal/hr for 13 kts at split shaft								
	0.0238	barrel/gal								
	100	Price of fuel in $/barrel								
	50	Price of fuel in $/barrel								
	200	Price of fuel in $/barrel								
	14	# of DDGs in SD								
	Savings:			$100/barr	$50/barrel	$200/barrel				
	at 0% discount in $/yr/ship=			6,143	3,071	12,286				
	at 0% discount in $/yr/SD ships=			86,000	43,000	172,000				

	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18
Cum Savings at 0% & $100/barrel	86,000	172,000	258,000	344,000	430,000	516,000	602,000	688,000	774,000	860,000
Cum Savings at 0% & $50/barrel	43,000	86,000	129,000	172,000	215,000	258,000	301,000	344,000	387,000	430,000
Cum Savings at 0% & $200/barrel	172,000	344,000	516,000	688,000	860,000	1,032,000	1,204,000	1,376,000	1,548,000	1,720,000
Cum Savings at 5% & $100/barrel	81,905	159,909	234,199	304,952	372,335	436,510	497,628	555,836	611,273	664,069
Cum Savings at 5% & $50/barrel	40,952	79,955	117,100	152,476	186,167	218,255	248,814	277,918	305,636	332,035
Cum Savings at 5% & $200/barrel	163,810	319,819	468,399	609,903	744,670	873,019	995,256	1,111,673	1,222,545	1,328,138

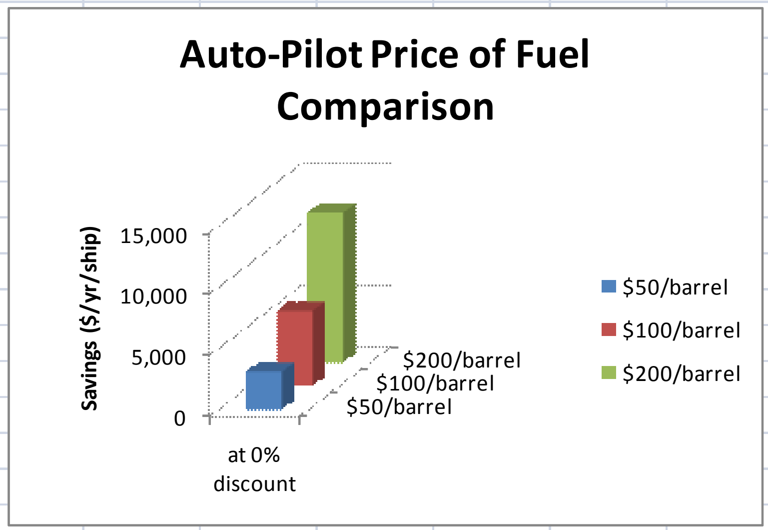






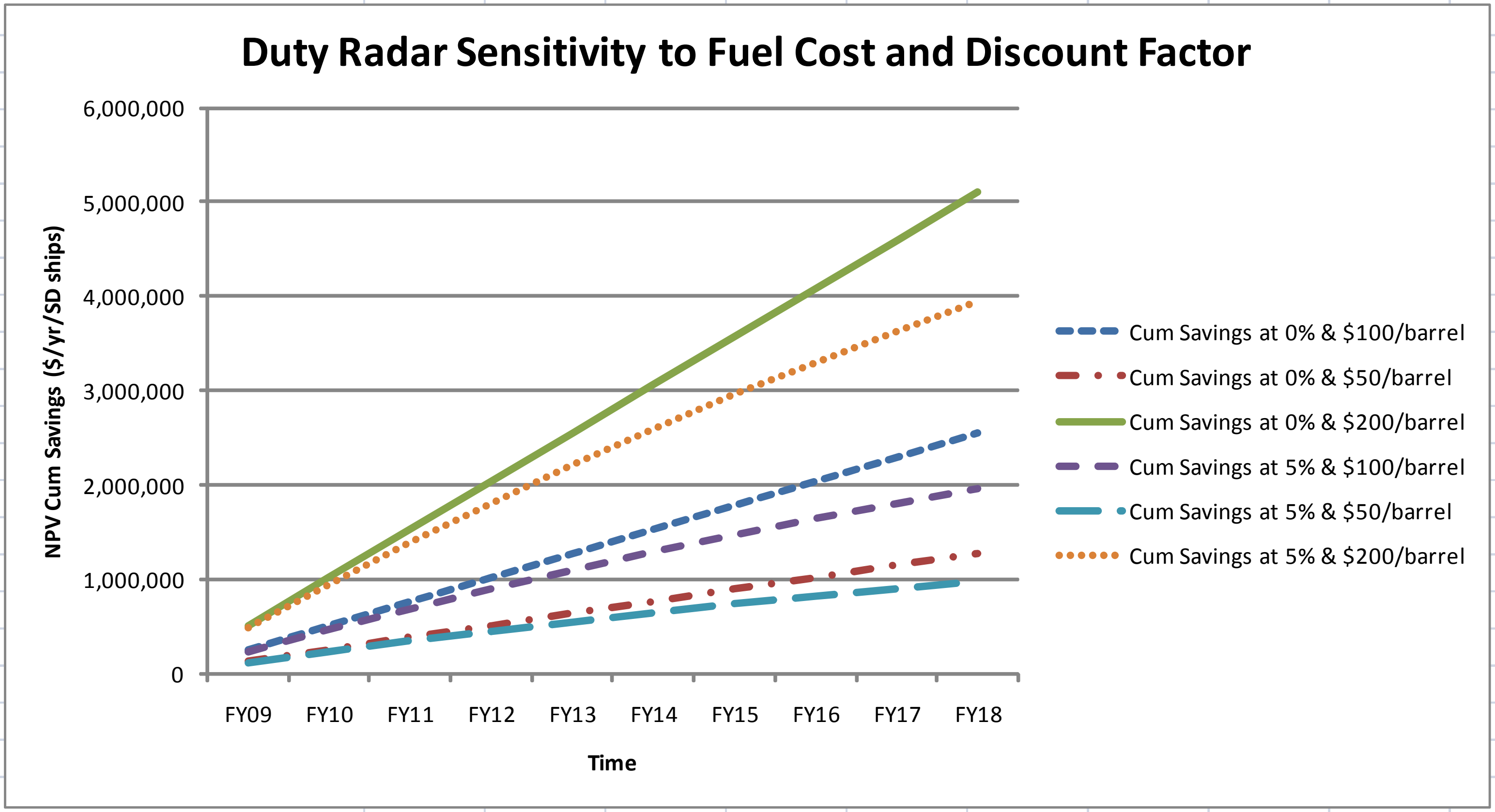
Savings in $/yr/ship:	$50/barrel	$100/barre	$200/barrel
at 0% discount	3,071	6,143	12,286

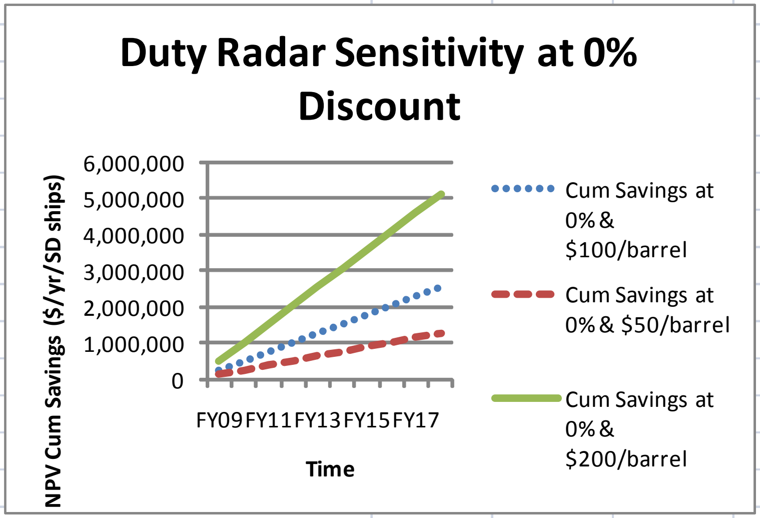
Increments for stacked graph	$50/barrel	$100/barre	$200/barrel
Auto-Pilot	3,071	3,071	6,143

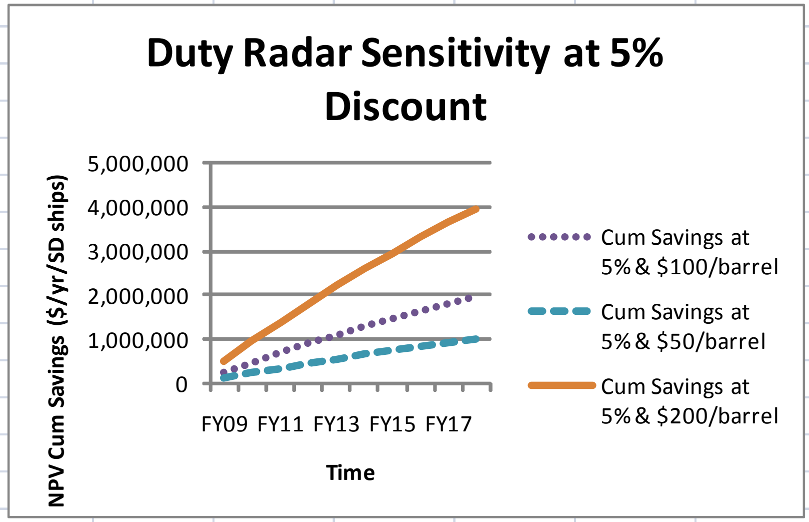


Duty Radar										
	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18
R/D, Proc, & Impl	0	0	0	0	0	0	0	0	0	0
Savings at 0% & $100/barrel	255,500	255,500	255,500	255,500	255,500	255,500	255,500	255,500	255,500	255,500
Cum Savings at 0% & $100/barrel	255,500	511,000	766,500	1,022,000	1,277,500	1,533,000	1,788,500	2,044,000	2,299,500	2,555,000
Savings at 5% & $100/barrel	243,333	231,746	220,711	210,200	200,191	190,658	181,579	172,932	164,698	156,855
Cum Savings at 5% & $100/barrel	243,333	475,079	695,790	905,990	1,106,181	1,296,839	1,478,418	1,651,351	1,816,048	1,972,903
Savings at 0% & $50/barrel	127,750	127,750	127,750	127,750	127,750	127,750	127,750	127,750	127,750	127,750
Cum Savings at 0% & $50/barrel	127,750	255,500	383,250	511,000	638,750	766,500	894,250	1,022,000	1,149,750	1,277,500
Savings at 5% & $50/barrel	121,667	115,873	110,355	105,100	100,095	95,329	90,790	86,466	82,349	78,427
Cum Savings at 5% & $50/barrel	121,667	237,540	347,895	452,995	553,091	648,420	739,209	825,675	908,024	986,452
Savings at 0% & $200/barrel	511,000	511,000	511,000	511,000	511,000	511,000	511,000	511,000	511,000	511,000
Cum Savings at 0% & $200/barrel	511,000	1,022,000	1,533,000	2,044,000	2,555,000	3,066,000	3,577,000	4,088,000	4,599,000	5,110,000
Savings at 5% & $200/barrel	486,667	463,492	441,421	420,401	400,382	381,316	363,158	345,865	329,395	313,710
Cum Savings at 5% & $200/barrel	486,667	950,159	1,391,580	1,811,981	2,212,363	2,593,679	2,956,837	3,302,702	3,632,097	3,945,807
Assume:	50%	Percent of time in High								
	50%	Percent of time in Low								
	40	difference in gal/hr used in High vs secured (baseline 2000 KW, 600 KW more needed for High)								
	20	difference in gal/hr used in Low vs secured (baseline 2000 KW, 300 KW more needed for Low)								
	30%	Prob (operating with another DDG/CG & in range)								
	15.56%	Prob ship is underway based on 14 underway days per quarter								
	8760	hrs/yr								
	0.0238	barrel/gal								
	100	Price of fuel in $/barrel								
	50	Price of fuel in $/barrel								
	200	Price of fuel in $/barrel								
	14	# of DDGs in SD								
	7	# of CGs in SD								
	2	total number of DDG/CGs operating with another in range)								
		(Note: new equations required if operating w/ 3 or more DDG/CGs)								
	Savings:			$100/barre	$50/barrel	$200/barrel				
	at 0% discount in $/yr/ship=			12,167	6,083	24,333				
	at 0% discount in $/yr/SD ships=			255,500	127,750	511,000				

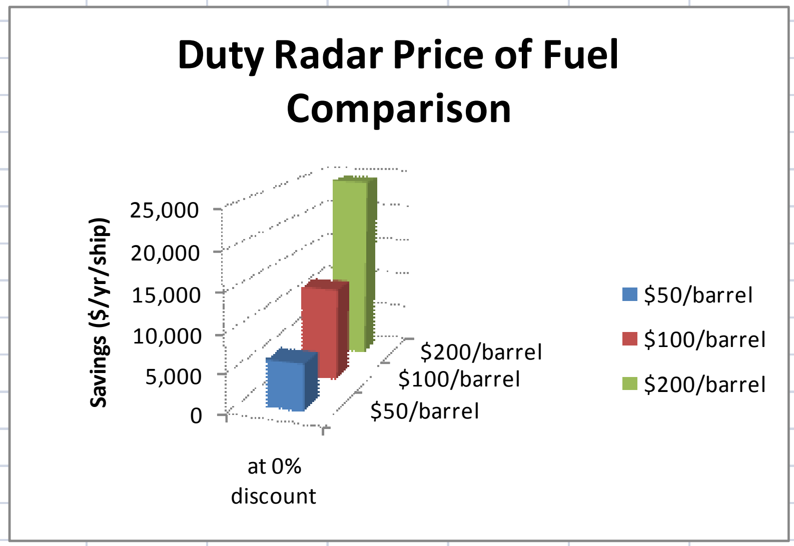
	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18
Cum Savings at 0% & $100/barrel	255,500	511,000	766,500	1,022,000	1,277,500	1,533,000	1,788,500	2,044,000	2,299,500	2,555,000
Cum Savings at 0% & $50/barrel	127,750	255,500	383,250	511,000	638,750	766,500	894,250	1,022,000	1,149,750	1,277,500
Cum Savings at 0% & $200/barrel	511,000	1,022,000	1,533,000	2,044,000	2,555,000	3,066,000	3,577,000	4,088,000	4,599,000	5,110,000
Cum Savings at 5% & $100/barrel	243,333	475,079	695,790	905,990	1,106,181	1,296,839	1,478,418	1,651,351	1,816,048	1,972,903
Cum Savings at 5% & $50/barrel	121,667	237,540	347,895	452,995	553,091	648,420	739,209	825,675	908,024	986,452
Cum Savings at 5% & $200/barrel	486,667	950,159	1,391,580	1,811,981	2,212,363	2,593,679	2,956,837	3,302,702	3,632,097	3,945,807





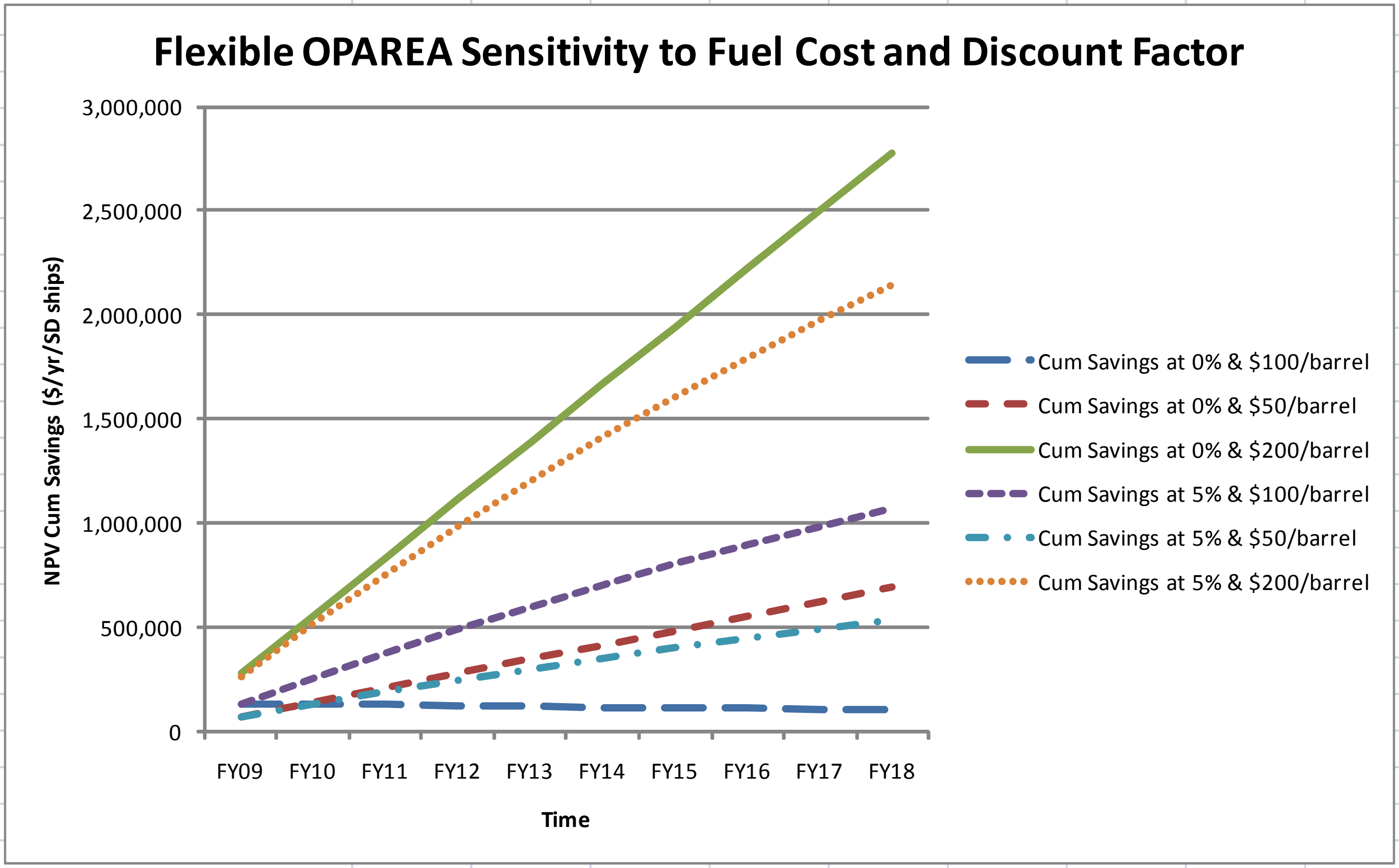


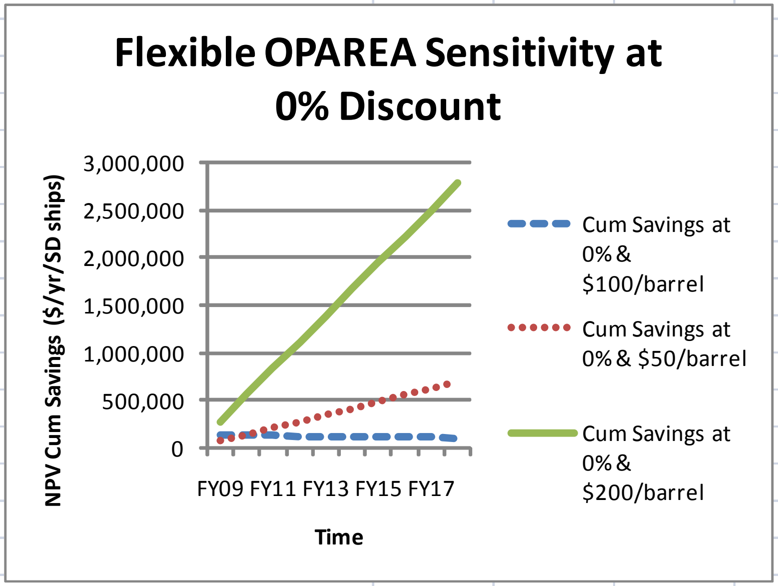
Savings in $/yr/ship:	$50/barrel	$100/barre	$200/barrel
at 0% discount	6,083	12,167	24,333
Increments for stacked graph	$50/barrel	$100/barre	$200/barrel
Duty Radar	6,083	6,083	12,167

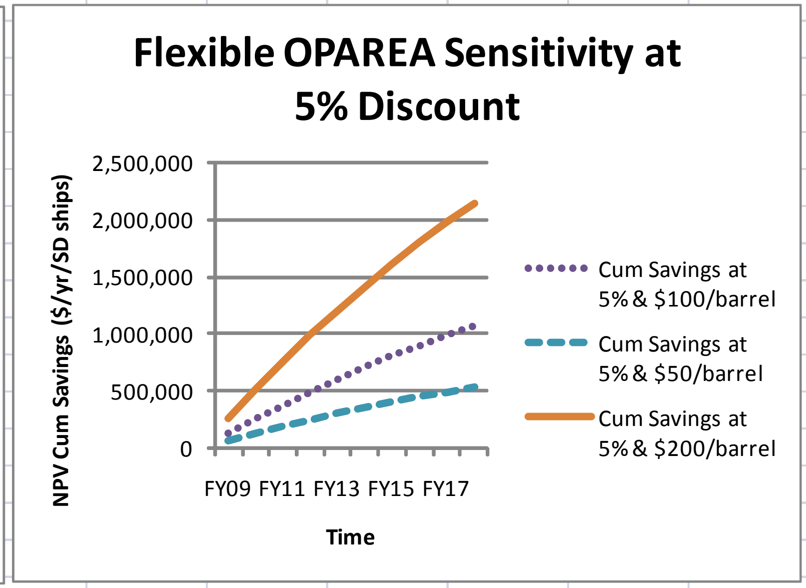


Flexible OPAREAs										
	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18
R/D, Proc, & Impl	0	0	0	0	0	0	0	0	0	0
Savings at 0% & $100/barrel	138,900	138,900	138,900	138,900	138,900	138,900	138,900	138,900	138,900	138,900
Cum Savings at 0% & $100/barrel	134,854	130,927	127,113	123,411	119,816	116,327	112,938	109,649	106,455	103,355
Savings at 5% & $100/barrel	132,286	125,986	119,987	114,273	108,832	103,649	98,714	94,013	89,536	85,273
Cum Savings at 5% & $100/barrel	132,286	258,272	378,259	492,533	601,364	705,014	803,727	897,740	987,276	1,072,549
Savings at 0% & $50/barrel	69,450	69,450	69,450	69,450	69,450	69,450	69,450	69,450	69,450	69,450
Cum Savings at 0% & $50/barrel	69,450	138,900	208,350	277,800	347,250	416,700	486,150	555,600	625,050	694,500
Savings at 5% & $50/barrel	66,143	62,993	59,994	57,137	54,416	51,825	49,357	47,006	44,768	42,636
Cum Savings at 5% & $50/barrel	66,143	129,136	189,130	246,266	300,682	352,507	401,864	448,870	493,638	536,274
Savings at 0% & $200/barrel	277,800	277,800	277,800	277,800	277,800	277,800	277,800	277,800	277,800	277,800
Cum Savings at 0% & $200/barrel	277,800	555,600	833,400	1,111,200	1,389,000	1,666,800	1,944,600	2,222,400	2,500,200	2,778,000
Savings at 5% & $200/barrel	264,571	251,973	239,974	228,547	217,664	207,299	197,427	188,026	179,072	170,545
Cum Savings at 5% & $200/barrel	264,571	516,544	756,518	985,065	1,202,729	1,410,027	1,607,455	1,795,481	1,974,553	2,145,098
Assume:	5%	Flexible OPAREA yields this percentage of fuel savings								
	4	# of times times ships operates in Flexible OPAREA in a year								
	300	Avg distance in NM traveled while in OPAREA								
	10	kts or NM/hr, estimated avg speed during transit								
	463	avg rate of consumption in gal/hr for 10 kts at split shaft								
	0.0238	barrel/gal								
	100	Price of fuel in $/barrel								
	50	Price of fuel in $/barrel								
	200	Price of fuel in $/barrel								
	14	# of DDGs in SD								
	7	# of CGs in SD								
	Savings:			$100/barre	$50/barrel	$200/barrel				
	at 0% discount in $/yr/ship=			6,614	3,307	13,229				
	at 0% discount in $/yr/SD ships=			138,900	69,450	277,800				

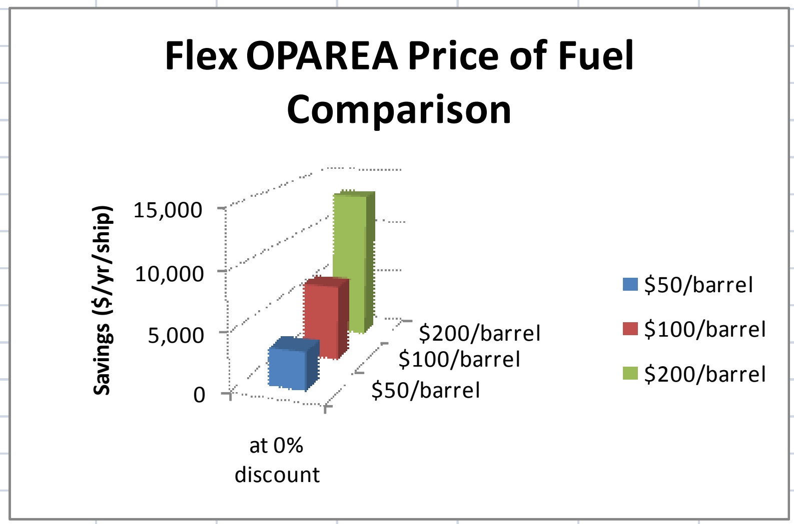
	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18
Cum Savings at 0% & $100/barrel	134,854	130,927	127,113	123,411	119,816	116,327	112,938	109,649	106,455	103,355
Cum Savings at 0% & $50/barrel	69,450	138,900	208,350	277,800	347,250	416,700	486,150	555,600	625,050	694,500
Cum Savings at 0% & $200/barrel	277,800	555,600	833,400	1,111,200	1,389,000	1,666,800	1,944,600	2,222,400	2,500,200	2,778,000
Cum Savings at 5% & $100/barrel	132,286	258,272	378,259	492,533	601,364	705,014	803,727	897,740	987,276	1,072,549
Cum Savings at 5% & $50/barrel	66,143	129,136	189,130	246,266	300,682	352,507	401,864	448,870	493,638	536,274
Cum Savings at 5% & $200/barrel	264,571	516,544	756,518	985,065	1,202,729	1,410,027	1,607,455	1,795,481	1,974,553	2,145,098





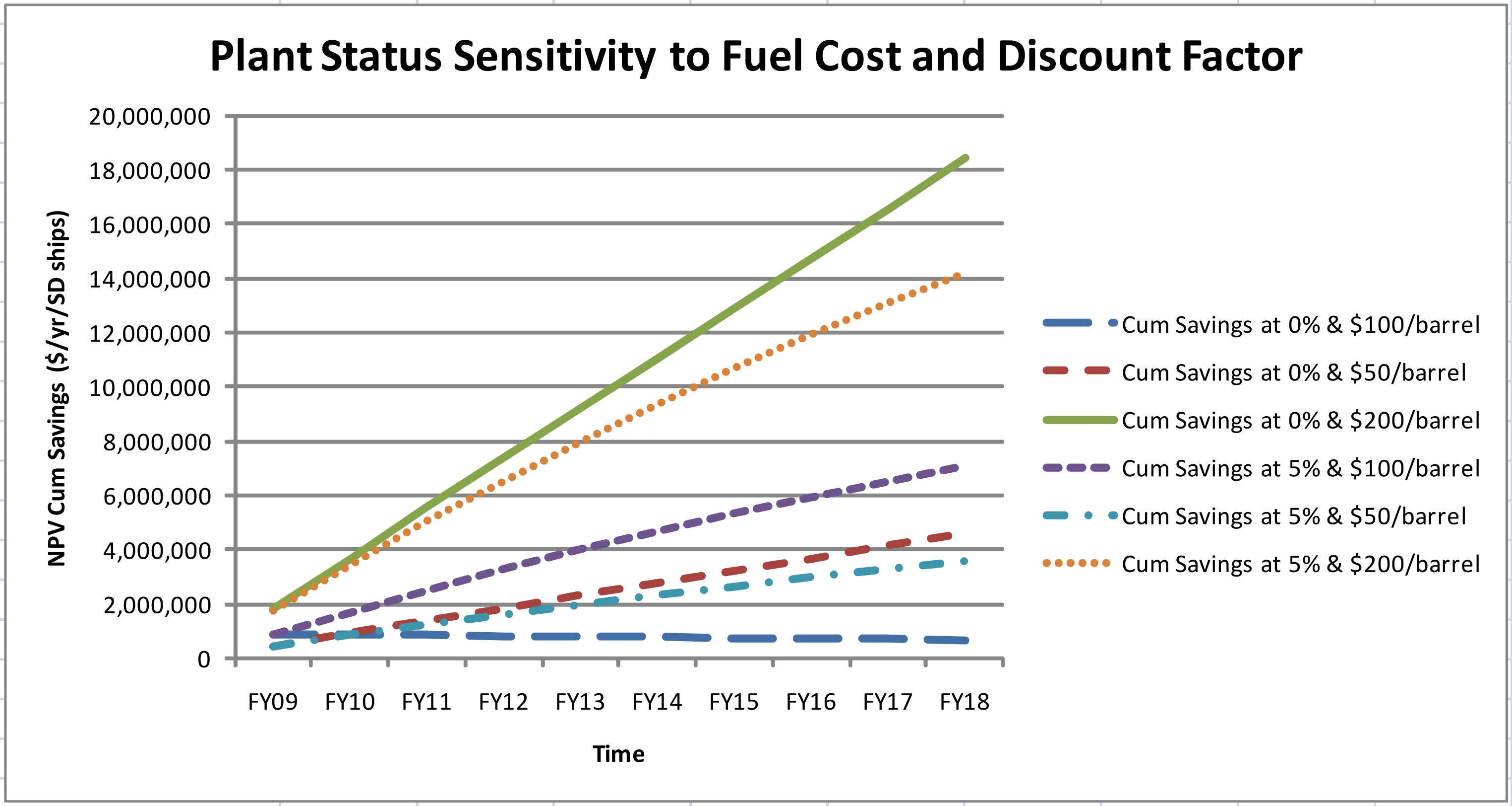


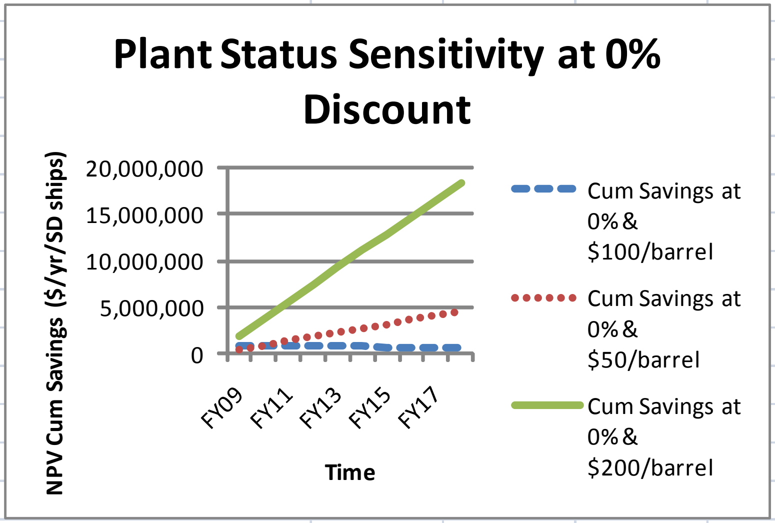
Savings in $/yr/ship:	$50/barrel	$100/barre	$200/barrel
at 0% discount	3,307	6,614	13,229
Increments for stacked graph	$50/barrel	$100/barre	$200/barrel
Flex OPAREA	3,307	3,307	6,614

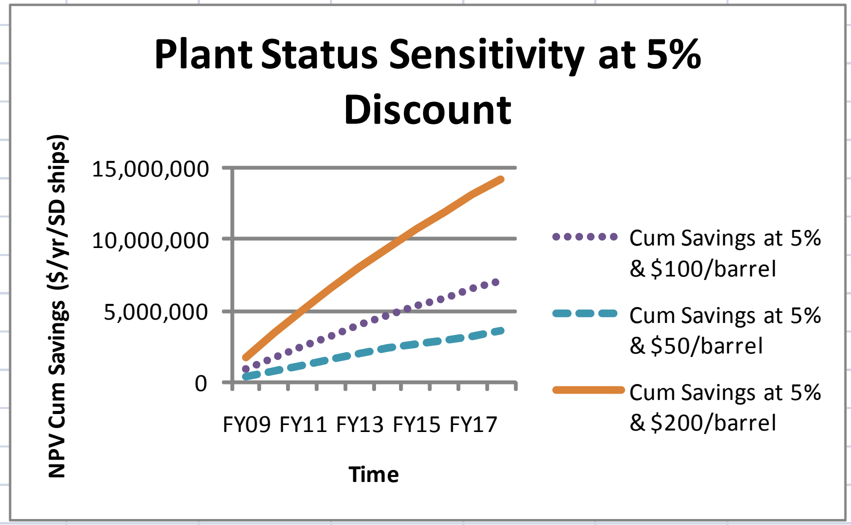


Plant Status										
	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18
R/D, Proc, & Impl	0	0	0	0	0	0	0	0	0	0
Savings at 0% & $100/barre	920,000	920,000	920,000	920,000	920,000	920,000	920,000	920,000	920,000	920,000
Cum Savings at 0% & $100/	893,204	867,188	841,930	817,408	793,600	770,486	748,044	726,256	705,103	684,566
Savings at 5% & $100/barre	876,190	834,467	794,731	756,886	720,844	686,518	653,827	622,692	593,040	564,800
Cum Savings at 5% & $100/	876,190	1,710,658	2,505,388	3,262,274	3,983,119	4,669,637	5,323,464	5,946,156	6,539,196	7,103,996
Savings at 0% & $50/barrel	460,000	460,000	460,000	460,000	460,000	460,000	460,000	460,000	460,000	460,000
Cum Savings at 0% & $50/b	460,000	920,000	1,380,000	1,840,000	2,300,000	2,760,000	3,220,000	3,680,000	4,140,000	4,600,000
Savings at 5% & $50/barrel	438,095	417,234	397,365	378,443	360,422	343,259	326,913	311,346	296,520	282,400
Cum Savings at 5% & $50/b	438,095	855,329	1,252,694	1,631,137	1,991,559	2,334,818	2,661,732	2,973,078	3,269,598	3,551,998
Savings at 0% & $200/barre	1,840,000	1,840,000	1,840,000	1,840,000	1,840,000	1,840,000	1,840,000	1,840,000	1,840,000	1,840,000
Cum Savings at 0% & $200/	1,840,000	3,680,000	5,520,000	7,360,000	9,200,000	11,040,000	12,880,000	14,720,000	16,560,000	18,400,000
Savings at 5% & $200/barre	1,752,381	1,668,934	1,589,461	1,513,773	1,441,688	1,373,036	1,307,654	1,245,384	1,186,080	1,129,600
Cum Savings at 5% & $200/	1,752,381	3,421,315	5,010,776	6,524,549	7,966,237	9,339,273	10,646,927	11,892,311	13,078,392	14,207,992
Assume:	0.5	hours saved during engine start (secured vs full plant)								
	0.5	hours saved during Sea & Anchor Detail (split vs full plant)								
	0.5	hours saved during UNREP/CONREP (split vs full plant)								
	0.5	hours saved during transfer to auxiliary steaming (secured vs full plant)								
	550	consumption difference between secured vs full plant at 1 kts in gal/hr								
	400	consumption difference between split vs full plant at 19 kts in gal/hr								
	16	number of times per year engine start								
	32	number of times per year Sea & Anchor Detail								
	16	number of times per year UNREP/CONREP								
	16	number of times per year transfer to auxiliary steaming								
	0.0238095	barrel/gal								
	100	Price of fuel in $/barrel								
	50	Price of fuel in $/barrel								
	200	Price of fuel in $/barrel								
	14	# of DDGs in SD								
	7	# of CGs in SD								
	Savings:			$100/barre	$50/barrel	$200/barrel				
	at 0% discount in $/yr/ship=			43,810	21,905	87,619				
	at 0% discount in $/yr/SD ships=			920,000	460,000	1,840,000				

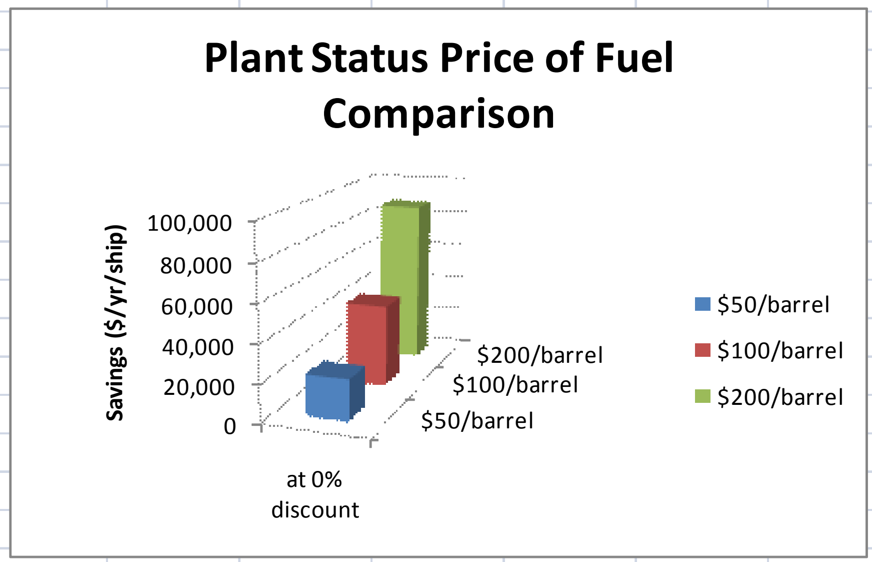
	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18
Cum Savings at 0% & $100/	893,204	867,188	841,930	817,408	793,600	770,486	748,044	726,256	705,103	684,566
Cum Savings at 0% & $50/b	460,000	920,000	1,380,000	1,840,000	2,300,000	2,760,000	3,220,000	3,680,000	4,140,000	4,600,000
Cum Savings at 0% & $200/	1,840,000	3,680,000	5,520,000	7,360,000	9,200,000	11,040,000	12,880,000	14,720,000	16,560,000	18,400,000
Cum Savings at 5% & $100/	876,190	1,710,658	2,505,388	3,262,274	3,983,119	4,669,637	5,323,464	5,946,156	6,539,196	7,103,996
Cum Savings at 5% & $50/b	438,095	855,329	1,252,694	1,631,137	1,991,559	2,334,818	2,661,732	2,973,078	3,269,598	3,551,998
Cum Savings at 5% & $200/	1,752,381	3,421,315	5,010,776	6,524,549	7,966,237	9,339,273	10,646,927	11,892,311	13,078,392	14,207,992





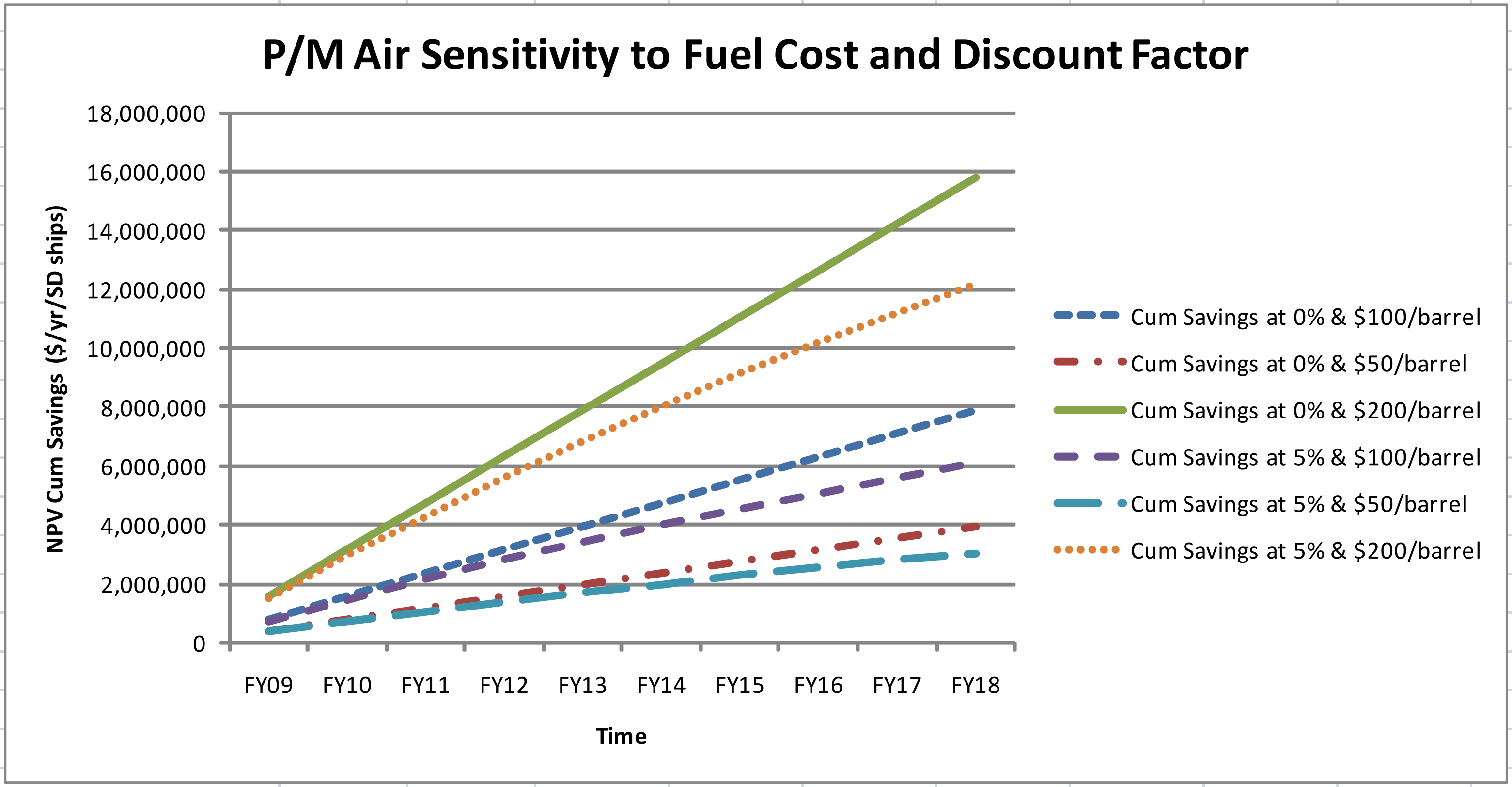


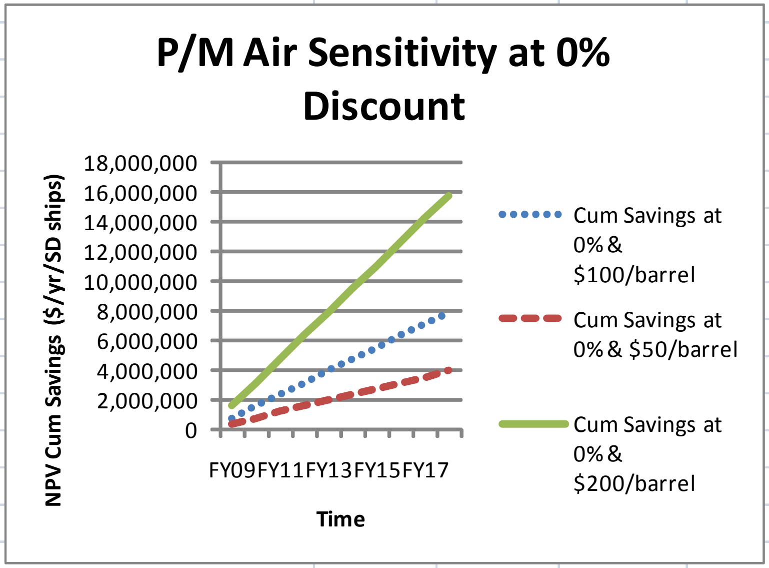
Savings in $/yr/ship:	$50/barrel	$100/barre	$200/barrel
at 0% discount	21,905	43,810	87,619
Increments for stacked gra	$50/barrel	$100/barre	$200/barrel
Plant Status	21,905	21,905	43,810

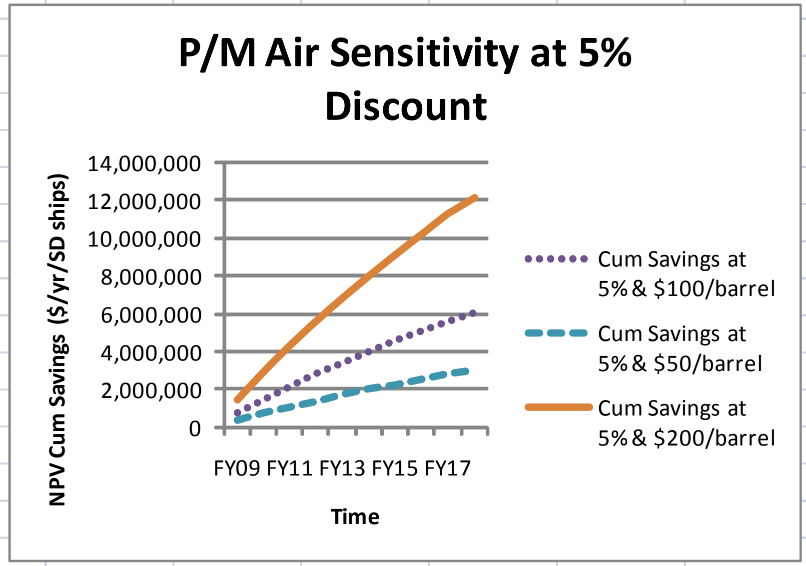


P/M Air										
	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18
R/D, Proc, & Impl	0	0	0	0	0	0	0	0	0	0
Savings at 0% & $100/barrel	788,643	788,643	788,643	788,643	788,643	788,643	788,643	788,643	788,643	788,643
Cum Savings at 0% & $100/b	788,643	1,577,287	2,365,930	3,154,573	3,943,217	4,731,860	5,520,503	6,309,147	7,097,790	7,886,433
Savings at 5% & $100/barrel	751,089	715,323	681,260	648,819	617,923	588,498	560,474	533,785	508,367	484,159
Cum Savings at 5% & $100/b	751,089	1,466,412	2,147,671	2,796,490	3,414,413	4,002,911	4,563,385	5,097,170	5,605,536	6,089,695
Savings at 0% & $50/barrel	394,322	394,322	394,322	394,322	394,322	394,322	394,322	394,322	394,322	394,322
Cum Savings at 0% & $50/ba	394,322	788,643	1,182,965	1,577,287	1,971,608	2,365,930	2,760,252	3,154,573	3,548,895	3,943,217
Savings at 5% & $50/barrel	375,544	357,661	340,630	324,409	308,961	294,249	280,237	266,892	254,183	242,079
Cum Savings at 5% & $50/ba	375,544	733,206	1,073,836	1,398,245	1,707,206	2,001,455	2,281,692	2,548,585	2,802,768	3,044,847
Savings at 0% & $200/barrel	1,577,287	1,577,287	1,577,287	1,577,287	1,577,287	1,577,287	1,577,287	1,577,287	1,577,287	1,577,287
Cum Savings at 0% & $200/b	1,577,287	3,154,573	4,731,860	6,309,147	7,886,433	9,463,720	11,041,007	12,618,293	14,195,580	15,772,867
Savings at 5% & $200/barrel	1,502,178	1,430,646	1,362,520	1,297,638	1,235,845	1,176,996	1,120,948	1,067,570	1,016,733	968,317
Cum Savings at 5% & $200/b	1,502,178	2,932,823	4,295,343	5,592,980	6,828,826	8,005,821	9,126,770	10,194,339	11,211,072	12,179,390
Assume:	5%	Not using P/M Air yields this percentage of fuel savings								
	50%	Percent of time < 5 kts (gal/hr)								
	50%	Percent of time > 5 kts (gal/hr)								
	15.56%	Prob ship is underway based on 14 underway days per quarter								
	463	avg rate of consumption in gal/hr (at 10 kts at split shaft)								
	8760	hrs/yr								
	0.02381	barrel/gal								
	100	Price of fuel in $/barrel								
	50	Price of fuel in $/barrel								
	200	Price of fuel in $/barrel								
	14	# of DDGs in SD								
	7	# of CGs in SD								
	Savings:			$100/barre	$50/barrel	$200/barrel				
	at 0% discount in $/yr/ship=			37,554	18,777	75,109				
	at 0% discount in $/yr/SD ships=			788,643	394,322	1,577,287				

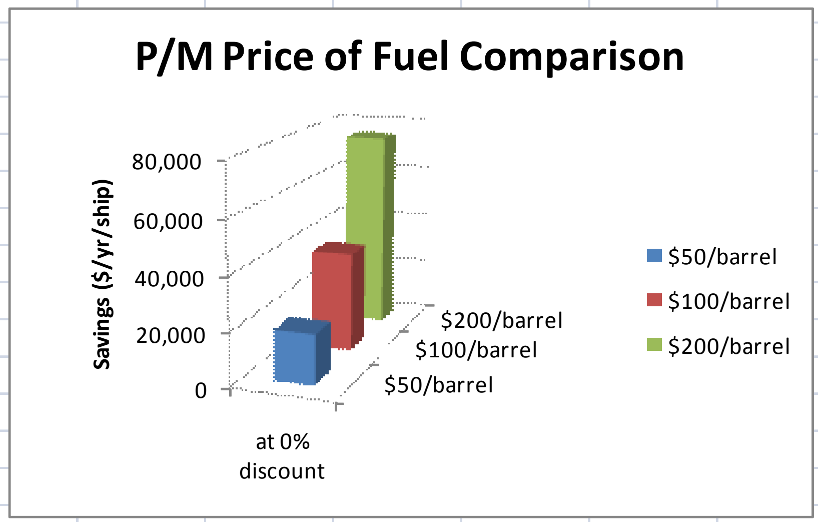
	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18
Cum Savings at 0% & $100/b	788,643	1,577,287	2,365,930	3,154,573	3,943,217	4,731,860	5,520,503	6,309,147	7,097,790	7,886,433
Cum Savings at 0% & $50/ba	394,322	788,643	1,182,965	1,577,287	1,971,608	2,365,930	2,760,252	3,154,573	3,548,895	3,943,217
Cum Savings at 0% & $200/b	1,577,287	3,154,573	4,731,860	6,309,147	7,886,433	9,463,720	11,041,007	12,618,293	14,195,580	15,772,867
Cum Savings at 5% & $100/b	751,089	1,466,412	2,147,671	2,796,490	3,414,413	4,002,911	4,563,385	5,097,170	5,605,536	6,089,695
Cum Savings at 5% & $50/ba	375,544	733,206	1,073,836	1,398,245	1,707,206	2,001,455	2,281,692	2,548,585	2,802,768	3,044,847
Cum Savings at 5% & $200/b	1,502,178	2,932,823	4,295,343	5,592,980	6,828,826	8,005,821	9,126,770	10,194,339	11,211,072	12,179,390





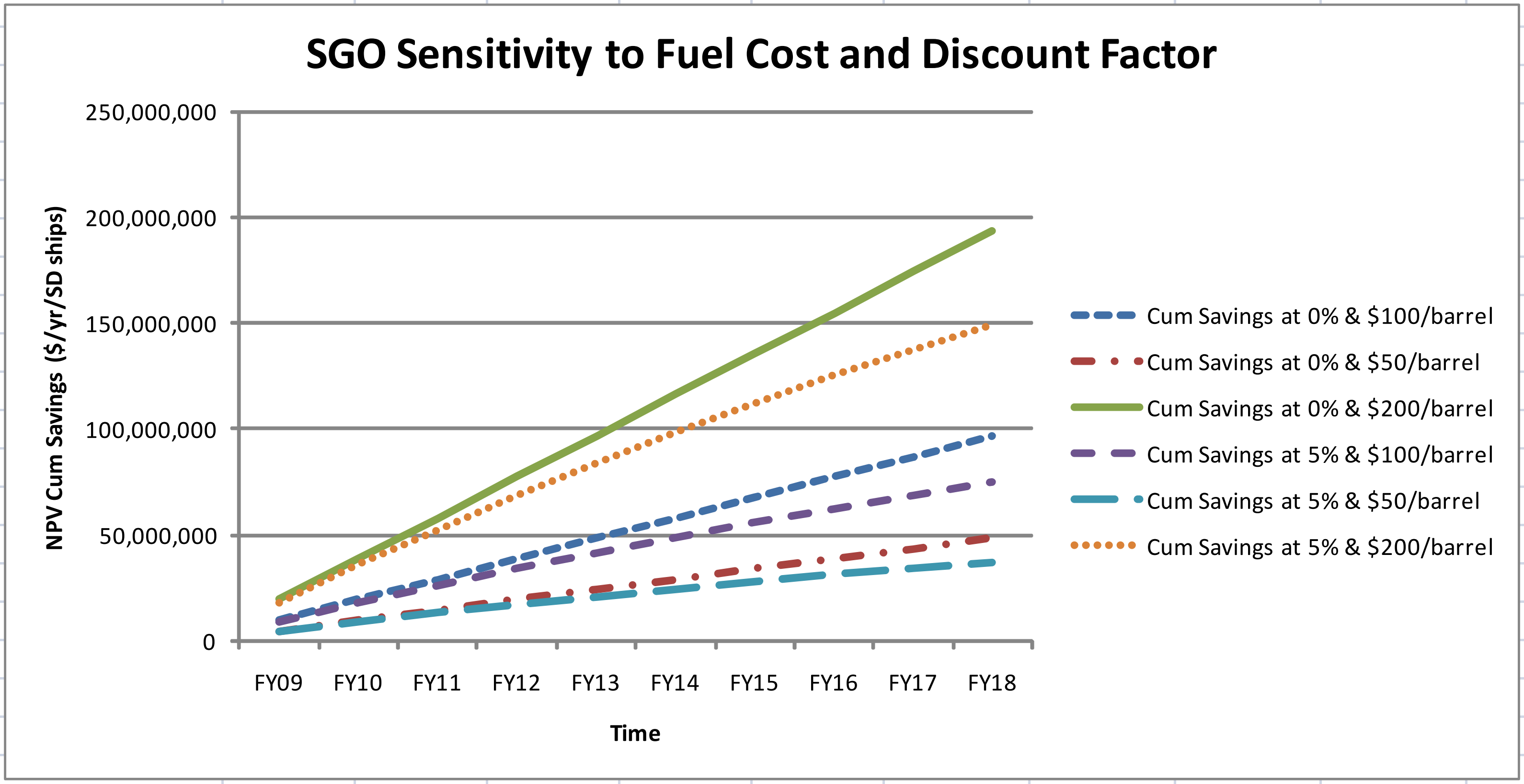


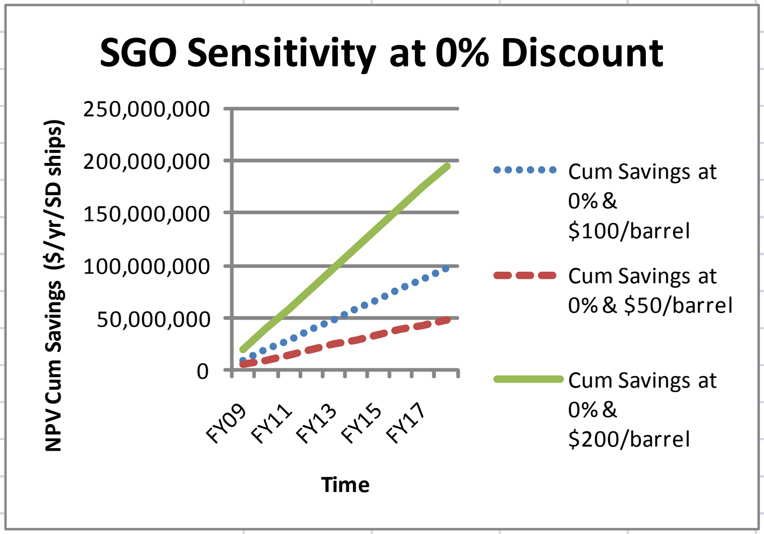
Savings in $/yr/ship:	$50/barrel	$100/barre	$200/barrel
at 0% discount	18,777	37,554	75,109
Increments for stacked grap	$50/barrel	$100/barre	$200/barrel
P/M Air	18,777	18,777	37,554

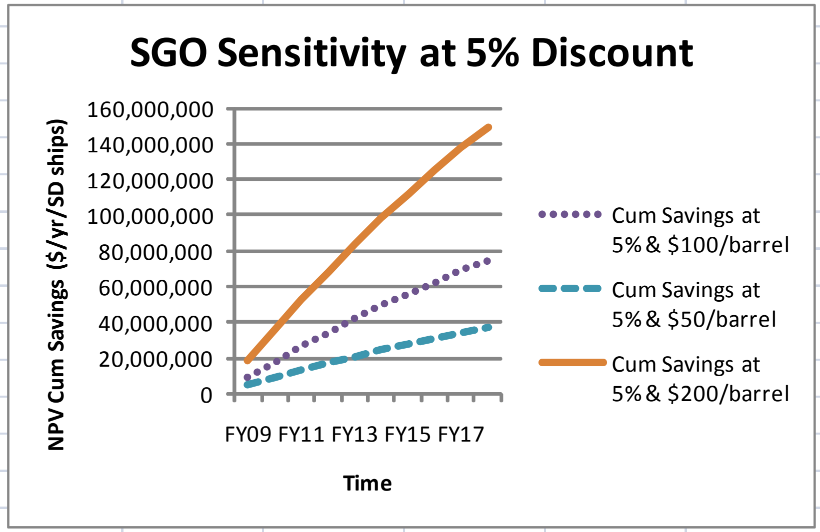


SGO										
	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18
R/D, Proc, & Impl	0	0	0	0	0	0	0	0	0	0
Savings at 0% & $100/	9,689,533	9,689,533	9,689,533	9,689,533	9,689,533	9,689,533	9,689,533	9,689,533	9,689,533	9,689,533
Cum Savings at 0% &	9,689,533	19,379,067	29,068,600	38,758,133	48,447,667	58,137,200	67,826,733	77,516,267	87,205,800	96,895,333
Savings at 5% & $100/	9,228,127	8,788,692	8,370,183	7,971,603	7,592,003	7,230,479	6,886,170	6,558,258	6,245,960	5,948,533
Cum Savings at 5% &	9,228,127	18,016,819	26,387,003	34,358,606	41,950,609	49,181,087	56,067,258	62,625,515	68,871,475	74,820,008
Savings at 0% & $50/b	4,844,767	4,844,767	4,844,767	4,844,767	4,844,767	4,844,767	4,844,767	4,844,767	4,844,767	4,844,767
Cum Savings at 0% &	4,844,767	9,689,533	14,534,300	19,379,067	24,223,833	29,068,600	33,913,367	38,758,133	43,602,900	48,447,667
Savings at 5% & $50/b	4,614,063	4,394,346	4,185,092	3,985,802	3,796,001	3,615,239	3,443,085	3,279,129	3,122,980	2,974,266
Cum Savings at 5% &	4,614,063	9,008,410	13,193,501	17,179,303	20,975,304	24,590,544	28,033,629	31,312,758	34,435,738	37,410,004
Savings at 0% & $200/	19,379,067	19,379,067	19,379,067	19,379,067	19,379,067	19,379,067	19,379,067	19,379,067	19,379,067	19,379,067
Cum Savings at 0% &	19,379,067	38,758,133	58,137,200	77,516,267	96,895,333	116,274,400	135,653,467	155,032,533	174,411,600	193,790,667
Savings at 5% & $200/	18,456,254	17,577,385	16,740,366	15,943,206	15,184,006	14,460,958	13,772,341	13,116,515	12,491,919	11,897,066
Cum Savings at 5% &	18,456,254	36,033,639	52,774,005	68,717,211	83,901,217	98,362,175	112,134,516	125,251,031	137,742,950	149,640,016
Assume:	0.25	Percent of time > 2300 KW needed								
	0.75	Percent of time < 2300 KW needed								
	15.56%	Prob ship is underway based on 14 underway days per quarter								
	362	avg rate of consumption in gal/hr (conservative estimate at 7 kts at trail shaft)								
	8760	hrs/yr								
	0.0238095	barrel/gal								
	100	Price of fuel in $/barrel								
	50	Price of fuel in $/barrel								
	200	Price of fuel in $/barrel								
	11	# of FLT II DDGs in SD								
	Savings:			$100/barre	$50/barrel	$200/barrel				
	at 0% discount in $/yr/ship=			880,867	440,433	1,761,733				
	at 0% discount in $/yr/SD ships=			9,689,533	4,844,767	19,379,067				

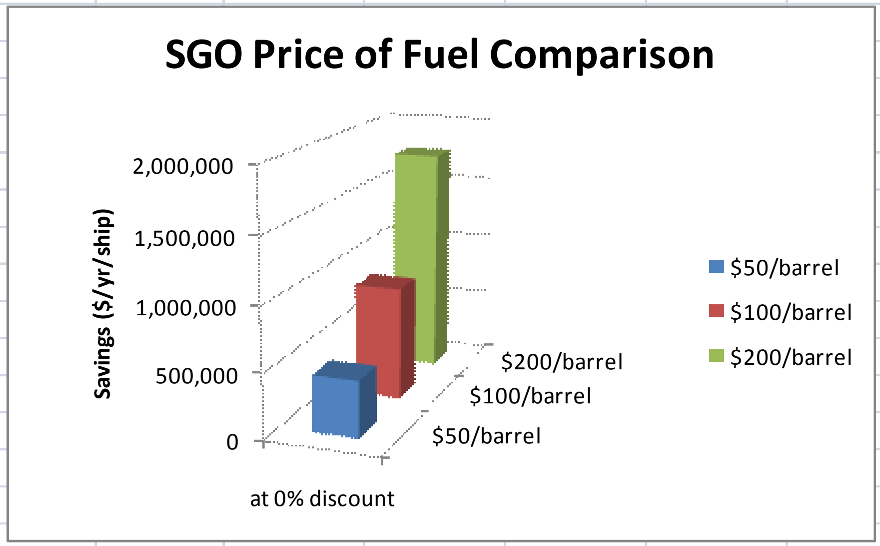
	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18
Cum Savings at 0% &	9,689,533	19,379,067	29,068,600	38,758,133	48,447,667	58,137,200	67,826,733	77,516,267	87,205,800	96,895,333
Cum Savings at 0% &	4,844,767	9,689,533	14,534,300	19,379,067	24,223,833	29,068,600	33,913,367	38,758,133	43,602,900	48,447,667
Cum Savings at 0% &	19,379,067	38,758,133	58,137,200	77,516,267	96,895,333	116,274,400	135,653,467	155,032,533	174,411,600	193,790,667
Cum Savings at 5% &	9,228,127	18,016,819	26,387,003	34,358,606	41,950,609	49,181,087	56,067,258	62,625,515	68,871,475	74,820,008
Cum Savings at 5% &	4,614,063	9,008,410	13,193,501	17,179,303	20,975,304	24,590,544	28,033,629	31,312,758	34,435,738	37,410,004
Cum Savings at 5% &	18,456,254	36,033,639	52,774,005	68,717,211	83,901,217	98,362,175	112,134,516	125,251,031	137,742,950	149,640,016







Savings in $/yr/ship:	$50/barrel	$100/barre	$200/barrel
at 0% discount	440,433	880,867	1,761,733
Increments for stacke	$50/barrel	$100/barre	$200/barrel
Single Generator Ops	440,433	440,433	880,867



APPENDIX D: CALCULATIONS FOR TECHNOLOGIES

FLEET READINESS RESEARCH & DEVELOPMENT PROGRAM (FRR&DP) INVESTMENT PROFILE

PROJECT TITLE: DDG 51/CG 47 CLASS ONLINE WATERWASH INITIATIVE (Development & Implementation)

Development/Implementation Investment
(Enter Millions of *Then Year Dollars*)

Enter Project name	FY08	FY09	FY10	FY11	FY12	FY13	FY14	Sum
DDG/CG ONLINE WATERWASH	0.530	0.300	1.152	1.152	1.152	1.152	1.152	6.590

INVESTMENT PROFILE COMES FROM BCA SPREADSHEET. ADDS ALL INVESTMENT COSTS FOR INSTALLATIONS ON ALL DDG's & CG's OVER IDEAL FIT UP OF 5 YEARS WITH ALL INSTALLATIONS BEING COMPLETE BY FY 14

Total Investment (TY$M)
6.590

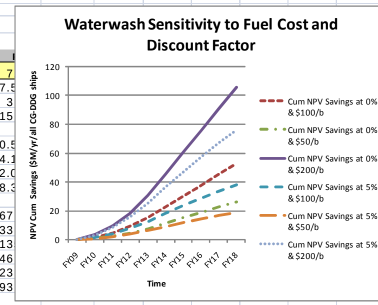
10-Year Discount Factor for Then Year (Nominal) Dollars
5.0%

	FY08	FY09	FY10	FY11	FY12	FY13	FY14
Discount Factors	1.000	0.952	0.907	0.864	0.823	0.784	0.746
Present Value(s) of Investment(s)	0.530	0.286	1.045	0.995	0.948	0.903	0.860
		0.098051	1.435627	2.645592	3.737068	4.718594	5.598168

Total Discounted Investment
5.566

Savings/Cost Avoidance **(Fuel Cost for F-76 $96.16/Barrel)**
(Enter Millions of FY08 *Constant Dollars*)

Project name	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19		FY28
DDG/CG ONLINE WATERWASH	0.000	0.099	1.522	2.945	4.368	5.791	7.214	7.214	7.214	7.214	7.214	7.214	7	7.214
Savings at 0% & $100/barrel	0	0.103	1.5828	3.0626	4.5424	6.0223	7.5021	7.5021	7.5021	7.5021	7.5021	7.5021	7.5	7.5021
Savings at 0% & $50/barrel	0	0.0515	0.7914	1.5313	2.2712	3.0111	3.751	3.751	3.751	3.751	3.751	3.751	3	3.751
Savings at 0% & $200/barrel	0	0.2059	3.1656	6.1252	9.0849	12.045	15.004	15.004	15.004	15.004	15.004	15.004	15	15.004
5.0%														
Discount Factors	1	0.9524	0.907	0.8638	0.8227	0.7835	0.7462	0.7107	0.6768	0.6446	0.6139	0.5847	0.5	0.3769
NPV Savings at 5% & $100/barrel	0	0.0981	1.4356	2.6456	3.7371	4.7186	5.5982	5.3316	5.0777	4.8359	4.6056	4.3863	4.1	2.8275
NPV Savings at 5% & $50/barrel	0	0.049	0.7178	1.3228	1.8685	2.3593	2.7991	2.6658	2.5389	2.418	2.3028	2.1932	2.0	1.4137
NPV Savings at 5% & $200/barrel	0	0.1961	2.8713	5.2912	7.4741	9.4372	11.196	10.663	10.155	9.6718	9.2113	8.7726	8.3	5.6549
	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18			
Cum NPV Savings at 0% & $100/b	0	0.103	1.6857	4.7483	9.2908	15.313	22.815	30.317	37.819	45.321	52.823	60.325	67	127.84
Cum NPV Savings at 0% & $50/b	0	0.0515	0.8429	2.3742	4.6454	7.6565	11.408	15.159	18.91	22.661	26.412	30.163	33	63.922
Cum NPV Savings at 0% & $200/b	0	0.2059	3.3715	9.4967	18.582	30.626	45.63	60.634	75.639	90.643	105.65	120.65	13	255.69
Cum NPV Savings at 5% & $100/b	0	0.0981	1.5337	4.1793	7.9163	12.635	18.233	23.565	28.642	33.478	38.084	42.47	46	73.647
Cum NPV Savings at 5% & $50/b	0	0.049	0.7668	2.0896	3.9582	6.3175	9.1165	11.782	14.321	16.739	19.042	21.235	23	36.824
Cum NPV Savings at 5% & $200/b	0	0.1961	3.0674	8.3585	15.833	25.27	36.466	47.129	57.285	66.957	76.168	84.94	93	147.29



Total FYDP Savings/Cost Avoidance (CY$M) (through FY14)
21.939

Total 10 Year Savings/ Cost Avoidance (CY$M) (through FY18)
50.795

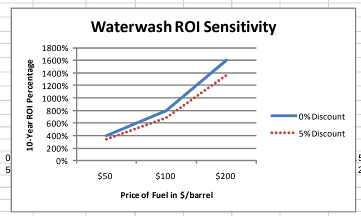
10-Year ROI

	0% Disc	5% Discount
$50	401%	342%
$100	802%	684%
$200	1603%	1369%

Total Life Cycle Savings/Cost Avoidance (CY$M)
122.935

10-Year Discount Factor for Constant (Real) Dollars
2.8%

	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19			
Discount Factors	1.000	0.973	0.946	0.920	0.895	0.871	0.847	0.824	0.802	0.780	0.759	0.738	0	592	0.576
Present Values of Savings/Cost Avoidances	0.000	0.096	1.440	2.711	3.911	5.044	6.112	5.946	5.784	5.626	5.473	5.324	5	269	4.153



Total FYDP Discounted Savings/Cost Avoidance (through FY14)
19.315

Total 10 Year Discounted Savings/Cost Avoidance (through FY18)
42.145

Convert to $K

Total Life Cycle Discounted Savings/Cost Avoidance
89.313

Savings

	$100/barrel		$50/barrel		$200/barrel	
	Total 10-Yr at 0%	5%	Total 10-Yr at 0%	5%	Total 10-Yr at 0%	5%
	52.823	38.084	26.412	19.042	105.65	76.168
	52823	38084	26412	19042	105647	76168

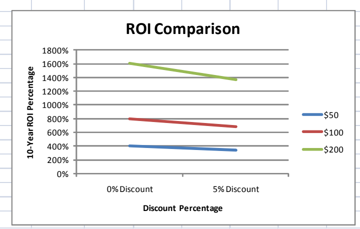
ROI (FYDP)
3.47

ROI (10 Year)
7.57

ROI

$100/barrel		$50/barrel		$200/barrel	
10-Yr ROI at 0%	10-Yr ROI at 5%	0%	5%	0%	5%
802%	684%	401%	342%	1603%	1369%

ROI (LCC)
16.05



FLEET READINESS RESEARCH & DEVELOPMENT PROGRAM (FRR&DP) INVESTMENT PROFILE

PROJECT TITLE: DDG-51 CLASS U/W HULL COATING INITIATIVE (Development & Implementation)

Development/Implementation Investment
(Enter Millions of *Then Year Dollars*)

Enter Project name	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	Sum
DDG CLASS U/W Hull Coating	0.572	0.247	0.665	0.484	3.400	3.400	3.400	3.400	3.400	18.968

INVESTMENT PROFILE COMES FROM BCA SPREADSHEET. ADDS ALL INVESTMENT COSTS FOR INSTALLATIONS ON ALL DDG,s OVER IDEAL FIT UP OF 5 YEARS WITH ALL INSTALLATIONS BEING COMPLETE BY FY 16

Total Investment (TY$M)
15.568

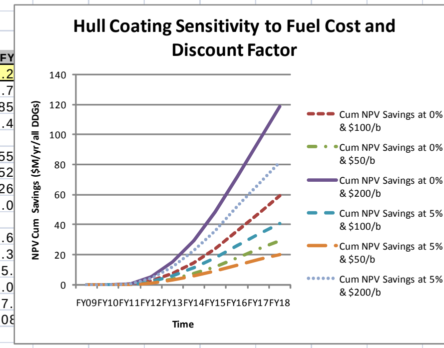
10-Year Discount Factor for Then Year (Nominal) Dollars
5.0%

	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16
Discount Factors	1.000	0.952	0.907	0.864	0.823	0.784	0.746	0.711	0.677
Present Value(s) of Investment(s)	0.572	0.235	0.603	0.418	2.797	2.664	2.537	2.416	2.301

Total Discounted Investment
12.243

Savings/Cost Avoidance (Fuel Cost for F-76 $127.68/Barrel)
(Enter Millions of FY08 *Constant Dollars*)

Project name	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY	Y28	FY29
DDG CLASS U/W Hull Coating	0.000	0.000	0.000	0.221	2.429	4.638	6.846	9.055	11.263	11.263	11.263	11.263	11.2	263	11.263
Savings at 0% & $100/barrel	0	0	0	0.2298	2.526	4.8232	7.1194	9.4166	11.713	11.713	11.713	11.713	11.7	713	11.713
Savings at 0% & $50/barrel	0	0	0	0.1149	1.263	2.4116	3.5597	4.7083	5.8564	5.8564	5.8564	5.8564	5.85	564	5.8564
Savings at 0% & $200/barrel	0	0	0	0.4597	5.052	9.6464	14.239	18.833	23.426	23.426	23.426	23.426	23.4	426	23.426
5.0%															
Discount Factors	1	0.9524	0.907	0.8638	0.8227	0.7835	0.7462	0.7107	0.6768	0.6446	0.6139	0.5847	0.55	769	0.3589
NPV Savings at 5% & $100/barrel	0	0	0	0.1985	2.0781	3.7791	5.3126	6.6922	7.9277	7.5502	7.1906	6.8482	6.52	144	4.2042
NPV Savings at 5% & $50/barrel	0	0	0	0.0993	1.0391	1.8896	2.6563	3.3461	3.9638	3.7751	3.5953	3.4241	3.26	072	2.1021
NPV Savings at 5% & $200/barrel	0	0	0	0.3971	4.1563	7.5582	10.625	13.384	15.855	15.1	14.381	13.696	13.0	288	8.4084
	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18				
Cum NPV Savings at 0% & $100/b	0	0	0	0.2298	2.7558	7.579	14.698	24.115	35.828	47.541	59.253	70.966	82.6	.38	188.09
Cum NPV Savings at 0% & $50/b	0	0	0	0.1149	1.3779	3.7895	7.3492	12.058	17.914	23.77	29.627	35.483	41.3	191	94.047
Cum NPV Savings at 0% & $200/b	0	0	0	0.4597	5.5116	15.158	29.397	48.23	71.656	95.081	118.51	141.93	165.	.76	376.19
Cum NPV Savings at 5% & $100/b	0	0	0	0.1985	2.2767	6.0558	11.368	18.061	25.988	33.538	40.729	47.577	54.0	253	100.46
Cum NPV Savings at 5% & $50/b	0	0	0	0.0993	1.1383	3.0279	5.6842	9.0303	12.994	16.769	20.365	23.789	27.	127	50.229
Cum NPV Savings at 5% & $200/b	0	0	0	0.3971	4.5534	12.112	22.737	36.121	51.976	67.077	81.458	95.154	108	.51	200.91



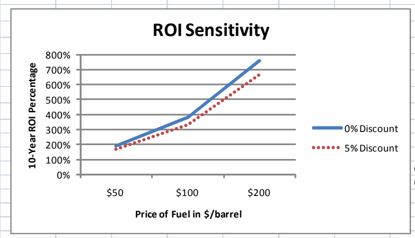
Total FYDP Savings/Cost Avoidance (CY$M) (through FY14)
14.134

Total 10 Year Savings/ Cost Avoidance (CY$M) (through FY18)
56.978

10-Year ROI

	0% Disc	5% Discount
$50	190%	166%
$100	381%	333%
$200	761%	665%

Total Life Cycle Savings/Cost Avoidance (CY$M)
180.871



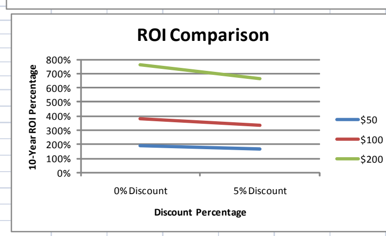
10-Year Discount Factor for Constant (Real) Dollars
2.8%

	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY28	FY29
Discount Factors	1.000	0.973	0.946	0.920	0.895	0.871	0.847	0.824	0.802	0.780	0.759	0.738	0.718	0.576	0.560
Present Values of Savings/Cost Avoidances	0.000	0.000	0.000	0.203	2.175	4.040	5.801	7.463	9.030	8.784	8.545	8.312	8.086	6.483	6.307

Total FYDP Discounted Savings/Cost Avoidance (through FY14)
19.682

Total 10 Year Discounted Savings/Cost Avoidance (through FY18)
46.042

Total Life Cycle Discounted Savings/Cost Avoidance
125.991



Savings

	$100/barrel		$50/barrel		$200/barrel	
	Total 10-Yr at 0%	5%	Total 10-Yr at 0%	5%	Total 10-Yr at 0%	5%
	59.253	40.729	29.627	20.365	118.51	81.458

ROI (FYDP)
1.61

ROI (10 Year)
3.76

ROI

	$100/barrel		$50/barrel		$200/barrel	
	10-Yr ROI at 0%	10-Yr ROI at 5%	0%	5%	0%	5%
	381%	333%	190%	166%	761%	665%

ROI (LCC)
10.29

FLEET READINESS RESEARCH & DEVELOPMENT PROGRAM (FRR&DP) INVESTMENT PROFILE

PROJECT TITLE: LHD-1/LHA-1/LPD-4 CLASS PROPELLER COATING INITIATIVE (Development & Implementation)

Development/Implementation Investment
(Enter Millions of *Then Year Dollars*)

Enter Project name	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	Sum
LHD-1/LHA-1/LPD-4 PROP COATING	0.546	0.345	0.402	0.390	0.390	0.390	0.390	0.390	3.243

INVESTMENT PROFILE COMES FROM BCA SPREADSHEET. ADDS ALL INVESTMENT COSTS FOR INSTALLATIONS ON ALL LHDs/LHAs/LPDs (21 Total) OVER IDEAL FIT UP OF 5 YEARS WITH ALL INSTALLATIONS BEING COMPLETE BY FY 15

Total Investment (TY$M)
3.243

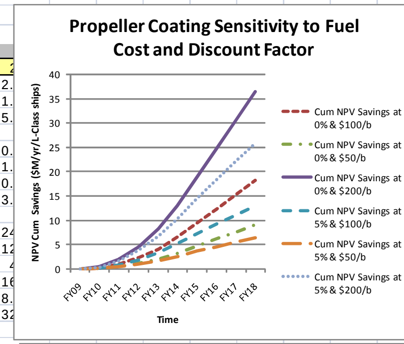
10-Year Discount Factor for Then Year (Nominal) Dollars
5.0%

Discount Factors	1.000	0.952	0.907	0.864	0.823	0.784	0.746	0.711
Present Value(s) of Investment(s)	0.546	0.329	0.365	0.337	0.321	0.306	0.291	0.277

Total Discounted Investment
2.771

Savings/Cost Avoidance **(Fuel Cost for F-76 $96.16/Barrel)**
(Enter Millions of FY08 *Constant Dollars*)

Project name	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19		
LHD-1/LHA-1/LPD-4 PROP COATING	0.000	0.000	0.202	0.726	1.250	1.774	2.299	2.823	2.823	2.823	2.823	2.823	2	3
Savings at 0% & $100/barrel	0	0	0.2101	0.755	1.2999	1.8448	2.3908	2.9357	2.9357	2.9357	2.9357	2.936	2.	6
Savings at 0% & $50/barrel	0	0	0.105	0.3775	0.65	0.9224	1.1954	1.4679	1.4679	1.4679	1.4679	1.468	1.	8
Savings at 0% & $200/barrel	0	0	0.4201	1.51	2.5998	3.6897	4.7816	5.8715	5.8715	5.8715	5.8715	5.871	5.	1
5.0%														
Discount Factors	1	0.9524	0.907	0.8638	0.8227	0.7835	0.7462	0.7107	0.6768	0.6446	0.6139	0.585	0.	7
NPV Savings at 5% & $100/barrel	0	0	0.1905	0.6522	1.0694	1.4455	1.7841	2.0864	1.987	1.8924	1.8023	1.716	1.	6
NPV Savings at 5% & $50/barrel	0	0	0.0953	0.3261	0.5347	0.7227	0.892	1.0432	0.9935	0.9462	0.9011	0.858	0.	3
NPV Savings at 5% & $200/barrel	0	0	0.3811	1.3044	2.1389	2.891	3.5681	4.1727	3.974	3.7848	3.6046	3.433	3.	3
	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18			
Cum NPV Savings at 0% & $100/b	0	0	0.2101	0.9651	2.265	4.1098	6.5006	9.4364	12.372	15.308	18.244	21.18	24	6
Cum NPV Savings at 0% & $50/b	0	0	0.105	0.4825	1.1325	2.0549	3.2503	4.7182	6.186	7.6539	9.1218	10.59	12	8
Cum NPV Savings at 0% & $200/b	0	0	0.4201	1.9301	4.53	8.2196	13.001	18.873	24.744	30.616	36.487	42.36	4	2
Cum NPV Savings at 5% & $100/b	0	0	0.1905	0.8427	1.9122	3.3577	5.1417	7.2281	9.2151	11.107	12.91	14.63	16	3
Cum NPV Savings at 5% & $50/b	0	0	0.0953	0.4214	0.9561	1.6788	2.5709	3.614	4.6075	5.5537	6.4549	7.313	8.	1
Cum NPV Savings at 5% & $200/b	0	0	0.3811	1.6855	3.8243	6.7153	10.283	14.456	18.43	22.215	25.82	29.25	32	5



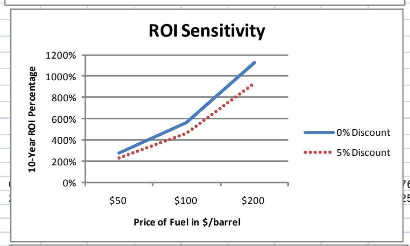
Total FYDP Savings/Cost Avoidance (CY$M) (through FY14)
6.251

Total 10 Year Savings/ Cost Avoidance (CY$M) (through FY18)
17.543

Total Life Cycle Savings/Cost Avoidance (CY$M)
45.773

10-Year ROI

	0% Disc	5% Discount
$50	281%	233%
$100	563%	466%
$200	1125%	932%



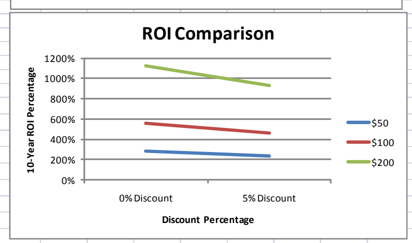
10-Year Discount Factor for Constant (Real) Dollars
2.8%

Discount Factors	1.000	0.973	0.946	0.920	0.895	0.871	0.847	0.824	0.802	0.780	0.759	0.738	(	76
Present Values of Savings/Cost Avoidances	0.000	0.000	0.191	0.668	1.119	1.545	1.948	2.327	2.263	2.202	2.142	2.083	2	25

Total FYDP Discounted Savings/Cost Avoidance (through FY14)
5.472

Total 10 Year Discounted Savings/Cost Avoidance (through FY18)
14.406

Total Life Cycle Discounted Savings/Cost Avoidance
32.864



ROI (FYDP)
1.97

ROI (10 Year)
5.20

ROI (LCC)
11.86

Savings

$100/barrel		$50/barrel		$200/barrel	
Total 10-Yr at 0%	5%	Total 10-Yr at 0%	5%	Total 10-Yr at 0%	5%
18.244	12.91	9.1218	6.4549	36.487	25.82

ROI

$100/barrel		$50/barrel		$200/barrel	
10-Yr ROI at 0%	10-Yr ROI at 5%	0%	5%	0%	5%
563%	466%	281%	233%	1125%	932%

FLEET READINESS RESEARCH & DEVELOPMENT PROGRAM (FRR&DP) INVESTMENT PROFILE

PROJECT TITLE: LHD-1/LHA-1 CLASS TRIM LOOP INITIATIVE (Development & Implementation)

Development/Implementation Investment
(Enter Millions of *Then Year Dollars*)

Enter Project name	FY08	FY09	FY10	FY11	FY12	FY13	FY14	Sum
LHD-1/LHA-1 CLASS TRIM LOOP	0.350	0.085	0.213	0.213	0.213	0.213	0.213	1.500

INVESTMENT PROFILE COMES FROM BCA SPREADSHEET. ADDS ALL INVESTMENT COSTS FOR INSTALLATIONS ON ALL LHDs/LHAs OVER IDEAL FIT UP OF 5 YEARS WITH ALL INSTALLATIONS BEING COMPLETE BY FY 14

Total Investment (TY$M)
1.500

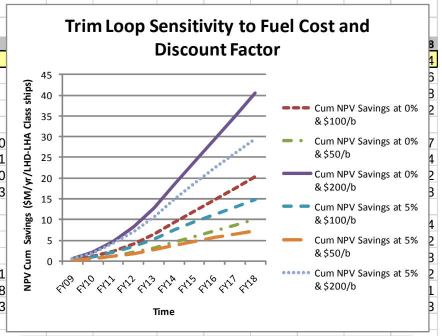
10-Year Discount Factor for Then Year (Nominal) Dollars
5.0%

Discount Factors	1.000	0.952	0.907	0.864	0.823	0.784	0.746
Present Value(s) of Investment(s)	0.350	0.081	0.193	0.184	0.175	0.167	0.159

Total Discounted Investment
1.309

Savings/Cost Avoidance **(Fuel Cost for F-76 $96.16/Barrel)**
(Enter Millions of FY08 *Constant Dollars*)

Project name	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19		
LHD-1/LHA-1 CLASS TRIM LOOP	0.000	0.295	0.767	1.239	1.710	2.182	2.654	2.654	2.654	2.654	2.654	2.654		4
Savings at 0% & $100/barrel	0	0.3068	0.7976	1.2885	1.7783	2.2691	2.76	2.76	2.76	2.76	2.76	2.76		6
Savings at 0% & $50/barrel	0	0.1534	0.3988	0.6442	0.8891	1.1346	1.38	1.38	1.38	1.38	1.38	1.38		3
Savings at 0% & $200/barrel	0	0.6136	1.5953	2.577	3.5566	4.5383	5.52	5.52	5.52	5.52	5.52	5.52		2
5.0%														
Discount Factors	1	0.9524	0.907	0.8638	0.8227	0.7835	0.7462	0.7107	0.6768	0.6446	0.6139	0.585	0	7
NPV Savings at 5% & $100/barrel	0	0.2922	0.7235	1.113	1.463	1.7779	2.0595	1.9615	1.8681	1.7791	1.6944	1.614	1	4
NPV Savings at 5% & $50/barrel	0	0.1461	0.3617	0.5565	0.7315	0.889	1.0298	0.9807	0.934	0.8896	0.8472	0.807	0	2
NPV Savings at 5% & $200/barrel	0	0.5843	1.4469	2.2261	2.926	3.5559	4.1191	3.9229	3.7361	3.5582	3.3888	3.227	3	3
	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18			
Cum NPV Savings at 0% & $100/b	0	0.3068	1.1044	2.3929	4.1712	6.4403	9.2003	11.96	14.72	17.48	20.24	23		4
Cum NPV Savings at 0% & $50/b	0	0.1534	0.5522	1.1964	2.0856	3.2202	4.6001	5.9801	7.3601	8.7401	10.12	11.5		2
Cum NPV Savings at 0% & $200/b	0	0.6136	2.2088	4.7858	8.3423	12.881	18.401	23.921	29.441	34.96	40.48	46		3
Cum NPV Savings at 5% & $100/b	0	0.2922	1.0156	2.1287	3.5917	5.3696	7.4291	9.3906	11.259	13.038	14.732	16.35	1	2
Cum NPV Savings at 5% & $50/b	0	0.1461	0.5078	1.0643	1.7958	2.6848	3.7146	4.6953	5.6293	6.5189	7.3661	8.173	8	1
Cum NPV Savings at 5% & $200/b	0	0.5843	2.0313	4.2574	7.1834	10.739	14.858	18.781	22.517	26.076	29.464	32.69	3	3



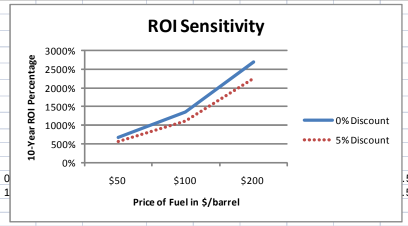
Total FYDP Savings/Cost Avoidance (CY$M) (through FY14)
8.847

Total 10 Year Savings/ Cost Avoidance (CY$M) (through FY18)
19.463

Total Life Cycle Savings/Cost Avoidance (CY$M)
46.003

10-Year ROI

	0% Disc	5% Discount
$50	675%	563%
$100	1349%	1125%
$200	2699%	2251%



10-Year Discount Factor for Constant (Real) Dollars
2.8%

Discount Factors	1.000	0.973	0.946	0.920	0.895	0.871	0.847	0.824	0.802	0.780	0.759	0.738	0	.576
Present Values of Savings/Cost Avoidances	0.000	0.287	0.726	1.140	1.531	1.901	2.249	2.188	2.128	2.070	2.014	1.959	1	.528

Total FYDP Discounted Savings/Cost Avoidance (through FY14)
7.834

Total 10 Year Discounted Savings/Cost Avoidance (through FY18)
16.233

Total Life Cycle Discounted Savings/Cost Avoidance
33.586

ROI (FYDP)
5.98

ROI (10 Year)
12.40

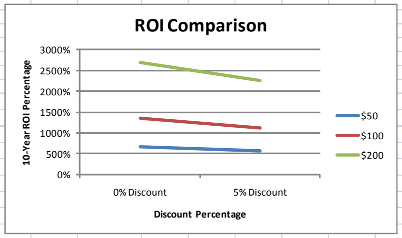
ROI (LCC)
25.65

Savings

$100/barrel		$50/barrel		$200/barrel	
Total 10-Yr at 0%	5%	Total 10-Yr at 0%	5%	Total 10-Yr at 0%	5%
20.24	14.732	10.12	7.3661	40.48	29.46

ROI

$100/barrel		$50/barrel		$200/barrel	
10-Yr ROI at 0%	10-Yr ROI at 5%	0%	5%	0%	5%
1349%	1125%	675%	563%	2699%	2251%



FLEET READINESS RESEARCH & DEVELOPMENT PROGRAM (FRR&DP) INVESTMENT PROFILE

PROJECT TITLE: DDG-51 CLASS HULL ASSESSMENT TOOL (HAT) INITIATIVE (Development & Implementation)

Development/Implementation Investment
(Enter Millions of *Then Year Dollars*)

Enter Project name	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	Sum
DDG-51 CLASS HAT	0.286	0.242	0.121	1.500	1.500	1.500	1.500	1.500	8.149

INVESTMENT PROFILE COMES FROM BCA SPREADSHEET. ADDS ALL INVESTMENT COSTS FOR INSTALLATIONS ON ALL DDG's OVER IDEAL FIT UP OF 5 YEARS WITH ALL INSTALLATIONS BEING COMPLETE BY FY 16

Total Investment (TY$M)
8.149

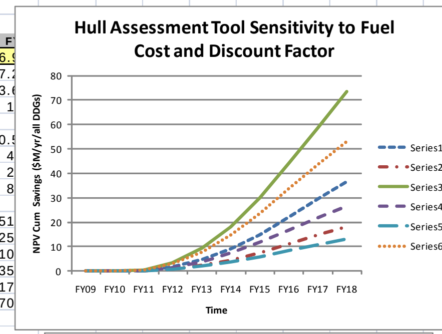
10-Year Discount Factor for Then Year (Nominal) Dollars
5.0%

	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16
Discount Factors	1.000	0.952	0.907	0.864	0.823	0.784	0.746	0.711
Present Value(s) of Investment(s)	0.286	0.230	0.110	1.296	1.234	1.175	1.119	1.066

Total Discounted Investment
6.517

Savings/Cost Avoidance **(Fuel Cost for F-76 $127.68/Barrel)**
(Enter Millions of FY08 *Constant Dollars*)

Project name	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	F	29
DDG-51 CLASS HAT	0.000	0.000	0.137	1.504	2.871	4.238	5.605	6.973	6.973	6.973	6.973	6.9	73
Savings at 0% & $100/barrel	0	0	0.1425	1.5641	2.9856	4.4072	5.8288	7.2515	7.2515	7.2515	7.2515	7.2	51
Savings at 0% & $50/barrel	0	0	0.0712	0.782	1.4928	2.2036	2.9144	3.6257	3.6257	3.6257	3.6257	3.6	26
Savings at 0% & $200/barrel	0	0	0.2849	3.1281	5.9713	8.8145	11.658	14.503	14.503	14.503	14.503	1	.5
5.0%													
Discount Factors	1	0.9524	0.907	0.8638	0.8227	0.7835	0.7462	0.7107	0.6768	0.6446	0.6139	0.5	77
NPV Savings at 5% & $100/barrel	0	0	0.1292	1.3511	2.4563	3.4532	4.3496	5.1535	4.9081	4.6744	4.4518	4	33
NPV Savings at 5% & $50/barrel	0	0	0.0646	0.6755	1.2282	1.7266	2.1748	2.5767	2.454	2.3372	2.2259	2	66
NPV Savings at 5% & $200/barrel	0	0	0.2585	2.7022	4.9126	6.9064	8.6991	10.307	9.8161	9.3487	8.9035	8	66
	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18			
Cum NPV Savings at 0% & $100/b	0	0	0.1425	1.7065	4.6922	9.0994	14.928	22.18	29.431	36.683	43.934	51	.4
Cum NPV Savings at 0% & $50/b	0	0	0.0712	0.8533	2.3461	4.5497	7.4641	11.09	14.716	18.341	21.967	25	22
Cum NPV Savings at 0% & $200/b	0	0	0.2849	3.4131	9.3844	18.199	29.856	44.359	58.862	73.365	87.868	10	.9
Cum NPV Savings at 5% & $100/b	0	0	0.1292	1.4803	3.9366	7.3898	11.739	16.893	21.801	26.475	30.927	35	.3
Cum NPV Savings at 5% & $50/b	0	0	0.0646	0.7402	1.9683	3.6949	5.8697	8.4464	10.9	13.238	15.464	17	65
Cum NPV Savings at 5% & $200/b	0	0	0.2585	2.9606	7.8732	14.78	23.479	33.786	43.602	52.951	61.854	70	.6



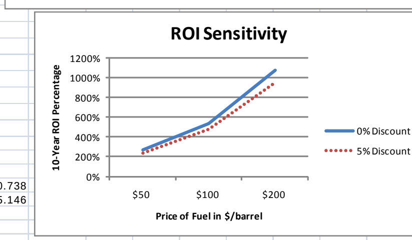
Total FYDP Savings/Cost Avoidance (CY$M) (through FY14)
8.750

Total 10 Year Savings/ Cost Avoidance (CY$M) (through FY18)
35.274

10-Year ROI

	0% Disc	5% Discount
$50	270%	237%
$100	539%	475%
$200	1078%	949%

Total Life Cycle Savings/Cost Avoidance (CY$M)
111.977



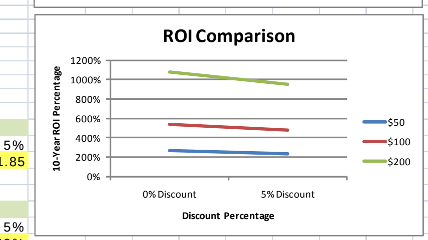
10-Year Discount Factor for Constant (Real) Dollars
2.8%

Discount Factors	1.000	0.973	0.946	0.920	0.895	0.871	0.847	0.824	0.802	0.780	0.759	0.738	0.576
Present Values of Savings/Cost Avoidances	0.000	0.000	0.130	1.384	2.571	3.691	4.749	5.747	5.591	5.439	5.290	5.146	4.014

Total FYDP Discounted Savings/Cost Avoidance (through FY14)
7.776

Total 10 Year Discounted Savings/Cost Avoidance (through FY18)
29.302

Total Life Cycle Discounted Savings/Cost Avoidance
80.185



Savings

	$100/barrel		$50/barrel		$200/barrel	
	Total 10-Yr at 0%	5%	Total 10-Yr at 0%	5%	Total 10-Yr at 0%	5%
	43.934	30.927	21.967	15.464	87.868	61.85

ROI (FYDP)
1.19

ROI (10 Year)
4.50

ROI

	$100/barrel		$50/barrel		$200/barrel	
	10-Yr ROI at 0%	10-Yr ROI at 5%	0%	5%	0%	5%
	539%	475%	270%	237%	1078%	949%

ROI (LCC)
12.30

FLEET READINESS RESEARCH & DEVELOPMENT PROGRAM (FRR&DP) INVESTMENT PROFILE

PROJECT TITLE: LSD-41/49 CLASS SOLID STATE LIGHTING (SSL) INITIATIVE (Development & Implementation)

Development/Implementation Investment
(Enter Millions of *Then Year Dollars*)

Enter Project name	FY09	FY10	FY11	FY12	FY13	FY14	FY15	Sum
LSD Class SSL	0.550	0.374	1.203	1.203	1.203	1.203	1.203	6.939

INVESTMENT PROFILE COMES FROM BCA SPREADSHEET. ADDS ALL INVESTMENT COSTS FOR INSTALLATIONS ON ALL LSD's OVER IDEAL FIT UP OF 5 YEARS WITH ALL INSTALLATIONS BEING COMPLETE BY FY 15

Total Investment (TY$M)
6.939

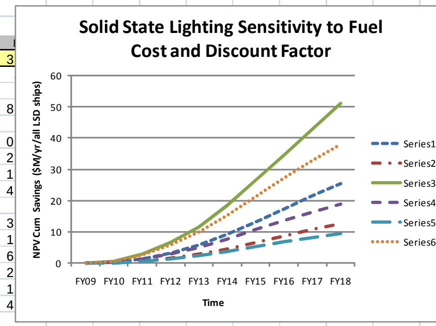
10-Year Discount Factor for Then Year (Nominal) Dollars
5.0%

	FY09	FY10	FY11	FY12	FY13	FY14	FY15
Discount Factors	1.000	0.952	0.907	0.864	0.823	0.784	0.746
Present Value(s) of Investment(s)	0.550	0.356	1.091	1.039	0.990	0.943	0.898

Total Discounted Investment
5.867

Savings/Cost Avoidance (Fuel Cost for F-76 $127.68/Barrel)
(Enter Millions of FY08 *Constant Dollars*)

Project name	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19		
LSD Class SSL	0.000	0.327	1.046	1.765	2.484	3.204	3.923	3.923	3.923	3.923	3.923	3	23
Savings at 0% & $100/barrel	0	0.3401	1.0878	1.8355	2.5832	3.3319	4.0797	4.0797	4.0797	4.0797	4.0797		08
Savings at 0% & $50/barrel	0	0.17	0.5439	0.9177	1.2916	1.666	2.0398	2.0398	2.0398	2.0398	2.0398		04
Savings at 0% & $200/barrel	0	0.6801	2.1755	3.671	5.1664	6.6639	8.1593	8.1593	8.1593	8.1593	8.1593	8	59
5.0%													
Discount Factors	1	0.9524	0.907	0.8638	0.8227	0.7835	0.7462	0.7107	0.6768	0.6446	0.6139	0	77
NPV Savings at 5% & $100/barrel	0	0.3239	0.9866	1.5856	2.1252	2.6107	3.0443	2.8993	2.7613	2.6298	2.5046	2	38
NPV Savings at 5% & $50/barrel	0	0.1619	0.4933	0.7928	1.0626	1.3053	1.5222	1.4497	1.3806	1.3149	1.2523	1	69
NPV Savings at 5% & $200/barrel	0	0.6477	1.9733	3.1711	4.2504	5.2213	6.0886	5.7987	5.5225	5.2596	5.0091	4	75
	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18			
Cum NPV Savings at 0% & $100/b	0	0.3401	1.4278	3.2633	5.8465	9.1785	13.258	17.338	21.417	25.497	29.577	3	37
Cum NPV Savings at 0% & $50/b	0	0.17	0.7139	1.6317	2.9233	4.5892	6.6291	8.6689	10.709	12.749	14.788	1	19
Cum NPV Savings at 0% & $200/b	0	0.6801	2.8557	6.5266	11.693	18.357	26.516	34.676	42.835	50.994	59.153	6	.7
Cum NPV Savings at 5% & $100/b	0	0.3239	1.3105	2.8961	5.0213	7.6319	10.676	13.576	16.337	18.967	21.471	2	81
Cum NPV Savings at 5% & $50/b	0	0.1619	0.6553	1.448	2.5106	3.816	5.3381	6.7878	8.1684	9.4833	10.736	1	41
Cum NPV Savings at 5% & $200/b	0	0.6477	2.621	5.7921	10.043	15.264	21.352	27.151	32.674	37.933	42.942	4	62



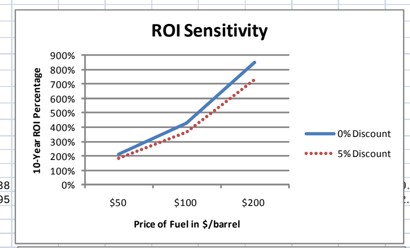
Total FYDP Savings/Cost Avoidance (CY$M) (through FY14)
8.826

Total 10 Year Savings/ Cost Avoidance (CY$M) (through FY18)
24.518

Total Life Cycle Savings/Cost Avoidance (CY$M)
67.671

10-Year ROI

	0% Disc	5% Discount
$50	213%	183%
$100	426%	366%
$200	852%	732%



10-Year Discount Factor for Constant (Real) Dollars
2.8%

Discount Factors	1.000	0.973	0.946	0.920	0.895	0.871	0.847	0.824	0.802	0.780	0.759	0.738	.576
Present Values of Savings/Cost Avoidances	0.000	0.318	0.990	1.625	2.224	2.791	3.324	3.233	3.145	3.060	2.976	2.895	.258

Total FYDP Discounted Savings/Cost Avoidance (through FY14)
7.948

Total 10 Year Discounted Savings/Cost Avoidance (through FY18)
20.710

Total Life Cycle Discounted Savings/Cost Avoidance
49.337

ROI (FYDP)
1.35

ROI (10 Year)
3.53

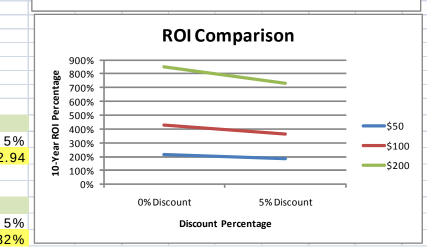
ROI (LCC)
8.41

Savings

$100/barrel		$50/barrel		$200/barrel	
Total 10-Yr at 0%	5%	Total 10-Yr at 0%	5%	Total 10-Yr at 0%	5%
29.577	21.471	14.788	10.736	59.153	42.94

ROI

$100/barrel		$50/barrel		$200/barrel	
10-Yr ROI at 0%	10-Yr ROI at 5%	0%	5%	0%	5%
426%	366%	213%	183%	852%	732%



FLEET READINESS RESEARCH & DEVELOPMENT PROGRAM (FRR&DP) INVESTMENT PROFILE

PROJECT TITLE: LSD-41/49 CLASS COMMON RAIL EFI INITIATIVE (Development & Implementation)

Development/Implementation Investment
(Enter Millions of *Then Year Dollars*)

Enter Project name	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	Sum
LSD-41/49 EFI	1.318	3.072	0.561	5.170	5.170	5.170	5.170	5.170	30.801

INVESTMENT PROFILE COMES FROM BCA SPREADSHEET. ADDS ALL INVESTMENT COSTS FOR INSTALLATIONS ON ALL LSD-41/49 OVER IDEAL FIT UP OF 5 YEARS WITH ALL INSTALLATIONS BEING COMPLETE BY FY 16

Total Investment (TY$M)
30.801

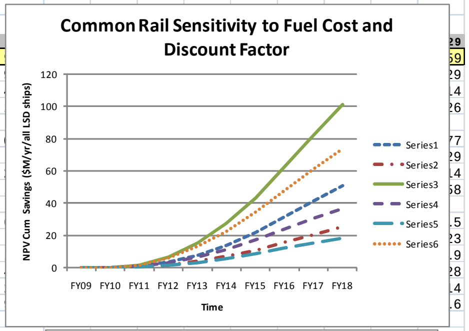
10-Year Discount Factor for Then Year (Nominal) Dollars
5.0%

	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16
Discount Factors	1.000	0.952	0.907	0.864	0.823	0.784	0.746	0.711
Present Value(s) of Investment(s)	1.318	2.926	0.509	4.466	4.253	4.051	3.858	3.674

Total Discounted Investment
25.055

Savings/Cost Avoidance
(Fuel Cost for F-76 $127.68/Barrel)
(Enter Millions of FY08 *Constant Dollars*)

Project name	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19
LSD-41/49 EFI	0.000	0.000	0.772	2.469	4.167	5.864	7.562	9.259	9.259	9.259	9.259
Savings at 0% & $100/barrel	0	0	0.8028	2.5676	4.3334	6.0982	7.864	9.6287	9.6287	9.6287	9.6287
Savings at 0% & $50/barrel	0	0	0.4014	1.2838	2.1667	3.0491	3.932	4.8144	4.8144	4.8144	4.8144
Savings at 0% & $200/barrel	0	0	1.6057	5.1352	8.6668	12.196	15.728	19.257	19.257	19.257	19.257
5.0%											
Discount Factors	1	0.9524	0.907	0.8638	0.8227	0.7835	0.7462	0.7107	0.6768	0.6446	0.6139
NPV Savings at 5% & $100/barrel	0	0	0.7282	2.218	3.5651	4.7781	5.8682	6.843	6.5171	6.2068	5.9112
NPV Savings at 5% & $50/barrel	0	0	0.3641	1.109	1.7826	2.389	2.9341	3.4215	3.2586	3.1034	2.9556
NPV Savings at 5% & $200/barrel	0	0	1.4564	4.436	7.1302	9.5562	11.736	13.686	13.034	12.414	11.822
	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	
Cum NPV Savings at 0% & $100/b	0	0	0.8028	3.3704	7.7038	13.802	21.666	31.295	40.923	50.552	60.181
Cum NPV Savings at 0% & $50/b	0	0	0.4014	1.6852	3.8519	6.901	10.833	15.647	20.462	25.276	30.09
Cum NPV Savings at 0% & $200/b	0	0	1.6057	6.7408	15.408	27.604	43.332	62.589	81.847	101.1	120.36
Cum NPV Savings at 5% & $100/b	0	0	0.7282	2.9462	6.5113	11.289	17.158	24.001	30.518	36.724	42.636
Cum NPV Savings at 5% & $50/b	0	0	0.3641	1.4731	3.2556	5.6447	8.5788	12	15.259	18.362	21.318
Cum NPV Savings at 5% & $200/b	0	0	1.4564	5.8923	13.023	22.579	34.315	48.001	61.035	73.449	85.271



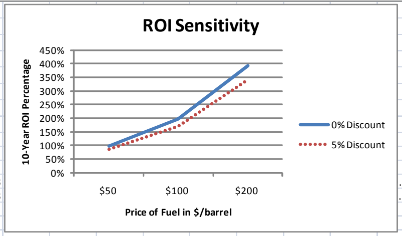
Total FYDP Savings/Cost Avoidance (CY$M) (through FY14)
13.272

Total 10 Year Savings/ Cost Avoidance (CY$M) (through FY18)
48.611

Total Life Cycle Savings/Cost Avoidance (CY$M)
150.460

10-Year ROI

	0% Disc	5% Discount
$50	98%	85%
$100	195%	170%
$200	391%	340%



10-Year Discount Factor for Constant (Real) Dollars
2.8%

Discount Factors	1.000	0.973	0.946	0.920	0.895	0.871	0.847	0.824	0.802	0.780	0.759	0.738
Present Values of Savings/Cost Avoidances	0.000	0.000	0.731	2.273	3.731	5.108	6.407	7.632	7.424	7.221	7.025	6.833

Total FYDP Discounted Savings/Cost Avoidance (through FY14)
11.842

Total 10 Year Discounted Savings/Cost Avoidance (through FY18)
40.526

Total Life Cycle Discounted Savings/Cost Avoidance
108.090

ROI (FYDP)
0.47

ROI (10 Year)
1.62

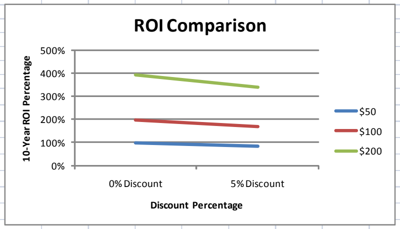
ROI (LCC)
4.31

Savings

$100/barrel		$50/barrel		$200/barrel	
Total 10-Yr at 0%	5%	Total 10-Yr at 0%	5%	Total 10-Yr at 0%	5%
60.181	42.636	30.09	21.318	120.36	85.27

ROI

$100/barrel		$50/barrel		$200/barrel	
10-Yr ROI at 0%	10-Yr ROI at 5%	0%	5%	0%	5%
195%	170%	98%	85%	391%	340%



FLEET READINESS RESEARCH & DEVELOPMENT PROGRAM (FRR&DP) INVESTMENT PROFILE

PROJECT TITLE: LHD 1-7 CLASS STERN FLAP INITIATIVE (Development & Implementation)

Development/Implementation Investment
(Enter Millions of *Then Year Dollars*)

Enter Project name	FY08	FY09	FY10	F11	FY12	FY13	FY14	FY15	Sum
LHD 1-7 STERN FLAP	0.600	0.688	0.150	0.960	0.960	0.960	0.960	0.960	6.238

INVESTMENT PROFILE COMES FROM BCA SPREADSHEET. ADDS ALL INVESTMENT COSTS FOR INSTALLATIONS ON ALL LHDs OVER IDEAL FIT UP OF 5 YEARS WITH ALL INSTALLATIONS BEING COMPLETE BY FY 15

Total Investment (TY$M)
6.238

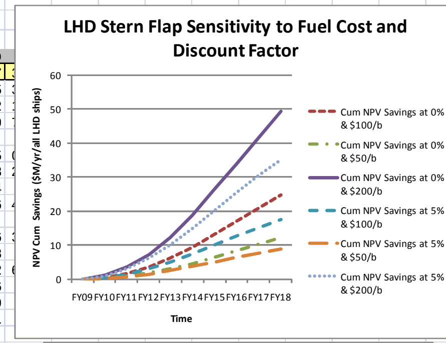
10-Year Discount Factor for Then Year (Nominal) Dollars
5.0%

	FY08	FY09	FY10	F11	FY12	FY13	FY14	FY15
Discount Factors	1.000	0.952	0.907	0.864	0.823	0.784	0.746	0.711
Present Value(s) of Investment(s)	0.600	0.655	0.136	0.829	0.790	0.752	0.716	0.682

Total Discounted Investment
5.161

Savings/Cost Avoidance **(Fuel Cost for F-76 $96.16/Barrel)**
(Enter Millions of FY08 *Constant Dollars*)

Project name	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19
LHD 1-7 STERN FLAP	0.000	0.000	0.528	1.162	1.796	2.430	3.064	3.697	3.697	3.697	3.697	3.697
Savings at 0% & $100/barrel	0	0	0.5491	1.2084	1.8677	2.527	3.1864	3.8446	3.8446	3.8446	3.8446	3.845
Savings at 0% & $50/barrel	0	0	0.2745	0.6042	0.9339	1.2635	1.5932	1.9223	1.9223	1.9223	1.9223	1.922
Savings at 0% & $200/barrel	0	0	1.0982	2.4168	3.7354	5.0541	6.3727	7.6893	7.6893	7.6893	7.6893	7.689
5.0%												
Discount Factors	1	0.9524	0.907	0.8638	0.8227	0.7835	0.7462	0.7107	0.6768	0.6446	0.6139	0.585
NPV Savings at 5% & $100/barrel	0	0	0.498	1.0439	1.5366	1.98	2.3777	2.7323	2.6022	2.4783	2.3603	2.248
NPV Savings at 5% & $50/barrel	0	0	0.249	0.5219	0.7683	0.99	1.1889	1.3662	1.3011	1.2391	1.1801	1.124
NPV Savings at 5% & $200/barrel	0	0	0.9961	2.0877	3.0732	3.96	4.7554	5.4646	5.2044	4.9566	4.7205	4.496
	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	
Cum NPV Savings at 0% & $100/b	0	0	0.5491	1.7575	3.6252	6.1522	9.3386	13.183	17.028	20.873	24.717	28.56
Cum NPV Savings at 0% & $50/b	0	0	0.2745	0.8787	1.8126	3.0761	4.6693	6.5916	8.5139	10.436	12.359	14.28
Cum NPV Savings at 0% & $200/b	0	0	1.0982	3.515	7.2504	12.304	18.677	26.366	34.056	41.745	49.434	57.12
Cum NPV Savings at 5% & $100/b	0	0	0.498	1.5419	3.0785	5.0585	7.4362	10.168	12.771	15.249	17.609	19.86
Cum NPV Savings at 5% & $50/b	0	0	0.249	0.7709	1.5392	2.5292	3.7181	5.0842	6.3853	7.6245	8.8046	9.929
Cum NPV Savings at 5% & $200/b	0	0	0.9961	3.0838	6.157	10.117	14.872	20.337	25.541	30.498	35.219	39.71



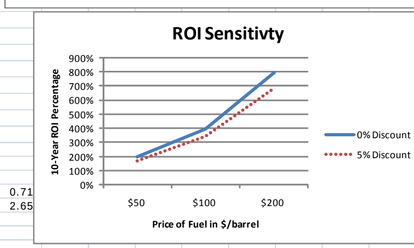
Total FYDP Savings/Cost Avoidance (CY$M) (through FY14)
8.980

Total 10 Year Savings/ Cost Avoidance (CY$M) (through FY18)
23.768

10-Year ROI

	0% Disc	5% Discount
$50	198%	171%
$100	396%	341%
$200	792%	682%

Total Life Cycle Savings/Cost Avoidance (CY$M)
64.435



10-Year Discount Factor for Constant (Real) Dollars
2.8%

Discount Factors	1.000	0.973	0.946	0.920	0.895	0.871	0.847	0.824	0.802	0.780	0.759	0.738	0.71	0.560
Present Values of Savings/Cost Avoidances	0.000	0.000	0.500	1.070	1.608	2.117	2.596	3.047	2.964	2.883	2.805	2.729	2.65	2.070

Total FYDP Discounted Savings/Cost Avoidance (through FY14)
7.890

Total 10 Year Discounted Savings/Cost Avoidance (through FY18)
19.590

Total Life Cycle Discounted Savings/Cost Avoidance
45.832

ROI (FYDP)
1.53

ROI (10 Year)
3.80

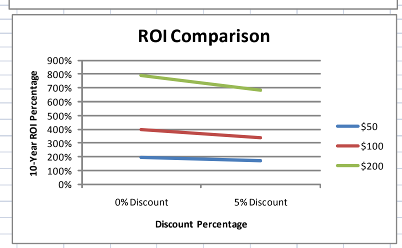
ROI (LCC)
8.88

Savings

$100/barrel		$50/barrel		$200/barrel	
Total 10-Yr at 0%	5%	Total 10-Yr at 0%	5%	Total 10-Yr at 0%	5%
24.717	17.609	12.359	8.8046	49.434	35.22

ROI

$100/barrel		$50/barrel		$200/barrel	
10-Yr ROI at 0%	10-Yr ROI at 5%	0%	5%	0%	5%
396%	341%	198%	171%	792%	682%



FLEET READINESS RESEARCH & DEVELOPMENT PROGRAM (FRR&DP) INVESTMENT PROFILE

PROJECT TITLE: LSD 41-49 CLASS STERN FLAP INITIATIVE (Development & Implementation)

Development/Implementation Investment
(Enter Millions of *Then Year Dollars*)

Enter Project name	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	Sum
LSD 41-49 STERN FLAP	0.500	0.792	0.245	1.760	1.760	1.760	1.760	1.760	10.337

INVESTMENT PROFILE COMES FROM BCA SPREADSHEET. ADDS ALL INVESTMENT COSTS FOR INSTALLATIONS ON ALL LSDs OVER IDEAL FIT UP OF 5 YEARS WITH ALL INSTALLATIONS BEING COMPLETE BY FY 15

Total Investment (TY$M)
10.337

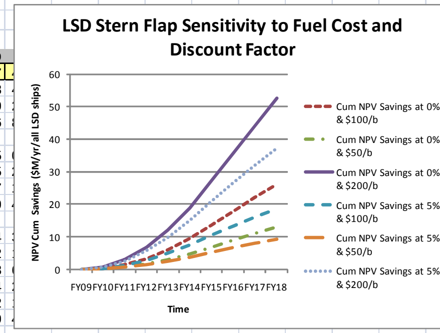
10-Year Discount Factor for Then Year (Nominal) Dollars
5.0%

	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15
Discount Factors	1.000	0.952	0.907	0.864	0.823	0.784	0.746	0.711
Present Value(s) of Investment(s)	0.500	0.754	0.222	1.520	1.448	1.379	1.313	1.251

Total Discounted Investment
8.388

Savings/Cost Avoidance
(Fuel Cost for F-76 $96.16/Barrel)
(Enter Millions of FY08 *Constant Dollars*)

Project name	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	'29
LSD 41-49 STERN FLAP	0.000	0.000	0.336	1.077	1.817	2.557	3.297	4.037	4.037	4.037	4.037	4.037	37
Savings at 0% & $100/barrel	0	0	0.3494	1.12	1.8896	2.6591	3.4287	4.1982	4.1982	4.1982	4.1982	4.198	98
Savings at 0% & $50/barrel	0	0	0.1747	0.56	0.9448	1.3296	1.7143	2.0991	2.0991	2.0991	2.0991	2.099	99
Savings at 0% & $200/barrel	0	0	0.6988	2.24	3.7791	5.3182	6.8573	8.3964	8.3964	8.3964	8.3964	8.396	96
5.0%													
Discount Factors	1	0.9524	0.907	0.8638	0.8227	0.7835	0.7462	0.7107	0.6768	0.6446	0.6139	0.585	59
NPV Savings at 5% & $100/barrel	0	0	0.3169	0.9675	1.5545	2.0835	2.5585	2.9836	2.8415	2.7062	2.5773	2.455	07
NPV Savings at 5% & $50/barrel	0	0	0.1585	0.4838	0.7773	1.0417	1.2793	1.4918	1.4208	1.3531	1.2887	1.227	53
NPV Savings at 5% & $200/barrel	0	0	0.6339	1.935	3.1091	4.167	5.117	5.9672	5.683	5.4124	5.1547	4.909	14
	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18		
Cum NPV Savings at 0% & $100/b	0	0	0.3494	1.4694	3.359	6.0181	9.4468	13.645	17.843	22.041	26.24	30.44	42
Cum NPV Savings at 0% & $50/b	0	0	0.1747	0.7347	1.6795	3.009	4.7234	6.8225	8.9216	11.021	13.12	15.22	21
Cum NPV Savings at 0% & $200/b	0	0	0.6988	2.9389	6.718	12.036	18.894	27.29	35.686	44.083	52.479	60.88	.8
Cum NPV Savings at 5% & $100/b	0	0	0.3169	1.2844	2.839	4.9225	7.481	10.465	13.306	16.012	18.59	21.04	40
Cum NPV Savings at 5% & $50/b	0	0	0.1585	0.6422	1.4195	2.4612	3.7405	5.2323	6.653	8.0061	9.2948	10.52	20
Cum NPV Savings at 5% & $200/b	0	0	0.6339	2.5689	5.678	9.8449	14.962	20.929	26.612	32.025	37.179	42.09	80



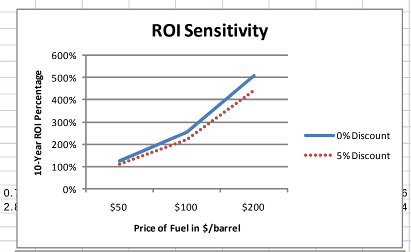
Total FYDP Savings/Cost Avoidance (CY$M) (through FY14)
9.084

Total 10 Year Savings/ Cost Avoidance (CY$M) (through FY18)
25.232

Total Life Cycle Savings/Cost Avoidance (CY$M)
69.639

10-Year ROI

	0% Disc	5% Discount
$50	127%	111%
$100	254%	222%
$200	508%	443%



10-Year Discount Factor for Constant (Real) Dollars
2.8%

	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20		
Discount Factors	1.000	0.973	0.946	0.920	0.895	0.871	0.847	0.824	0.802	0.780	0.759	0.738	0.7	6	0.560
Present Values of Savings/Cost Avoidances	0.000	0.000	0.318	0.991	1.627	2.227	2.794	3.327	3.237	3.149	3.063	2.979	2.8	4	2.260

Total FYDP Discounted Savings/Cost Avoidance (through FY14)
7.957

Total 10 Year Discounted Savings/Cost Avoidance (through FY18)
20.733

Total Life Cycle Discounted Savings/Cost Avoidance
49.389

ROI (FYDP)
0.95

ROI (10 Year)
2.47

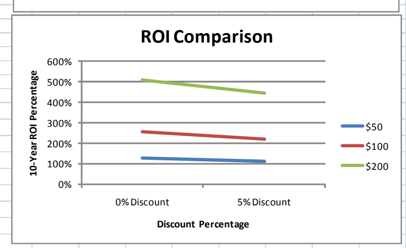
ROI (LCC)
5.89

Savings

$100/barrel		$50/barrel		$200/barrel	
Total 10-Yr at 0%	5%	Total 10-Yr at 0%	5%	Total 10-Yr at 0%	5%
26.24	18.59	13.12	9.2948	52.479	37.18

ROI

$100/barrel		$50/barrel		$200/barrel	
10-Yr ROI at 0%	10-Yr ROI at 5%	0%	5%	0%	5%
254%	222%	127%	111%	508%	443%



FLEET READINESS RESEARCH & DEVELOPMENT PROGRAM (FRR&DP) INVESTMENT PROFILE

PROJECT TITLE: LHD-1 CLASS STEERING & STABILITY (S&S) INITIATIVE (Development & Implementation)

Development/Implementation Investment
(Enter Millions of *Then Year Dollars*)

Enter Project name	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	Sum
LHD CLASS S&S	0.605	1.485	0.440	0.960	0.960	0.960	0.960	0.960	7.330

INVESTMENT PROFILE COMES FROM BCA SPREADSHEET. ADDS ALL INVESTMENT COSTS FOR INSTALLATIONS ON ALL LHD's OVER IDEAL FIT UP OF 5 YEARS WITH ALL INSTALLATIONS BEING COMPLETE BY FY 16

Total Investment (TY$M)
7.330

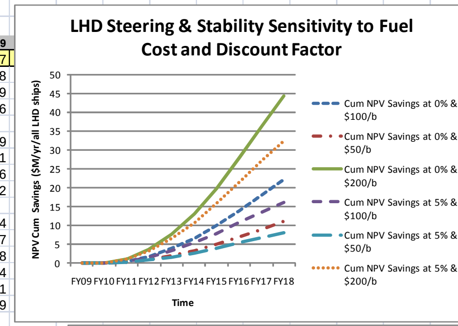
10-Year Discount Factor for Then Year (Nominal) Dollars
5.0%

Discount Factors	1.000	0.952	0.907	0.864	0.823	0.784	0.746	0.711
Present Value(s) of Investment(s)	0.605	1.414	0.399	0.829	0.790	0.752	0.716	0.682

Total Discounted Investment
6.188

Savings/Cost Avoidance **(Fuel Cost for F-76 $127.68/Barrel)**
(Enter Millions of FY08 *Constant Dollars*)

Project name	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19
LHD CLASS S&S	0.000	0.000	0.561	1.234	1.908	2.581	3.254	3.927	3.927	3.927	3.927
Savings at 0% & $100/barrel	0	0	0.5834	1.2833	1.9842	2.6841	3.3839	4.0838	4.0838	4.0838	4.0838
Savings at 0% & $50/barrel	0	0	0.2917	0.6416	0.9921	1.342	1.692	2.0419	2.0419	2.0419	2.0419
Savings at 0% & $200/barrel	0	0	1.1668	2.5666	3.9684	5.3681	6.7679	8.1676	8.1676	8.1676	8.1676
5.0%											
Discount Factors	1	0.9524	0.907	0.8638	0.8227	0.7835	0.7462	0.7107	0.6768	0.6446	0.6139
NPV Savings at 5% & $100/barrel	0	0	0.5292	1.1085	1.6324	2.103	2.5252	2.9023	2.7641	2.6325	2.5071
NPV Savings at 5% & $50/barrel	0	0	0.2646	0.5543	0.8162	1.0515	1.2626	1.4511	1.382	1.3162	1.2536
NPV Savings at 5% & $200/barrel	0	0	1.0583	2.2171	3.2648	4.2061	5.0503	5.8046	5.5282	5.2649	5.0142
	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	
Cum NPV Savings at 0% & $100/b	0	0	0.5834	1.8667	3.8509	6.5349	9.9189	14.003	18.087	22.17	26.254
Cum NPV Savings at 0% & $50/b	0	0	0.2917	0.9333	1.9254	3.2675	4.9594	7.0014	9.0433	11.085	13.127
Cum NPV Savings at 0% & $200/b	0	0	1.1668	3.7334	7.7017	13.07	19.838	28.005	36.173	44.341	52.508
Cum NPV Savings at 5% & $100/b	0	0	0.5292	1.6377	3.2701	5.3731	7.8983	10.801	13.565	16.197	18.704
Cum NPV Savings at 5% & $50/b	0	0	0.2646	0.8189	1.6351	2.6866	3.9491	5.4003	6.7823	8.0986	9.3521
Cum NPV Savings at 5% & $200/b	0	0	1.0583	3.2754	6.5402	10.746	15.797	21.601	27.129	32.394	37.409



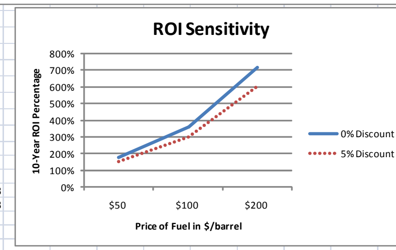
Total FYDP Savings/Cost Avoidance (CY$M) (through FY14)
6.284

Total 10 Year Savings/ Cost Avoidance (CY$M) (through FY18)
21.319

10-Year ROI

	0% Disc	5% Discount
$50	179%	151%
$100	358%	302%
$200	716%	605%

Total Life Cycle Savings/Cost Avoidance (CY$M)
64.516



10-Year Discount Factor for Constant (Real) Dollars
2.8%

Discount Factors	1.000	0.973	0.946	0.920	0.895	0.871	0.847	0.824	0.802	0.780	0.759	0.738
Present Values of Savings/Cost Avoidances	0.000	0.000	0.531	1.136	1.708	2.248	2.757	3.237	3.149	3.063	2.979	2.898

Total FYDP Discounted Savings/Cost Avoidance (through FY14)
5.623

Total 10 Year Discounted Savings/Cost Avoidance (through FY18)
17.829

Total Life Cycle Discounted Savings/Cost Avoidance
46.484

Savings

$100/barrel		$50/barrel		$200/barrel	
Total 10-Yr at 0%	5%	Total 10-Yr at 0%	5%	Total 10-Yr at 0%	5%
26.254	18.704	13.127	9.3521	52.508	37.41

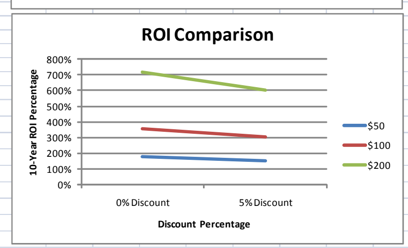
ROI (FYDP)
0.91

ROI (10 Year)
2.88

ROI

$100/barrel		$50/barrel		$200/barrel	
10-Yr ROI at 0%	10-Yr ROI at 5%	0%	5%	0%	5%
358%	302%	179%	151%	716%	605%

ROI (LCC)
7.51



FLEET READINESS RESEARCH & DEVELOPMENT PROGRAM (FRR&DP) INVESTMENT PROFILE

PROJECT TITLE: DDG-51 CLASS VSD MODULE COOLING FAN INITIATIVE (Development & Implementation)

Development/Implementation Investment
(Enter Millions of *Then Year Dollars*)

Enter Project name	FY09	FY10	FY11	FY12	FY13	FY14	FY15	Sum
DDG-51 VSD MCF	0.583	0.427	6.000	6.000	6.000	6.000	6.000	31.010

INVESTMENT PROFILE COMES FROM BCA SPREADSHEET. ADDS ALL INVESTMENT COSTS FOR INSTALLATIONS ON ALL LSD's OVER IDEAL FIT UP OF 5 YEARS WITH ALL INSTALLATIONS BEING COMPLETE BY FY 15

Total Investment (TY$M)
31.010

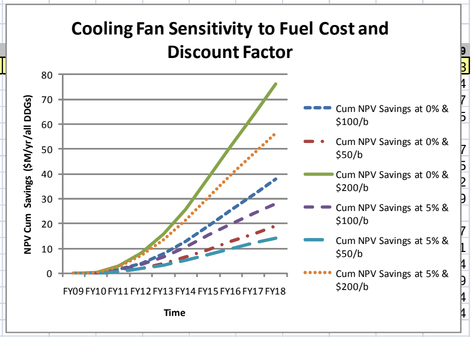
10-Year Discount Factor for Then Year (Nominal) Dollars
5.0%

	FY09	FY10	FY11	FY12	FY13	FY14	FY15
Discount Factors	1.000	0.952	0.907	0.864	0.823	0.784	0.746
Present Value(s) of Investment(s)	0.583	0.407	5.442	5.183	4.936	4.701	4.477

Total Discounted Investment
25.730

Savings/Cost Avoidance **(Fuel Cost for F-76 $127.68/Barrel)**
(Enter Millions of FY08 *Constant Dollars*)

Project name	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19
DDG-51 VSD MCF	0.000	0.118	1.301	2.484	3.667	4.850	6.033	6.033	6.033	6.033	6.033
Savings at 0% & $100/barrel	0	0.1227	1.353	2.5832	3.8134	5.0437	6.2739	6.2739	6.2739	6.2739	6.2739
Savings at 0% & $50/barrel	0	0.0614	0.6765	1.2916	1.9067	2.5218	3.137	3.137	3.137	3.137	3.137
Savings at 0% & $200/barrel	0	0.2454	2.7059	5.1664	7.6269	10.087	12.548	12.548	12.548	12.548	12.548
5.0%											
Discount Factors	1	0.9524	0.907	0.8638	0.8227	0.7835	0.7462	0.7107	0.6768	0.6446	0.6139
NPV Savings at 5% & $100/barrel	0	0.1169	1.2272	2.2315	3.1373	3.9519	4.6817	4.4588	4.2464	4.0442	3.8516
NPV Savings at 5% & $50/barrel	0	0.0584	0.6136	1.1157	1.5687	1.9759	2.3408	2.2294	2.1232	2.0221	1.9258
NPV Savings at 5% & $200/barrel	0	0.2337	2.4543	4.4629	6.2746	7.9037	9.3634	8.9175	8.4929	8.0884	7.7033
	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	
Cum NPV Savings at 0% & $100/b	0	0.1227	1.4757	4.0589	7.8723	12.916	19.19	25.464	31.738	38.012	44.286
Cum NPV Savings at 0% & $50/b	0	0.0614	0.7378	2.0294	3.9361	6.458	9.5949	12.732	15.869	19.006	22.143
Cum NPV Savings at 0% & $200/b	0	0.2454	2.9513	8.1177	15.745	25.832	38.38	50.928	63.475	76.023	88.571
Cum NPV Savings at 5% & $100/b	0	0.1169	1.344	3.5755	6.7128	10.665	15.346	19.805	24.052	28.096	31.947
Cum NPV Savings at 5% & $50/b	0	0.0584	0.672	1.7877	3.3564	5.3323	7.6732	9.9026	12.026	14.048	15.974
Cum NPV Savings at 5% & $200/b	0	0.2337	2.6881	7.151	13.426	21.329	30.693	39.61	48.103	56.192	63.895



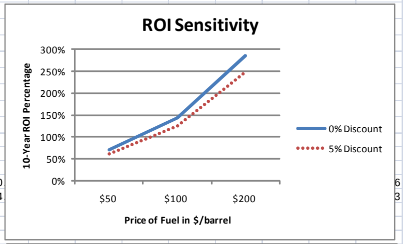
Total FYDP Savings/Cost Avoidance (CY$M) (through FY14)
12.420

Total 10 Year Savings/ Cost Avoidance (CY$M) (through FY18)
36.552

Total Life Cycle Savings/Cost Avoidance (CY$M)
102.915

10-Year ROI

	0% Disc	5% Discount
$50	71%	62%
$100	143%	124%
$200	286%	248%



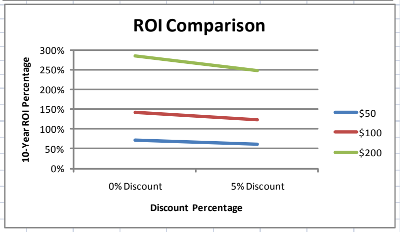
10-Year Discount Factor for Constant (Real) Dollars
2.8%

Discount Factors	1.000	0.973	0.946	0.920	0.895	0.871	0.847	0.824	0.802	0.780	0.759	0.738
Present Values of Savings/Cost Avoidances	0.000	0.115	1.231	2.287	3.284	4.225	5.112	4.973	4.837	4.705	4.577	4.453

Total FYDP Discounted Savings/Cost Avoidance (through FY14)
11.140

Total 10 Year Discounted Savings/Cost Avoidance (through FY18)
30.767

Total Life Cycle Discounted Savings/Cost Avoidance
74.791



Savings

$100/barrel		$50/barrel		$200/barrel	
Total 10-Yr at 0%	5%	Total 10-Yr at 0%	5%	Total 10-Yr at 0%	5%
44.286	31.947	22.143	15.974	88.571	63.89

ROI

$100/barrel		$50/barrel		$200/barrel	
10-Yr ROI at 0%	10-Yr ROI at 5%	0%	5%	0%	5%
143%	124%	71%	62%	286%	248%

ROI (FYDP)
0.43

ROI (10 Year)
1.20

ROI (LCC)
2.91

FLEET READINESS RESEARCH & DEVELOPMENT PROGRAM (FRR&DP) INVESTMENT PROFILE

PROJECT TITLE: DDG-51 REVERSE OSMOSIS INITIATIVE (Development & Implementation)

Development/Implementation Investment
(Enter Millions of *Then Year Dollars*)

Enter Project name	FY09	FY10	FY11	FY12	FY13	FY14	FY15	Sum
DDG-51 RO Initiative	1.540	0.550	1.600	1.600	1.600	1.600	1.600	10.090

INVESTMENT PROFILE COMES FROM BCA SPREADSHEET. ADDS ALL INVESTMENT COSTS FOR INSTALLATIONS ON ALL LSD's OVER IDEAL FIT UP OF 5 YEARS WITH ALL INSTALLATIONS BEING COMPLETE BY FY 15

Total Investment (TY$M)
10.090

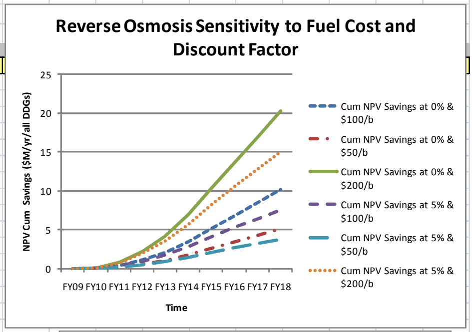
10-Year Discount Factor for Then Year (Nominal) Dollars
5.0%

Discount Factors	1.000	0.952	0.907	0.864	0.823	0.784	0.746
Present Value(s) of Investment(s)	1.540	0.524	1.451	1.382	1.316	1.254	1.194

Total Discounted Investment
8.661

Savings/Cost Avoidance
(Fuel Cost for F-76 $127.68/Barrel)
(Enter Millions of FY08 *Constant Dollars*)

Project name	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19
DDG-51 RO Initiative	0.000	0.032	0.347	0.663	0.979	1.295	1.611	1.611	1.611	1.611	1.611
Savings at 0% & $100/barrel	0	0.0333	0.3609	0.6895	1.0181	1.3467	1.6753	1.6753	1.6753	1.6753	1.6753
Savings at 0% & $50/barrel	0	0.0166	0.1804	0.3447	0.509	0.6734	0.8377	0.8377	0.8377	0.8377	0.8377
Savings at 0% & $200/barrel	0	0.0666	0.7217	1.379	2.0362	2.6934	3.3507	3.3507	3.3507	3.3507	3.3507
5.0%											
Discount Factors	1	0.9524	0.907	0.8638	0.8227	0.7835	0.7462	0.7107	0.6768	0.6446	0.6139
NPV Savings at 5% & $100/barrel	0	0.0317	0.3273	0.5956	0.8376	1.0552	1.2502	1.1906	1.1339	1.0799	1.0285
NPV Savings at 5% & $50/barrel	0	0.0158	0.1637	0.2978	0.4188	0.5276	0.6251	0.5953	0.567	0.54	0.5143
NPV Savings at 5% & $200/barrel	0	0.0634	0.6546	1.1912	1.6752	2.1104	2.5003	2.3813	2.2679	2.1599	2.057
	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	
Cum NPV Savings at 0% & $100/b	0	0.0333	0.3941	1.0836	2.1017	3.4484	5.1238	6.7991	8.4744	10.15	11.825
Cum NPV Savings at 0% & $50/b	0	0.0166	0.1971	0.5418	1.0509	1.7242	2.5619	3.3995	4.2372	5.0749	5.9125
Cum NPV Savings at 0% & $200/b	0	0.0666	0.7883	2.1672	4.2034	6.8968	10.248	13.598	16.949	20.3	23.65
Cum NPV Savings at 5% & $100/b	0	0.0317	0.359	0.9546	1.7922	2.8474	4.0975	5.2882	6.4221	7.502	8.5305
Cum NPV Savings at 5% & $50/b	0	0.0158	0.1795	0.4773	0.8961	1.4237	2.0488	2.6441	3.211	3.751	4.2653
Cum NPV Savings at 5% & $200/b	0	0.0634	0.718	1.9092	3.5844	5.6947	8.1951	10.576	12.844	15.004	17.061



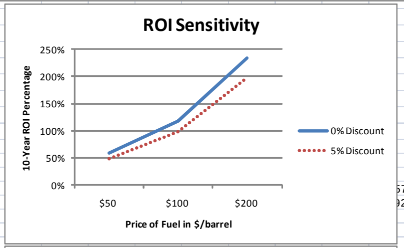
Total FYDP Savings/Cost Avoidance (CY$M) (through FY14)
3.316

Total 10 Year Savings/ Cost Avoidance (CY$M) (through FY18)
9.760

10-Year ROI

	0% Disc	5% Discount
$50	59%	49%
$100	117%	98%
$200	234%	197%

Total Life Cycle Savings/Cost Avoidance (CY$M)
27.481



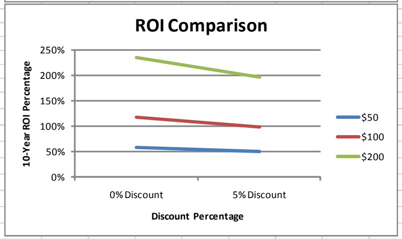
10-Year Discount Factor for Constant (Real) Dollars
2.8%

Discount Factors	1.000	0.973	0.946	0.920	0.895	0.871	0.847	0.824	0.802	0.780	0.759	0.738	576
Present Values of Savings/Cost Avoidances	0.000	0.031	0.328	0.610	0.877	1.128	1.365	1.328	1.292	1.256	1.222	1.189	927

Total FYDP Discounted Savings/Cost Avoidance (through FY14)
2.974

Total 10 Year Discounted Savings/Cost Avoidance (through FY18)
8.215

Total Life Cycle Discounted Savings/Cost Avoidance
19.971



ROI (FYDP)
0.34

ROI (10 Year)
0.95

ROI (LCC)
2.31

Savings

$100/barrel		$50/barrel		$200/barrel	
Total 10-Yr at 0%	5%	Total 10-Yr at 0%	5%	Total 10-Yr at 0%	5%
11.825	8.5305	5.9125	4.2653	23.65	17.06

ROI

$100/barrel		$50/barrel		$200/barrel	
10-Yr ROI at 0%	10-Yr ROI at 5%	0%	5%	0%	5%
117%	98%	59%	49%	234%	197%

APPENDIX E: USS JOHN PAUL JONES FUEL CONSUMPTION TABLE

Trail shaft				
Speed	Gal/hr	Gal/Day	BBL/hr	BBL/Day
1	93	11,827	2	282
2	138	12,902	3	307
3	182	13,978	4	333
4	227	15,053	5	358
5	272	16,128	6	384
6	317	17,203	8	410
7	362	18,278	9	435
8	406	19,354	10	461
9	451	20,429	11	486
10	496	21,492	12	512
11	542	22,618	13	539
12	589	23,743	14	565
13	636	24,869	15	592
14	683	25,994	16	619
15	730	27,120	17	646
16	820	29,270	20	697
17	909	31,421	22	748
18	999	33,571	24	799
19	1,088	35,722	26	851
20	1,178	37,872	28	902
21	1,338	41,712	32	993

Split Plant				
Speed	Gal/hr	Gal/Day	BBL/hr	BBL/Day
1	231	15,139	5	360
2	257	15,758	6	375
3	282	16,378	7	390
4	308	16,997	7	405
5	334	17,616	8	419
6	360	18,235	9	434
7	386	18,854	9	449
8	411	19,474	10	464
9	437	20,093	10	478
10	463	20,712	11	493
11	524	22,171	12	528
12	585	23,630	14	563
13	645	25,090	15	597
14	706	26,549	17	632
15	767	28,008	18	667
16	834	29,621	20	705
17	901	31,234	21	744
18	969	32,846	23	782
19	1,036	34,459	25	820
20	1,103	36,072	26	859
21	1,295	40,670	31	968
22	1,486	45,269	35	1,078
23	1,678	49,867	40	1,187
24	1,869	54,466	45	1,297
25	2,061	59,064	49	1,406
26	2,337	65,696	56	1,564
27	2,614	72,328	62	1,722
28	2,890	78,960	69	1,880

Full Power				
Speed	Gal/hr	Gal/Day	BBL/hr	BBL/Day
1	567	23,218	14	553
2	616	24,379	15	580
3	664	25,541	16	608
4	713	26,702	17	636
5	761	27,864	18	663
6	809	29,026	19	691
7	858	30,187	20	719
8	906	31,349	22	746
9	955	32,510	23	774
10	1,003	33,672	24	802
11	1,051	34,834	25	829
12	1,100	35,995	26	857
13	1,148	37,157	27	885
14	1,197	38,318	28	912
15	1,245	39,480	30	940
16	1,293	40,642	31	968
17	1,342	41,803	32	995
18	1,390	42,965	33	1,023
19	1,439	44,126	34	1,051
20	1,487	45,288	35	1,078
21	1,648	49,147	39	1,170
22	1,809	53,006	43	1,262
23	1,969	56,866	47	1,354
24	2,130	60,725	51	1,446
25	2,291	64,584	55	1,538
26	2,716	74,789	65	1,781
27	3,141	84,994	75	2,024
28	3,567	95,198	85	2,267
29	3,992	105,403	95	2,510
30	4,417	115,608	105	2,753

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APPENDIX F: DDG-51 CLASS FUEL RATE NOMOGRAM FROM SHIPBOARD ENCON GUIDE

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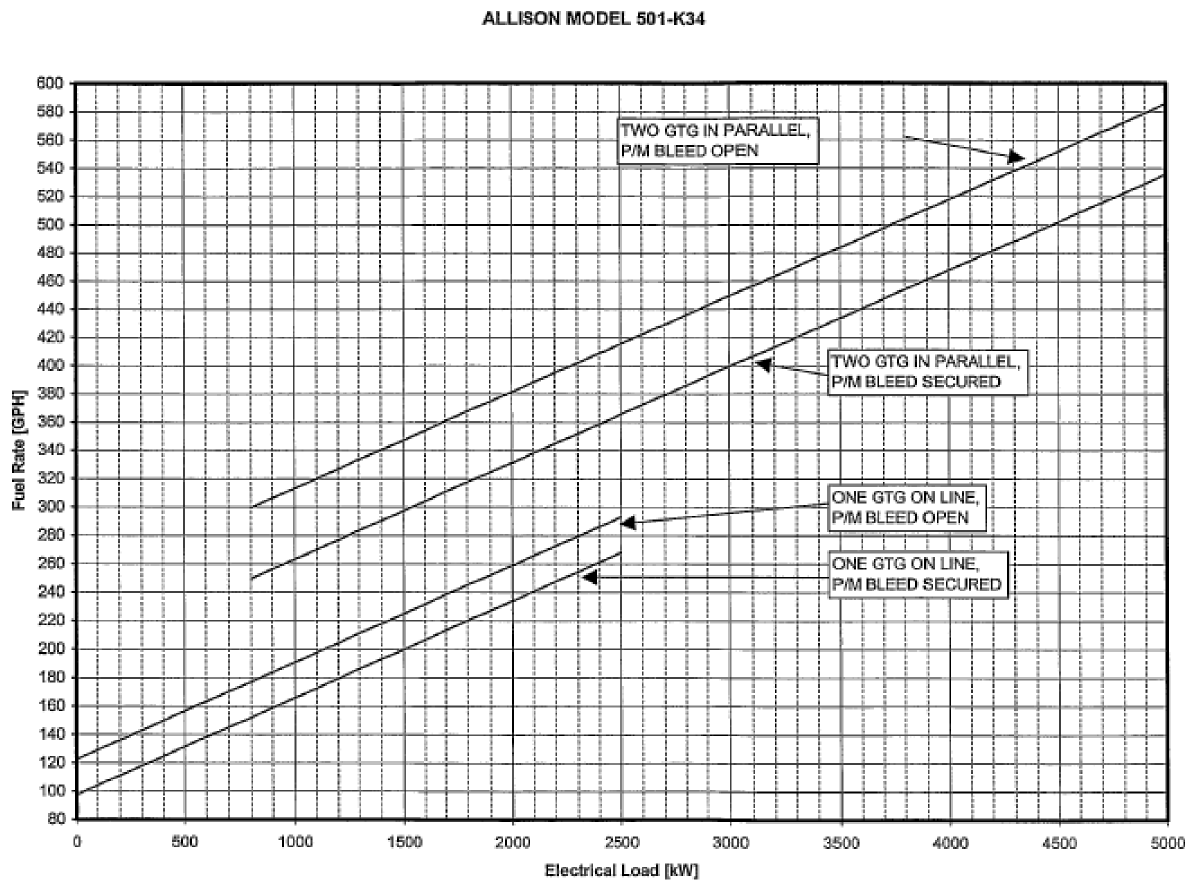

DDG 51 CLASS FUEL RATE NOMOGRAM

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