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Energy Division

**NAVY MOBILITY FUELS FORECASTING SYSTEM PHASE VI REPORT:
THE POTENTIAL IMPACTS OF A WORST-CASE MILITARY
CONFLICT ON WORLD PETROLEUM AVAILABILITY**

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ACRONYMS AND ABBREVIATIONS

BAU	Business-As-Usual
CPE	Centrally Planned Economies
DIS	Disruption Impact Simulator
DOD	Department of Defense
DOE	Department of Energy
DON	Department of Navy
EIA	Energy Information Administration
MBD	Thousand barrels per day
MMBD	Million barrels per day
NATO	North Atlantic Treaty Organization
OECD	Organization for Economic Cooperation and Development
OMS	Oil Market Simulation
OPEC	Organization of Petroleum Exporting Countries
ORNL	Oak Ridge National Laboratory
PADD	Petroleum Administration for Defense District
PAL	Petroleum Allocation
SPR	Strategic Petroleum Reserve

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THE POTENTIAL IMPACTS OF A WORST-CASE MILITARY CONFLICT ON WORLD PETROLEUM AVAILABILITY

ABSTRACT

A major Middle East and European military confrontation would cause an extremely large disruption in the supply of oil worldwide. There would be imbalances between oil supply and demand. These imbalances can only be solved by rationing and by military actions to ensure an adequate flow of crude oil and products.

THE POTENTIAL IMPACTS OF A WORST-CASE MILITARY CONFLICT ON WORLD PETROLEUM AVAILABILITY

EXECUTIVE SUMMARY

This report considers the impact of an extremely severe military confrontation and oil market disruption on the availability of petroleum products worldwide. Under a worst-case scenario, supply would significantly decline--by over 20 million barrels per day worldwide, especially with the likelihood of naval hostilities. There would be large imbalances in the supply and demand for petroleum products. Available supply would not meet demand, even taking into account higher prices and greatly reduced civilian demand. Additional reductions in demand in the form of rationing would be expected, possibly on the U.S. West Coast, Scandinavia, Venezuela, Asian Exporters and Iran. Additional sources of supply would also have to be found to meet European demand. A major problem is in ensuring the safe passage of crude oil, from the Norwegian North Sea to European refineries, and especially the safe passage of products to Europe from the U.S. and Norway. Great quantities of liquid gases, gasoline, distillates, and residual fuel would have to be shipped from the U. S. Gulf and East Coasts to Europe.

1. INTRODUCTION

A major European military confrontation and an extreme disruption in the supply of oil from the Middle East would likely result in a worst-case scenario for the world oil market. Although very unlikely, the possibility of such events in the long-run is highly uncertain and such scenarios should be studied as part of any long-range contingency planning. This paper describes an experiment to estimate the imbalances that may result between regional oil supply and demand in the world in such a worst-case scenario. Many previous papers and reports have considered the impacts of major disruptions in the supply of oil on the availability and quality of petroleum products.¹ Other studies have discussed oil disruptions, vulnerability, and security.²

One of the most severe scenarios considered in past studies was a hypothetical disruption in which Persian Gulf exports were entirely curtailed, and in which North Sea production was reduced by 40%, causing the overall reduction in the world supply of oil to be 16 million barrels per day (MMBD).³ Nevertheless, there was an economic solution to the disruption; there was an equilibrium between the supply and demand for products. That is, the demand for products in the world was met, without any shortages. The disruption did not seem "crippling", either in the sense of military needs going unsatisfied or in terms of the civilian sector requiring rationing or price controls. In some ways, this finding seemed surprising because the scenario included not just a severe disruption in oil supply but a large-scale military mobilization as well. To investigate this surprising result more closely, our study developed a more detailed military disruption scenario than the one in Das et al. (1988b).

¹Refer to Buck (1973); Cutler (1985, 1986a, 1986b, 1987); Das et al. (1988a, 1988b); EIA (1989); Hadder et al. (1988a, 1988b, 1989); Leiby and Lee (1988); and Mawn (1988).

²Refer to Curlee (1982); Curlee and Reister (1989); Horwich and Weimer (1984, 1988); and US DOE (1987). Several modeling approaches have been suggested by Curlee et al. (1988); Das et al. (1988b); Leiby and Lee (1988); and Reister (1987).

³Refer to Das et al. (1988b) for additional details.

2. DESCRIPTION OF MILITARY DISRUPTION SCENARIO

The military disruption is assumed to occur in the year 1995. The disruption is defined relative to the projected business-as-usual (BAU) conditions in 1995, as developed in Das et al. (1988b). This BAU projection was based on the most recent official Department of Energy/Energy Information Administration (DOE/EIA) mid-case forecast available at the beginning of that study. Additional detail was gathered from the most recent officially documented DOE models, including Oil Market Simulation (OMS), Disruption Impact Simulator (DIS), and the 1990 Petroleum Allocation (PAL) Model BAU case.

In its study of a military disruption scenario, Das et al. (1988b) did not consider the effect of naval hostilities on the flow of petroleum. This current study, on the other hand, assumed that extensive military hostilities would lead to massive naval engagements in the North Sea and Mediterranean Sea. The engagements would involve enemy naval vessels, aircraft, and mines attacking fuel supply vessels going into Europe. Enemy activities were assumed to be targeted on incoming flows and a worst-case situation was considered, with 37% of the incoming flows being cut (Buck et al., 1973). In effect, enemy ships and aircraft reduced the incoming flow of crude oil by 37% and products by 23% of what they would have been if such flows were free to occur.

In addition to the 37% curtailment of incoming flows to Europe, it was also assumed that 10% of any outgoing crude and product flows from Europe were interrupted. It was further assumed that 10% of the crude flows to and from the Asia-Pacific and Indian Ocean regions were eliminated. The idea behind this assumption was that naval and air action sank many oil tankers; and, for those that remained, enemy action made safe passage more difficult and time-consuming, thus further reducing the flow of oil.⁴

It was assumed that there would be: (a) maximum use of strategic stocks, including those in all OECD countries; (b) increased demand by the military and by the defense industrial base; (c) the use of military stocks; and (d) lost imports of Soviet natural gas into Europe. The scenario is summarized in Table 1. As indicated in Table 1, the total "shortfall" (i.e. the net reduction in supply relative to the BAU) for the Military Disruption was estimated to be 20.3 MMBD, about 40% of the BAU supply.

⁴Because of the physical nature of the interdiction, it was assumed that the disrupted flows would not be re-directed to other regions. Instead, there would be a limit to the volume of flows. The reduction in product flows was assumed to be 9% instead of 10%, since only 90% of the crude will be available for refinery operations.

**Table 1. Summary of oil market disruption in Military Disruption
scenario (quantities in MBD)**

Details of Scenario	Amount of Disruption
OPEC Disrupted Countries	
Algeria	
Iran	
Iraq	
Kuwait	
Libya	
Saudi Arabia	
UAE	
OPEC Crude and Product	[100%]
Export Disrupted	17,800
North Sea Crude Output Disrupted	[40%]
(affects Norway and United Kingdom)	1,240
Flows Disrupted by Naval Actions: 37% of crude	
(23% product) flows into Europe;	
and 10% of crude (9% product) flows	
out of Europe, in Indian Ocean,	
and South China Sea	
(a) Volume Crude Flows Disrupted	2,083
(b) Total Product Flows Disrupted	1,175
Centrally-planned Economies	[100%]
Net Exports Disrupted	920
Undisrupted OPEC Surge Production	To Capacity
(Ecuador, Venezuela, Nigeria)	-380
"Inventory Demand" (Used as Proxy for	80% European Gas
European Gas Import Substitution)	550
U.S. SPR Draw	-4,500
Foreign (Japan) SPR Draw	-900
Foreign (Other OECD) SPR Draw	-1,000
Military Demand Increase	
U.S. Military	943
NATO European Military	338
Non-NATO Military	106
U.S. Defense Industrial Base	1,667
European Defense Industrial Base	790
U.S. Military Stock Draw	-300
European Military Stock Draw	<u>-250</u>
Net Shortfall*	20,282

*Components may not sum to total due to independent rounding.

3. RESULTS

We focus on the models' results that relate to the reductions in world oil supply and demand, and to regional supply-demand imbalances. These balances have implications for (a) the possibility of rationing and other non-market measures to reduce demand, (b) special trade provisions and/or naval action to increase the supply of key exports, and (c) the general availability of fuels to meet both civilian and military demand.

3.1 WORLD OIL SUPPLY AND DEMAND

The OMS and DIS Models were used to forecast petroleum supply and demand in six regions in the world: United States, Japan, Western Europe, Canada, OPEC, and Other Countries. Table 2 shows the forecasted petroleum supply and demand in the six regions for the BAU scenario and for the Military Disruption. The forecasts were subdivided to provide estimates of crude oil supply and demand in the 33 regions used in the PAL Model.

The net reduction in supply of 20.3 MMBD caused a reduction in worldwide demand of 15.5 MMBD. Production increased in several countries in response to much higher oil prices. The increased military demand also caused price to increase. The price increase, as well as the physical interruption of oil flows, resulted in a sharp decline in civilian consumption. Traditional non-major petroleum consumers, particularly developing countries in Asia which are grouped as "Other Countries" in Table 2, were the most affected by the disruption. Petroleum demand in this region decreased 40.6% compared to demand in the BAU scenario. Also, a significant reduction in petroleum demand occurred in Western Europe, 31.8% lower than in the BAU scenario. This decrease reflected the reduction in imports due to the disruption of flows by naval actions.

Of course, the greatest reduction in supply (i.e., production) occurred in OPEC. Total crude supply fell in this region by 71.5% compared to the BAU scenario. The supply from "Other Countries" declined by 9.2% compared to the BAU scenario. A 0.1 MMBD reduction in the United States domestic crude supply was due to the disruption in its flows; much of the exports of products from the U.S. to Europe were no longer reaching Europe.

3.2 REGIONAL OIL SUPPLY AND DEMAND BALANCE

The PAL Model was used to obtain the supply and demand balance for 33 regions in the world. The appendix contains the definition of these 33 PAL regions. In PAL, crude and refined product distribution are calculated so as to minimize the total cost of crude supply, crude and product transportation, and refining. Historical trading patterns are taken into account in the model, but cannot be replicated given the available crude supplies.

In the Pal Model, refining activities in each region depend on its refinery configuration. For a given configuration, a yield or mix of end-products is associated with each crude or slate of crudes processed in each region. Thus, regional refinery configurations play an important role in the model in achieving an interregional balance between supply and demand. Because of a disruption, the

Table 2. World oil demand for BAU and Military Disruption scenarios		
	BAU	Military Disruption
<i>Demand (MMBD)</i>		
United States	16.8	12.0
Canada	1.7	1.1
Japan	4.6	2.8
Western Europe	12.6	8.6
OPEC	4.2	4.2
Other Countries	10.6	6.3
Total Free World	50.5	35.0
<i>Production (MMBD)</i>		
United States	8.3	8.4
Canada	1.6	1.6
Western Europe	3.5	2.2
Other Countries	9.8	8.9
CPE Net Exports	0.9	0.0
Total Non-OPEC (excluding SPRs)	24.1	21.1
U.S. SPR	0.0	4.5
Japan SPR	0.0	0.9
Other OECD SPR	0.0	1.0
OPEC	26.3	7.5
Total Free World	50.5	35.0

appropriate types of crudes may be unavailable to particular refineries, thereby resulting in less than desirable yields of certain products.

In the Military Disruption, supply and demand projections were obtained for each of the 6 categories of products in each of the 33 regions, by disaggregating the DIS Model's estimates of the projections at the aggregate scale. Additional crude and product flow constraints were input to the PAL Model in order to depict naval interdiction. Because of these constraints, a feasible PAL solution was obtained only after rationing was imposed in certain regions.⁵

There were four regions -- the U.S. West Coast, Scandinavia, Venezuela/Ecuador, and Asian Exporters -- which were unable to attain a supply-demand equilibrium even with an additional 30% reduction in demand imposed by rationing. To attain a world supply-demand equilibrium, the exports of products from the U.S. West Coast had to exceed the previously estimated maximum levels. Also, petroleum demand in Venezuela/Ecuador and in the Asian Exporter countries had to be reduced by 33%. The limit on Scandinavian crude exports was also increased in order to attain a supply-demand equilibrium.

The following paragraphs discuss in detail these supply-demand imbalances, that were forecasted to result from the given supply, demand, crude, and product flow constraints that were projected to occur during the Military Disruption. The imbalances are measured in terms of the changes (both in absolute and in percentage terms) in demand, crude flows and product flows that would be required from the original input values (that gave the infeasible solution) in order to give a feasible supply and demand balance.

Regional Demand: Table 3 gives the estimates of petroleum demand in each of the PAL Model's regions for the BAU and the Military Disruption. The fourth and fifth column in this table show the further reductions in demand (in absolute and in percentage terms respectively) that would be required during the Military Disruption compared to demand if the oil market was left solely to market forces, without government intervention.⁶ The last two columns show the percentage reductions in demand during the Military Disruptions relative to the BAU (for both the original input-value for demand, i.e. free-market demand, and for demand after the reduction computed in the PAL Model, i.e. the reduction from government intervention).

⁵The PAL Model is a linear programming model. A "feasible" solution means that demands for crude oil and refined products are satisfied by available supplies, without violating certain limitations (i.e., constraints) on the capabilities of the transportation networks and refineries. The given supply, demand, crude, and product flow constraints that were projected to occur during the Military Disruption resulted in violations of around twenty-five constraints to obtain a feasible PAL supply-demand equilibrium solution. Most of these violations were in crude and product flow constraints; additional crude and product flows were required in order to satisfy regional demand. In order to obtain a computationally feasible solution, regional crude oil demand was allowed to decrease by as much as 30% of its original input crude oil demand. Demand reductions of 10%, 20%, and 25% were tried; but the number of violations in the constraints decreased significantly only when regional demands were allowed to decrease by up to 30% of their original input values. The purpose of this calculation was to spread the effect of the disruption across all regions.

⁶This reduction is done in the PAL Model: if supply does not meet demand, then PAL reduces demand beyond the reductions already calculated by the DIS Model.

Table 3. Demand Estimates (MBD)						
Regions (with PAL Designations)	BAU	Military Disruption			% Change in Military Disruption Demand Relative to BAU	
		Input Value Reflecting Free Market	Change To Have Supply In Equilibrium With Demand	% Change	Input Value Reflecting Free Market	Supply-Demand Equilibrium
East Coast	5403	3872		0.0%	-28.3%	-28.3%
Gulf Coast	8427	5986		0.0%	-29.0%	-29.0%
West Coast	2671	1914	-240	-12.5%	-28.3%	-37.3%
United States	16500	11772	-240	-2.0%	-28.7%	-30.1%
Puerto Rico/Virgin Islands (U)	300	215		0.0%	-28.3%	-28.3%
Canada (C)	1700	1059		0.0%	-37.7%	-37.7%
Japan (J)	4600	2844		0.0%	-38.2%	-38.2%
Australia/New Zealand (A)	800	470		0.0%	-41.3%	-41.3%
Scandinavia (1)	838	574	-102	-17.8%	-31.5%	-43.7%
United Kingdom/Ireland (2)	1779	1219		0.0%	-31.5%	-31.5%
Benelux/Denmark (3)	1366	936		0.0%	-31.5%	-31.5%
West Germany (4)	2500	1713		0.0%	-31.5%	-31.5%
France (5)	2000	1370		0.0%	-31.5%	-31.5%
Austria/Switzerland (6)	503	344		0.0%	-31.5%	-31.5%
Spain/Portugal (7)	1188	814		0.0%	-31.5%	-31.5%
Italy (8)	1800	1233		0.0%	-31.5%	-31.5%
Greece/Turkey (9)	627	430		0.0%	-31.4%	-31.4%
Venezuela/Ecuador (V)	529	529	-149	-28.2%	0.0%	-28.1%
Libya/Algeria (L)	341	341	-1	-0.3%	-0.0%	-0.3%
Nigeria/Gabon (N)	342	342		0.0%	0.0%	0.0%
Indonesia (I)	607	607	-13	-2.1%	0.0%	-2.1%
Iran (R)	895	895	-212	-23.7%	-0.0%	-23.7%
Persian Gulf (P)	1,437	1487	-37	-2.5%	0.0%	-2.5%
Caribbean (K)	305	182	-55	-30.2%	-40.2%	-58.3%
Mexico (M)	1564	933	-6	-0.6%	-40.4%	-40.7%
Bolivia/Peru (B)	868	585	-27	-4.6%	-32.6%	-35.7%
Egypt/Syria/Bahrain (Q)	653	389		0.0%	-40.4%	-40.4%
Angola/Congo/Zaire (O)	39	23	-7	-30.4%	-41.0%	-59.0%
Asian Exporters (Y)	896	534	-176	-33.0%	-40.4%	-60.0%
Other Latin America (S)	1635	907		0.0%	-44.5%	-44.5%
Other Africa (F)	944	563		0.0%	-40.4%	-40.4%
Other Asia (X)	2895	1726		0.0%	-40.4%	-40.4%
TOTAL	50500	35036	-1025	-2.9%	-30.6%	-32.7%

An additional reduction of 1 MMBD, or 2.9% of the total DIS world oil demand estimate of 35 MMBD, is projected to occur because of incompatibilities between the particular mix of crude available during the Military Disruption, and the refinery capabilities. This reduction in demand occurred in 12 of the 33 PAL regions. The most notable regions were: U.S. West Coast, Scandinavia, Venezuela/Ecuador, Iran, and Asian Exporters where reductions in demand would be more than 100 MBD below the reductions calculated in the DIS Model. The U.S. West Coast demand would decrease by 37.3% compared to the BAU, while in the other two U.S. regions the reduction in demand would be around 28%. However, additional products were exported from the U.S. West Coast, the largest share contributed by liquid gases. Similarly, most of the other 11 regions with further reductions in their own consumption also exported more crudes and products.

Regional Crude Exports: Table 4 gives estimates of crude oil exports during the Military Disruption scenario. The format of this table is similar to that in Table 3. Positive numbers in these columns indicate the amount of crude which may not flow due to the physical interdictions during the Military Disruption, but which are needed to maintain a supply-demand equilibrium.

During the Military Disruption, world crude oil exports would be reduced by 76.3% compared to the BAU. The Caribbean was the only region where the reduction in crude oil exports would be substantial (i.e., 72.2% of the BAU), other than the most severely disrupted regions such as OPEC and the United Kingdom/Ireland. Crudes that are available may be incompatible with refineries' configurations. These mismatches caused an additional 8% reduction in crude oil exports. Most of these reductions occurred in Nigeria/Gabon, Caribbean, and Asian Exporters.

For European and U.S. demands to be met, regional crude exports would have to increase from Scandinavia, Mexico, and Bolivia/Peru beyond those predicted during the Military Disruption. Scandinavia becomes a crude oil exporter. Most of its exports would go to neighboring European countries, and about 56 MBD of the 159 MBD crude oil exports would go to the U.S. Gulf coast. A major portion of the needed Mexican crude oil exports would go to Puerto Rico/Virgin Islands; additional Bolivian crudes would go to U.S. refineries. Bolivian crudes are exported only during the Military Disruption.

Regional Product Exports: Estimates of product exports during the Military Disruption are shown in Table 5. The format of this table is similar to Table 4. Total product exports, unlike crude oil demand and exports, would increase during the Military Disruption by 17.6% compared to the BAU level. Two of the three U.S. regions account for most of this great increase (i.e., 3.7 MMBD or 1083% of BAU) in product exports. Most of these product exports went to Europe, where need for imports were triggered by the shortage of crudes for its refineries. According to PAL Model calculations, the following product mix needs to be provided by the U.S. in order for Europe to satisfy its demand during the disruption: liquid gases: 1.3 MMBD⁷; gasoline: 0.7 MMBD; distillate: 0.5MMBD; and residual fuel: 0.3 MMBD. The increased jet fuel demand during the disruption can be met as long as additional supplies of crude are available to European refineries.

⁷It is very unlikely that the U.S. could be able to transport 1.3 MMBD of liquid gases to Europe. (Exports of liquid gases in 1988 amounted to 48 MBD.) There would be logistical problems as well as safety problems in handling large quantities of liquid gases.

Table 4. Crude oil export estimates (MBD)						
Regions (with PAL Designations)	BAU	Military Disruption			% Change in Military Disruption Relative to BAU	
		Input Value Reflecting Free Market	Change To Have Supply In Equilibrium With Demand	% Change	Input Value Reflecting Free Market	Supply-Demand Equilibrium
East Coast						
Gulf Coast						
West Coast						
United States	0	0			0.0%	0.0%
Puerto Rico/Virgin Islands (U)	0	0			0.0%	0.0%
Canada (C)	111	115	-8	-1.0%	3.6%	-3.6%
Japan (J)	0	0			0.0%	0.0%
Australia/New Zealand (A)	0	0			0.0%	0.0%
Scandinavia (1)	885	0	159		-100.0%	-82.0%
United Kingdom/Ireland (2)	976	90	1	1.1%	-90.8%	-90.7%
Benelux/Denmark (3)	0	0			0.0%	0.0%
West Germany (4)	0	0			0.0%	0.0%
France (5)	0	0			0.0%	0.0%
Austria/Switzerland (6)	0	0			0.0%	0.0%
Spain/Portugal (7)	0	0			0.0%	0.0%
Italy (8)	0	0			0.0%	0.0%
Greece/Turkey (9)	0	0			0.0%	0.0%
Venezuela/Ecuador (V)	730	677	-46	-6.8%	-7.3%	-13.6%
Libya/Algeria (L)	2458	4			-99.8%	-99.8%
Nigeria/Gabon(N)	1555	1224	-317	-25.9%	-21.3%	-41.7%
Indonesia (I)	793	713	-70	-9.8%	-10.1%	-18.9%
Iran (R)	2391	0	2		-100.0%	-99.9%
Persian Gulf (P)	11742	0			-100.0%	-100.0%
Caribbean (K)	212	185	-126	-68.1%	-12.7%	-72.2%
Mexico (M)	1864	1688	61	3.6%	-9.4%	-6.2%
Bolivia/Peru (B)	0	231	80	34.6%	N/A	N/A
Egypt/Syria/Bahrain (Q)	446	490	-41	-9.0%	9.9%	0.0%
Angola/Congo/Zaire (O)	265	289	-1	-0.3%	9.1%	8.7%
Asian Exporters (Y)	535	717	-208	-39.0%	34.0%	-4.9%
Other Latin America (S)	0	0			0.0%	0.0%
Other Africa (F)	0	0			0.0%	0.0%
Other Asia (X)	0	0			0.0%	0.0%
TOTAL	24963	6423	-517	-8.0%	-74.3%	-76.3%

Table 5. Product exports estimates (MBD)						
Regions (with PAL Designations)	BAU	Military Disruption			% Change in Military Disruption Relative to BAU	
		Input Value Reflecting Free Market	Change To Have Supply In Equilibrium With Demand	% Change	Input Value Reflecting Free Market	Supply-Demand Equilibrium
East Coast	9	6	3	50.0%	-33.3%	0.0%
Gulf Coast	181	1213	2297	189.4%	570.2%	1839.2%
West Coast	243	210	1395	663.3%	-13.6%	559.7%
United States	433	1429	3693	258.4%	230.0%	1082.9%
Puerto Rico/Virgin Islands (U)	288	289	67	23.2%	0.3%	23.6%
Canada (C)	282	259			8.2%	-8.2%
Japan (J)	59	22	36	163.6%	-62.7%	-1.7%
Australia/New Zealand (A)	84	76			-9.5%	-9.5%
Scandinavia (1)	160	122	128	105.0%	-23.8%	+56.3%
United Kingdom/Ireland (2)	404	312			-22.8%	-22.8%
Benelux/Denmark (3)	1334	1024	-197	-19.2%	-23.2%	-38.0%
West Germany (4)	136	104			-23.5%	-23.5%
France (5)	240	184	-184	-100.0%	-23.3%	-100.0%
Austria/Switzerland (6)	59	45	-1	-2.2%	-23.7%	-25.4%
Spain/Portugal (7)	202	154	-110	-71.4%	-23.8%	-78.2%
Italy (8)	241	183			-24.1%	-24.1%
Greece/Turkey (9)	78	59			-24.4%	-24.4%
Venezuela/Ecuador (V)	1423	1075			-24.5%	-24.5%
Libya/Algeria (L)	0	0			0.0%	0.0%
Nigeria/Gabon(N)	0	0			0.0%	0.0%
Indonesia (I)	0	0			0.0%	0.0%
Iran (R)	18	0			0.0%	-100.0%
Persian Gulf (P)	1204	0			0.0%	-100.0%
Caribbean (K)	283	248	107	41.1%	-12.4%	23.7%
Mexico (M)	135	129			-4.4%	-4.4%
Bolivia/Peru (B)	0	0			0.0%	0.0%
Egypt/Syria/Bahrain (Q)	0	0			0.0%	0.0%
Angola/Congo/Zaire (O)	0	0			0.0%	0.0%
Asian Exporters (Y)	790	114	-114	-100.0%	-85.6%	-100.0%
Other Latin America (S)	0	0			0.0%	0.0%
Other Africa (F)	0	0			0.0%	0.0%
Other Asia (X)	0	0			0.0%	0.0%
TOTAL	7853	5828	3419	58.7%	-25.8%	17.6%

Four other regions where product exports had to be increased from their free-market levels were: Puerto Rico/Virgin Islands, Caribbean, Japan, and Scandinavia. The maximum increase (i.e., 128 MBD) in product exports occurred in Scandinavia, most of it going to its neighboring countries.⁸ The Caribbean exports increased mostly in gasoline and other products, all of which went to the U.S. East Coast. Similarly, increased exports of residual fuel from Puerto Rico/Virgin Islands were needed to satisfy the U.S. East Coast demand.

France and Asian Exporters would no longer be product exporters during the Military Disruption. In Spain/Portugal the reduction in product exports would be comparatively less severe, 22.8% of its BAU level.

⁸Recall that Scandinavia also had rationing.

4. CONCLUSIONS

This report studied the impacts of an extreme worst-case military confrontation on petroleum availability. Under such a disruption, supply and demand would significantly decline -- by over 20 MMBD. Furthermore, the likelihood of naval hostilities means that ocean-going flows of both crude oil and products would also be greatly reduced. Under such a scenario, there would be large imbalances in supply and demand. Unlike previous studies involving oil market models, this study found that the available supply would not meet demand, even taking into account the greatly reduced civilian demand that would react to extremely high prices.

The problem of imbalances can only be solved by extraordinary actions, outside of normal economic markets.⁹ These actions take the form of rationing, and military actions to ensure the additional flow of crudes and products.

In particular, from Table 3, reductions in demand in the form of rationing could be expected on the U.S. West Coast, Scandinavia, Venezuela, Asian Exporters and Iran (though it may be difficult to envision the circumstances where Iran would unilaterally impose rationing).

Additional sources of supply would also have to be found to meet European demand. One major problem is in ensuring the safe passage of crude, from the Norwegian North Sea to European refineries, and especially the safe passage of products from the U.S. and Norway (refer to Table 4). Great quantities of liquid gases, gasoline, distillates, and residual fuel would be needed from both the U. S. Gulf Coast and East Coast -- a total of 2.8 MMBD. There would be logistical transportation problems as well. Major military support would be required to protect tankers from hostile actions. The military would then have to consider the trade-offs in allocating resources to protect tanker flows as opposed to other needs.

⁹This intuitive conclusion is an outcome of the modeling and analysis, rather than an assumption or a simple statement, and has heretofore not been observed in previous modeling exercises.

5. IMPLICATIONS FOR THE NAVY

The results and conclusions of this study could have several implications for the Navy:

- (1) The results in Table 4 suggest that the Navy may wish to plan for extensive engagements in the North Atlantic and North Sea to protect the important flows of products and crude oil destined for Europe from the North Sea region and from the U.S.
- (2) If oil exports from the Persian Gulf region are assumed to be lost, then from the standpoint of petroleum flows, the Mediterranean Sea appears to be less critical than the North Atlantic or North Sea. The results in Table 4 highlight the key flows that need to be protected in order to meet European demand.
- (3) The Navy may wish to pay special attention to pre-positioning product stocks, because needed fuels may be unavailable in the European theater (again, refer to Table 4 and Sect. 3).
- (4) Because of possible fuel availability problems, a flexible-fuel strategy may be worthwhile in terms of affording the Navy maximum flexibility in its mobility activities. The modeling results show that, in general, fuel shortages may develop under a worst-case scenario. Having the option to use alternative fuel sources would make the Navy less dependent on specialized fuels that are available from a limited number of refiners or that may be intercepted in transit to the theater. Any major changes in fuel specifications or flexible-fuel policies will also require more intensive research to improve, or at least maintain, engine performance.

These implications all are preliminary and deserve further study.

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APPENDIX

Definition of PAL Regions	
Regions (with PAL Designations)	List of Countries
East Coast (E)	U.S. PADD 1A/1B
Gulf Coast (G)	U.S. PADD 2A/2B/3/4
West Coast (W)	Alaska N. Slope, U.S. PADD 5
Puerto Rico/V.I. (U)	Puerto Rico, Virgin Islands
Canada (C)	Canada
Japan (J)	Japan
Australia/New Zealand (A)	Australia, New Zealand
Scandinavia (1)	Finland, Iceland, Norway, Sweden
United Kingdom/Ireland (2)	Ireland, United Kingdom
Benelux/Denmark (3)	Belgium, Denmark, Luxemburg, Netherlands
West Germany (4)	West Germany
France (5)	France
Austria/Switzerland (6)	Austria, Switzerland
Spain/Portugal (7)	Portugal, Spain
Italy (8)	Italy
Greece/Turkey (9)	Greece, Turkey
Venezuela/Ecuador (V)	Ecuador, Venezuela
Libya/Algeria (L)	Algeria, Libya
Nigeria/Gabon (H)	Gabon, Nigeria
Indonesia (I)	Indonesia
Iran (R)	Iran
Persian Gulf (P)	Iraq, Kuwait, Neutral Zone, Qatar, Saudi Arabia, United Arab Emirates
Caribbean (K)	Bahamas, Netherlands Antilles, Trinidad
Mexico (M)	Mexico

Bolivia/Peru (B)	Bolivia, Peru
Egypt/Syria/Bahrain (Q)	Egypt, Syrian Arab Republic, Tunisia, Bahrain
Angola/Congo/Zaire (O)	Angola, Congo, Zaire
Asian Exporters (Y)	Brunei, Malaysia, Singapore, Oman
Other Latin America (S)	Antarctica, Antigua-Leew. Island, Argentina, Barbados, Belize, Bermuda, Brazil, Caymans Islands, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, El Salvador, Falkland Islands, Greenland, Guadalupe, Guatemala, Guiana, Guyana, Haiti, Honduras, Jamaica, Martinique, Nicaragua, Panama Canal, Panama, Paraguay, St. Pierre, Surinam, Uruguay, Windward Island
Other Africa (F)	Burundi, Cape Verde, Central Africa Republic, Chad, Comoro Islands, Cyprus, Dahomey, Equatorial Guinea, Ethiopia, Faeroe Island, Former West Africa, Former Equatorial Africa, Gambia, Ghana, Gibraltar, Guinea Bissau, Israel, Ivory Coast, Jordan, Kenya, Lebanon, Liberia, Madagascar, Malawi, Mali, Malta, Mauritania, Mauritius, Morocco, Mozambique, Niger, Republic of Guinea, Reunion, Zimbabwe, Rwanda, Sao Tome de Principe Islands, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Tanganyika, Tanzania, Togo, Uganda, United Republic Cameroon, Upper Volta, Zambia, Zanzibar
Other Asia (X)	Afghanistan, Bangladesh, British Solomon Islands, Burma, Cambodia, Christmas Island, Fiji, Gibraltar Island, Guam, Hong Kong, India, Khmer Republic, Korea Republic, Laos, Macau, Malagasy Republic, Nauru, Nepal, New Caladonia, New Hebrides, North Borneo, Okinawa, Pacific Islands, Pakistan, Papua New Guinea, Philippines, Port Timor, Samoa, Sarawak, Sri Lanka, Taiwan, Thailand, Wake Island, Yemen

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