



FINAL REPORT

Submitted to:

**Office of Naval Research
875 North Randolph Street, Room 273
Arlington, VA 22203-1995**

**Dr. Paul Rispin, Program Manager
ONR Code 331
703.696.0339
rispinp@onr.navy.mil**

**In fulfillment of the requirements for:
FY 2004 Cooperative Agreement No. N00014-04-2-0003
*Agile Port and High Speed Ship Technologies***

**FY04 Project 9
*Advanced Technology Military Sealift//Commercial Express Pentamaran Design***

Classification: Unclassified

Prepared and submitted by:

**Center for the Commercial Deployment of Transportation Technologies
California State University, Long Beach Foundation
6300 State University Drive, Suite 220 • Long Beach, CA 90815 • 562.985.7394**

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Prepared for:

Center for the Commercial Deployment of Transportation Technologies

FY 04 Project 9, Program Element 2.31
Advanced Technology Military Sealift/Commercial Express Pentamaran Design

Task 9.4 Prepare and Submit Final Report

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ADVANCED TECHNOLOGY MILITARY
SEALIFT / COMMERCIAL EXPRESS
PENTAMARAN SHIP DESIGN

TASK 4 FINAL REPORT

BMT SYNTEK Technologies, Inc.
BMT Nigel Gee and Associates, Ltd.



Task 4 – Final Report

Subtask 4.1 – Introduction

Under the sponsorship of CCDOTT, BMT SYNTEK Technologies, Inc. of Arlington, VA and BMT Nigel Gee and Associates, Ltd. of Southampton, UK have conducted a feasibility study of an advanced technology military sealift/commercial express pentamaran ship concept with a 6,000-ton cargo payload and 40-knot service speed. This includes a summary of the technical, operational and economic aspects of such a ship concept from both a defense logistics and commercial business perspective. The prospective end user organizations for the military sealift variant would include the Deputy Chief of Naval Operations for Fleet Readiness and Logistics (N4), the Assistant Secretary of the Navy for Research, Development and Acquisition (ASNRDA), the Office of Naval Research (ONR), the Naval Sea Systems Command (NAVSEA), the Military Sealift Command (MSC) and the U.S. Transportation Command (USTRANSCOM). The prospective end user organizations for the express cargo variant would include the Maritime Administration (MARAD), innovative ship operating companies such as NOL/APL and Maersk Lines, and such commercial business interests as Federal Express (FEDEX) and United Parcel Service (UPS) and their future customers.



The ability to design, construct, and operate ships that achieve high sustained speed in dynamic ocean environments is a continuing challenge to the international marine community. Fast ships offer important advantages in both commercial and military applications in many missions throughout the maritime world. While each vessel must be uniquely designed to meet its specific mission requirements, there are some general methodologies available that permit the exploration of the key enabling technologies for high-speed ships. The purpose of this limited effort was to explore the applicability of such enabling technologies in a specific feasibility study, thereby laying the groundwork for a much larger development program to be funded at the discretion of CCDOTT.

It is clear that, in any ship design concept, it is important to maximize Lift/Drag Ratio (LDR), Overall Propulsive Coefficient (OPC), Deadweight / Displacement Ratio (DDR) and to minimize Specific Fuel Consumption (SFC) over time and distance. One concept that offers the potential to achieve these objectives is the Stabilized Slender Monohull

Displacement Ship family of designs. The ability to increase LDR in a displacement hull is achieved through the use of high Length / Beam (L/B) and Slenderness ($L/\nabla^{1/3}$) ratios. The problem with such hull forms is, of course, that they lack inherent transverse stability. The necessary stabilization is then provided through the use of outriggers or sponsons. These structures provide for the increased asymmetrical buoyancy that produces the necessary righting moments as the vessel heels or rolls.

The principal characteristics of the 6,000-ton cargo payload, 40- knot service speed pentamaran ship concept design, based on prior work, has been described in sufficient detail to accurately portray its technical, operational and economic parameters. A structural design (including midship section) and weight estimate has been provided based on such previous work for a major transportation company. Resistance, propulsion and seakeeping estimates and analyses have been provided as well from the prior work. Finally, machinery systems and propulsors have been defined and specified in order to meet performance requirements.

The basic pentamaran ship concept is applicable to either a commercial express or a defense logistics application. The two applications differ in their cargo handling features. Commercial express ships can be accommodated in modern port facilities and would most likely carry containers. Defense logistics ships would most likely be Ro-Ro (or combination Lo-Lo/Ro-Ro) and may need to utilize austere unloading facilities. General Dynamics NASSCO in San Diego, California has provided estimates of ship acquisition cost of each variant.

Subtask 4.2 – Summary of Work Performed

Task 1- Technical Design and Feasibility.

Subtask 1.1 – Commercial Express Containership

BMT SYNTEK and BMT NGA reviewed the prior design and development work done for the ADX Express transocean Pentamaran Lo/Lo Containership. We updated the design based on a current interpretation of ADX Express design requirements and technical approach, accounting for advances in the state-of-the-art since January 2001. We provided a thorough technical description and specification of the Commercial Express Containership in the Subtask 1.1 deliverables that included dimensions of the ship, preliminary weights for the ship, a general arrangement drawing, a midship section drawing, resistance and propulsion data, seakeeping analysis, machinery and systems summary, and short specification.

Subtask 1.2 – Military Logistics Roll-on/Roll-off

BMT SYNTEK and BMT NGA developed design requirements for the defense logistics Pentamaran Ro/Ro in conjunction with N42 and USTRANSCOM. These requirements considered current alternative Rapid Deployment Sealift System (RDSL) and Austere Access High Speed Sealift (AAHSS) requirements. We provided a thorough technical

description and specification of the Military Logistics Ro/Ro in the Subtask 1.2 deliverables that included dimensions of the ship, preliminary weights for the ship, a general arrangement drawing, a midship section drawing, resistance and propulsion data, seakeeping analysis, machinery and systems summary and short specification.

This work is summarized in the attached deliverables (provided earlier).

Task 2 - Commercial and Military Stakeholder Outreach

Subtask 2.1 – Commercial Outreach

During the month of August 2005, discussions related to the Lo/Lo Containership were conducted with Mr. David Heller and Mr. Richard Voelker of the Maritime Administration in their offices at DOT HQ in Washington, D.C. Additionally, Mr. Eugene Pentimonti of Maersk was briefed on the design concept, along with a review of the model test program conducted at Marintek in Trondheim, Norway. Both MARAD and Maersk expressed an interest in the CCDOTT project and it was agreed that updates would be provided periodically as appropriate. In November, at the IMPACT 2005 CCDOTT Conference aboard the Queen Mary in Long Beach, California, Mr. Jordan Toucan of American Ship Management was in attendance at the presentation (see attached) and received additional materials at his request after the meeting. In December, attendees at the SNAME Sealift Panel meeting were briefed at the N42 office in Crystal City, Virginia, including Mr. Robert Nevel of the Maritime Administration, Mr. Edward Kelley of the American Maritime Officers (AMO) and Mr. David Helgerson of CSC-AME.

Subtask 2.2 – Military Outreach

During the month of September 2005, Mr. Jonathan Kaskin of the U.S. Navy's Sealift Office (N42) was personally briefed in his office in Crystal City, Virginia on the pentamaran ship design concept and its potential role in the Sea Basing Concept of Operations (CONOPS). In October, RADM Marc Purcell and the staff (including CAPT (sel) Rodney Clark and CDR John Gosebrink) of the U.S. Transportation Command's (USTRANSCOM's) Requirements Office (J5) were similarly briefed in their offices at Scott Air Force Base in Illinois, just outside of St. Louis, Missouri. In November at the IMPACT 2005 CCDOTT Conference aboard the Queen Mary in Long Beach, California, LTGEN (USA-ret) Kenneth Wykle and RADM (USN-ret) Albert Herberger were in attendance at the presentation (see attached) and reviewed additional materials at their request after the meeting. In December, attendees at the SNAME Sealift Panel meeting were briefed on the further development of the Military Ro/Ro version at the N42 office in Crystal City, Virginia, including RADM (USN-ret) Carl Seiberlich, RADM Herberger and Mr. Kaskin. RADM Purcell's staff was sent updated information as well.

This work is summarized in the attached presentation given at various briefings including IMPACT 2005 (provided earlier).

Task 3 – Economic Analysis and Operational Feasibility

Subtask 3.1 – Ship Building Capital Cost Estimates

BMT Nigel Gee and Associates has estimated the costs of constructing the Commercial Express Pentamaran and the Military Logistics Pentamaran in a typical European shipyard. The estimates are \$103,877,492 for the commercial vessel and \$114,632,492 for the military vessel as of January 2006. The estimated European building costs should be viewed as both conservative and achievable. Estimates were scaled from actual shipbuilding estimates for similar size Pentamarans with similar powering and propulsion units. Quotations were provided by two European yards, the larger of which is a world leader in the construction of large container vessels. This yard has constructed a total of 1653 vessels of which 754 were merchant vessels and 100 of these container ships in the range 1000 to 5300 TEU.

Shipbuilding estimates provided by BMT NGA were carried out on the following basis:

- Original shipbuilding actual cost estimate for similar vessels.
- Adjustments made for steel weight and steel fabrication costs at January 2006.
- Actual machinery and equipment costs.

The estimated costs should be viewed in the context of the actual cost of high technology container ships being built today in Europe and in Far Eastern yards. Typical costs would be (for example):

- Container ships with the same steel weight as the Pentamaran vessels, but for speeds of approximately 22 knots, current building costs US\$45 million.
- Container ships with the same length as the Pentamaran vessels and for speeds of approximately 26 knots, but having much larger steel weights and carrying much higher deadweights, approximately US\$80 million.

National Steel and Shipbuilding Company has agreed to provide acquisition cost estimates for constructing the Commercial Express Pentamaran and the Military Logistics Pentamaran in the United States. NASSCO has been designing and building ships since 1960, specializing in auxiliary and support ships for the U.S. Navy and oil tankers and dry cargo carriers for commercial markets. Located in San Diego, California, NASSCO employs more than 4,000 people and is the only major ship construction yard on the West Coast of the United States. Over the last four decades, NASSCO has delivered over 110 ships to the world's fleets -- 57 ships to commercial customers, becoming America's leading commercial shipbuilder during this period; and 53 auxiliary and support ships for the U.S. Navy. These have included oil tankers, ferries, containerships, and oceanographic research ships for commercial customers; and hospital ships, fast combat support ships, tank landing ships, and roll-on/roll-off ships for the United States Navy. NASSCO currently has contracts to build four double-hull crude oil tankers for BP and eight T-AKE dry cargo/ammunition ships for the U.S. Navy.

NASSCO's shipyard facilities are capable of building commercial cargo ships and tankers and Navy auxiliary ships up to 1,000 feet in length and servicing or repairing any vessel sailing on the West Coast of the United States. The shipyard is located on San Diego Bay,

which has a channel depth of 35 feet. To reach NASSCO, ships pass under the Coronado Bridge, which has a vertical clearance of 195 feet.

The shipyard encompasses 80 acres of land and 46 acres of water and offers:

- A 1,000-foot long, 174-foot wide graving dock with a lift capacity of 30,000 long tons
- 10 whirley/portal cranes with individual lift capacities up to 300 tons and multi-crane lifts up to 550 tons
- 6 production workshops and 10 assembly areas

The pentamaran ships, both commercial containership and military logistics variants, can be fully assembled in the graving dock. In a letter dated February 20, 2006 (attached) NASSCO provided a Rough Order of Magnitude (ROM) price estimate for each variant. The construction cost estimates given are \$316,000,000 for the commercial vessel and \$361,000,000 for the military vessel (both on an each of five basis) as of January 2006.

Subtask 3.2 – Operational Deployment Scenarios

Commercial Express Pentamaran Ship Design:

Payload -

The payload consists of 462 8 x 8.5 x 40 foot ISO Containers at an average gross weight of 13 metric tons per box stowed in vertical cells, both below and upon the main deck for a total payload of 6000 metric tons.

Speed -

The trial speed of the ship is 40 knots in Sea State 4 at 100% MCR. The sustained speed of the ship is 38 knots in Sea State 4 at 90% MCR.

Range -

The range of the ship is 4000 nautical miles at 100% MCR with a 5% fuel reserve.

Deployment -

The ship is one of a fleet of five that can provide regularly scheduled service between New York and Rotterdam - 3383 nautical miles - on a sailing frequency of every two days. The ship shall be nominally at sea for four days in each direction with one day in each port for container discharge and loading for a ten day round voyage.

Military Sealift Pentamaran Ship Design:

Payload -

The payload consists of the vehicles and equipment of a Marine Expeditionary Unit (MEU). A summary of this is as follows:

12 MV-22 Osprey @ 31,772 lb empty weight each
4 CH-53 Super Stallion @ 33,226 lb empty weight each
3 UH-1N Iroquois @ 9,400 lb empty weight each
6 AH-1W Cobra @ 11,900 lb empty weight each
4 M1A1 Abrams @ 63 tons each
12 EFV (ex-AAAV) @ 31.5 tons empty weight each
6 M198 Howitzers @ 15,758 lb each
100 HMMV @ 5,200 lb each

These vehicles are to be stowed in approximately 62,000 sq ft of covered cargo space, with appropriate overhead clearances for each class of vehicle.

Additionally, 160,000 cu ft of cargo and equipment shall be carried in covered cargo space in a combination of ISO containers, QUADCONS, JMICS and JMIPS. At an estimated average of 100 cu ft per ton, this totals 1600 tons.

Note: These requirements are summarized from Table 3.1 on page 26 of “*Naval Expeditionary Logistics – Enabling Operational Maneuver from the Sea*”, Naval Studies Board, National Research Council, Washington, D.C., 1999

Speed -

The trial speed of the ship is 40 knots in Sea State 4 at 100% MCR. The sustained speed of the ship is 38 knots in Sea State 4 at 90% MCR.

Range -

The range of the ship is 6500 nautical miles at 100% MCR with a 15% fuel reserve.

Deployment -

The ship is capable of two typical voyage scenarios as follows:

1. San Diego, CA (Camp Pendleton – 11th/13th/15th MEU) – Naha, Okinawa (U.S. Marine Base) 5721 nautical miles.
2. Wilmington, NC (Camp Lejeune – 22nd/24th/26th MEU) – Mersin, Turkey (Incirlik Air Base) 5509 nautical miles.

Other voyage scenarios can be postulated as well.

Subtask 3.3 – Ship Operating Cost Estimates

A Microsoft Excel spreadsheet model was developed for both the Commercial Express and Military Logistics ship design variants. The model contains estimates of ship acquisition capital cost, and various operating costs such as manning, fuel, maintenance and repair, insurance, port fees and cargo handling. Future expansion of the model to include fleet costs such as management and administration, terminal expenses, and other system costs has been provided. The model was run for various cargo load factors and various returns on capital investment. The model produces estimates of fully allocated cost shown in both Dollars per (Metric) Ton – (Nautical) Mile as well as Dollars per Box for the Commercial Express ship and Dollars per Unit (defined as 100 metric tons) for the Military Logistics ship.

The attached six output charts summarize the results in the following order:

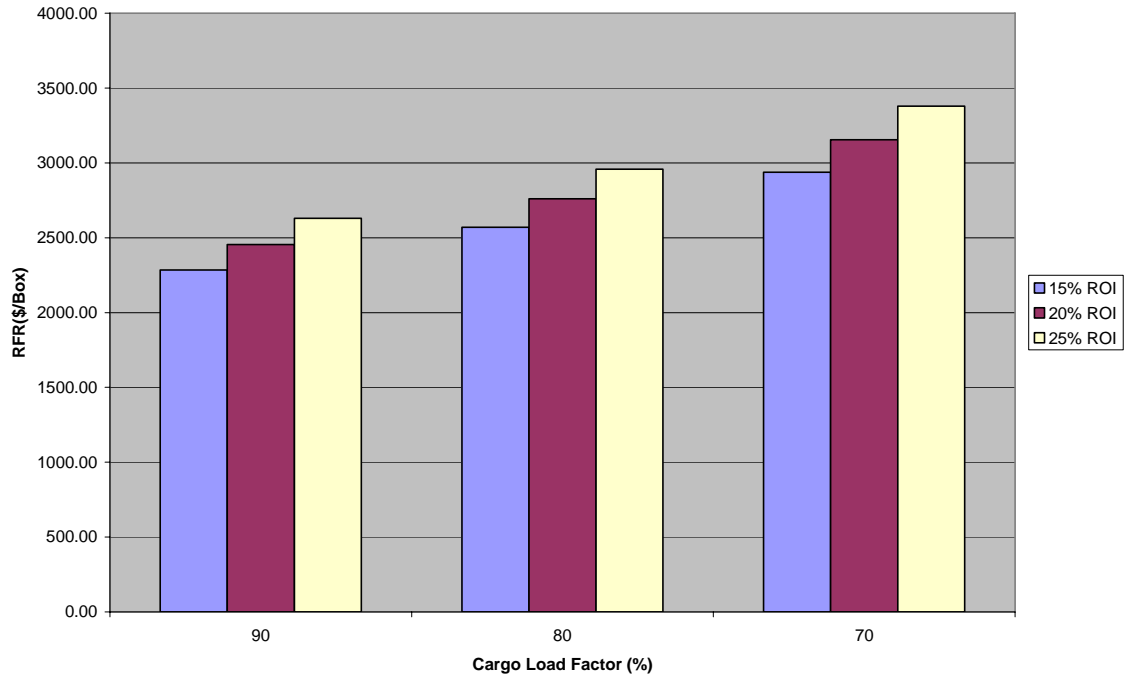
1. Commercial Containership – European Construction (Page 9 Top)
2. Military Roll-on/Roll-off – European Construction (Page 9 Bottom)
3. Commercial Containership – NGA Estimate x 2 (Page 10 Top)
4. Military Roll-on/Roll-off – NGA Estimate x 2 (Page 10 Bottom)
5. Commercial Containership – NASSCO Estimate (Page 11 Top)
6. Military Roll-on/Roll-off – NASSCO Estimate (Page 11 Bottom)

In all six cases, manning costs are typical of international western maritime nation flags of registry and may be lower than U.S. flag.

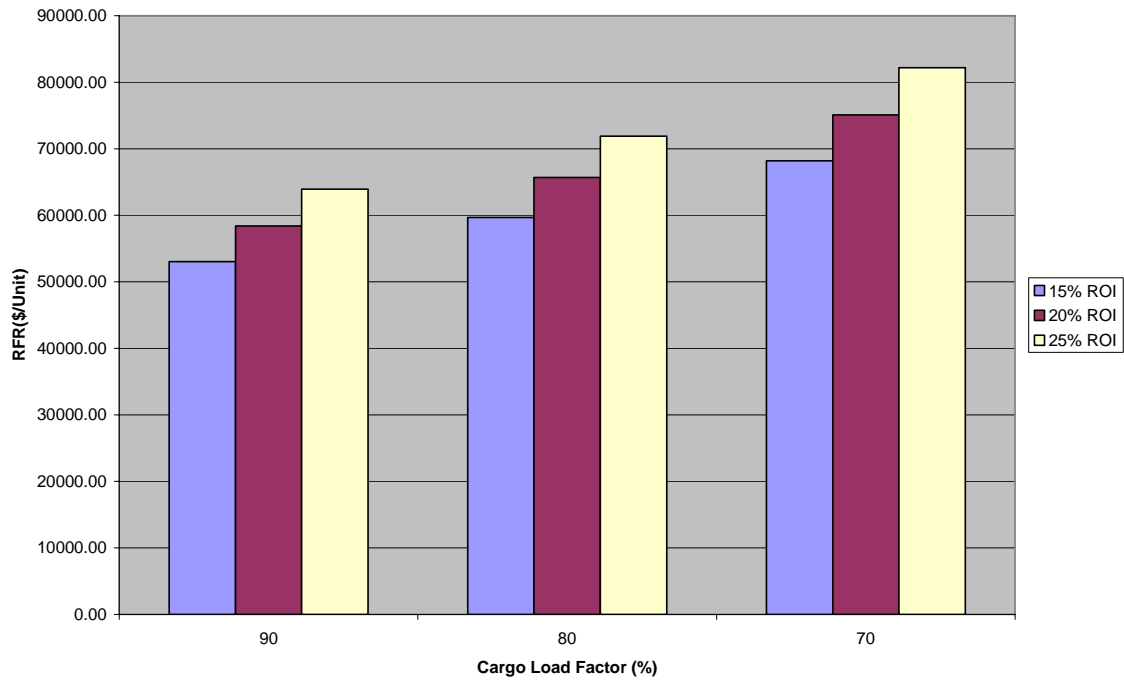
In conclusion, the Microsoft Excel spreadsheet model can be used to run an almost infinite number of cases that can illustrate many different assumptions and portray sensitivity to changes in any input variable, either in cost or operational scenarios. It is recommended that CCDOTT provide FY2006 funding to provide for such analyses to the degree desired for either N42 or USTRANSCOM use.

Note: Since the NASSCO letter dated February 20, 2006 raised certain issues relative to the design of the Pentamaran ships by BMT Nigel Gee and Associates, Ltd., a letter (by e-mail) from NGA dated February 24, 2006 responding to these issues is attached. Further technical research and engineering development beyond the scope of this project is required to fully resolve these issues.

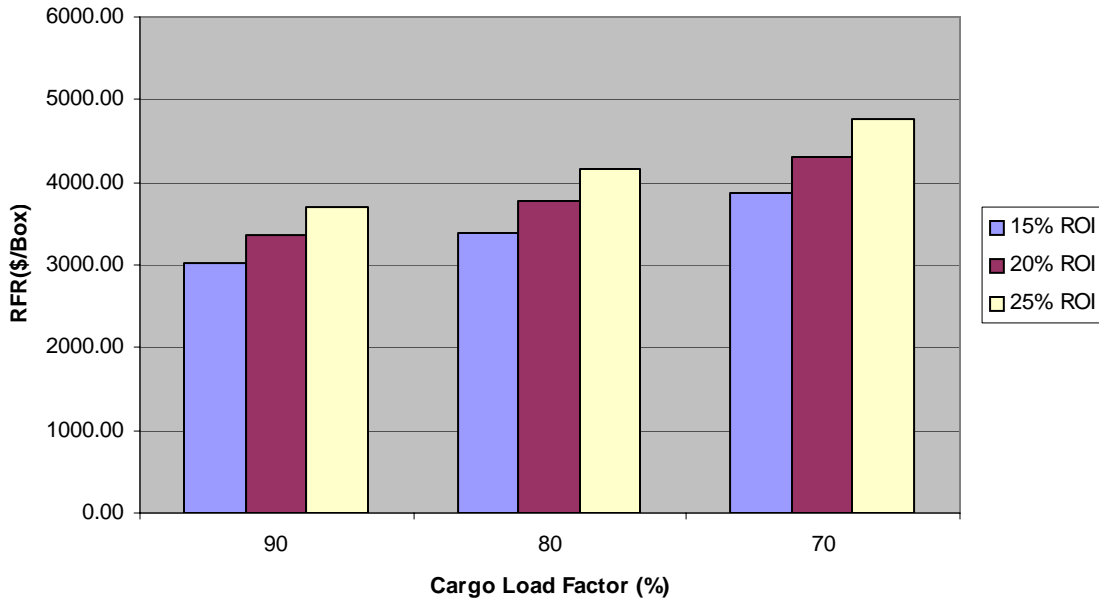
COMMERCIAL EXPRESS PENTAMARAN



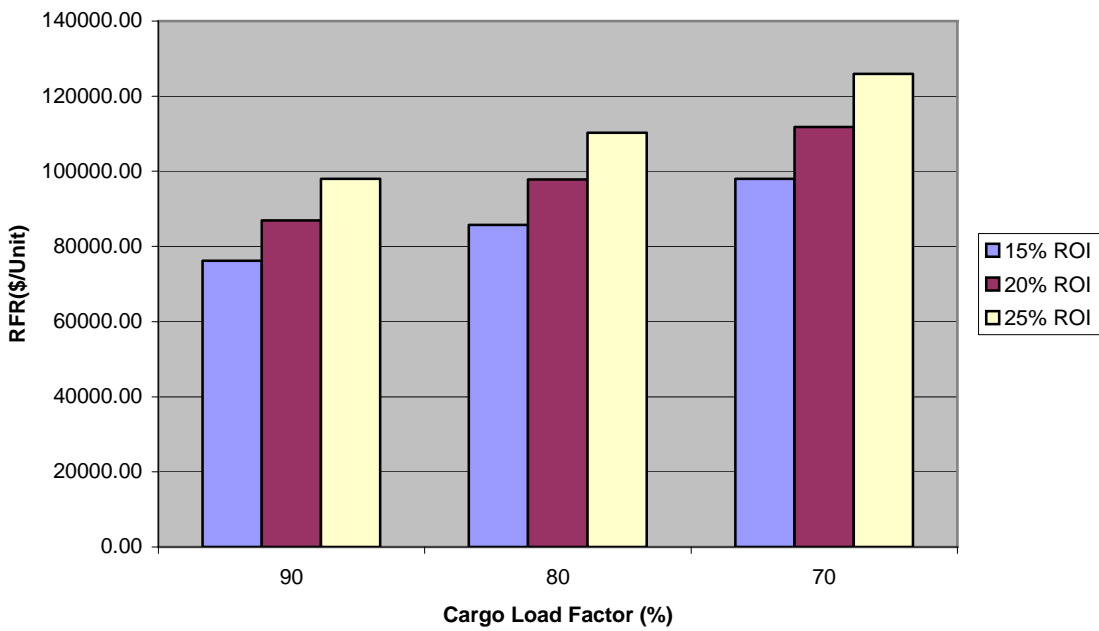
MILITARY LOGISTICS PENTAMARAN



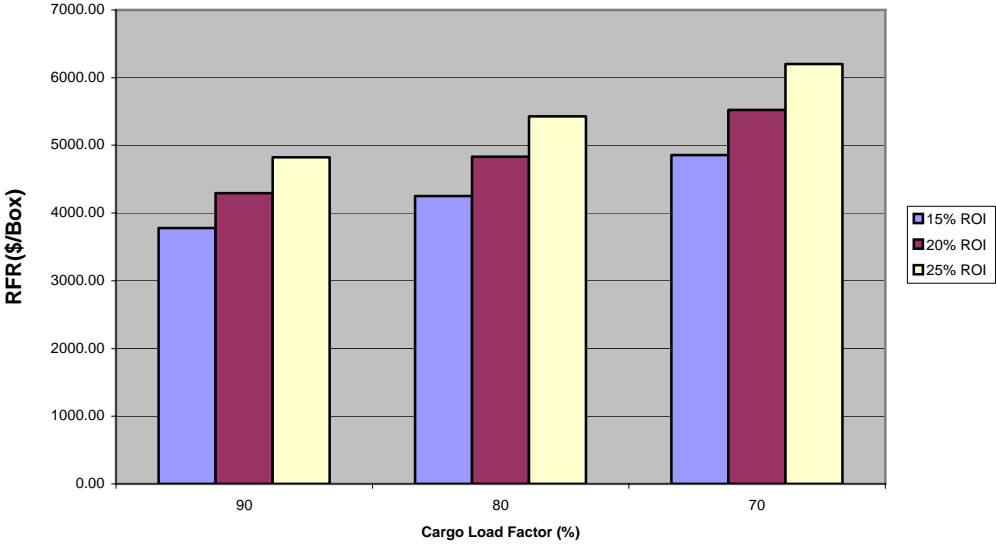
COMMERCIAL EXPRESS PENTAMARAN



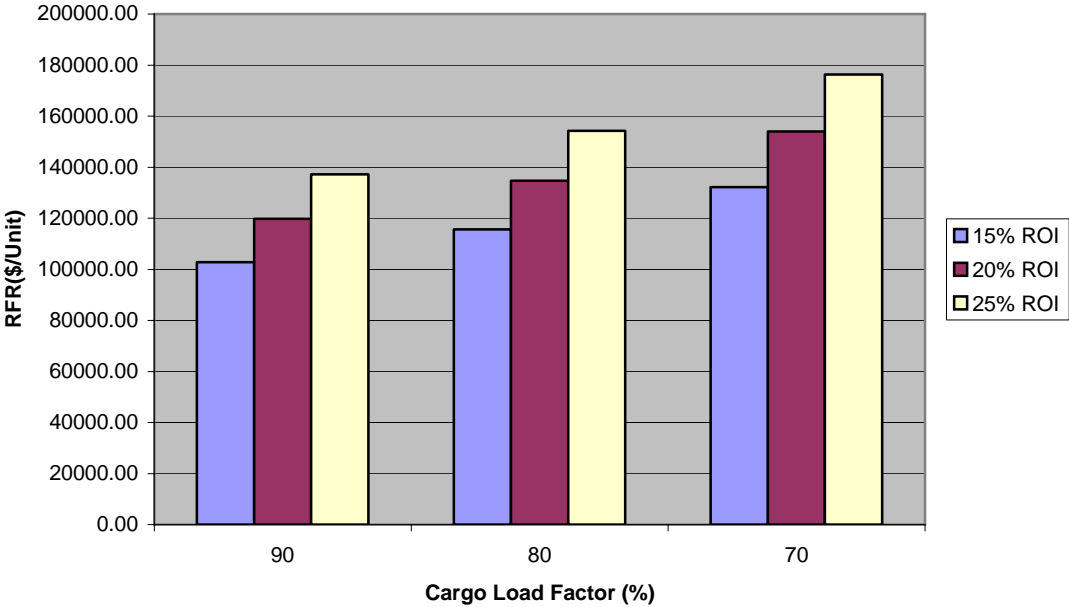
MILITARY LOGISTICS PENTAMARAN



COMMERCIAL EXPRESS PENTAMARAN



MILITARY LOGISTICS PENTAMARAN



Example of Microsoft Excel Spreadsheet (Page 1)

CCDOTT Marine Transportation System Economic Analysis Model

Commercial Containership - European Shipbuilding Cost

Descriptor

Configuration	Pentamaran	Pentamaran	Pentamaran	Pentamaran	Pentamaran
Gross Payload(mt)	6,000	6,000	6,000	6,000	6,000
Design Speed(knots)	40	40	40	40	40
Range(n.mi.)	4000	4000	4000	4000	4000
Gross Wt/Box(mt)	13	13	13	13	13
Internal Volume(cuft)	2388	2388	2388	2388	2388
Containers(8x8.5x40)	462	462	462	462	462
Tare Weight/Box(mt)	3.5	3.5	3.5	3.5	3.5
Net Weight/Box(mt)	9.5	9.5	9.5	9.5	9.5
C. Density(lbs/cu.ft.)	8.77	8.77	8.77	8.77	8.77
Net Payload(mt)	4,385	4,385	4,385	4,385	4,385
Displacement(mt)	19,000	19,000	19,000	19,000	19,000
Installed Power(MW)	95.6	95.6	95.6	95.6	95.6
Transport Factor(TF)	40.14	40.14	40.14	40.14	40.14
Fuel Rate(g/KW-hr)	184	184	184	184	184
Fuel Margin(%)	5	5	5	5	5
Fuel Weight(mt)	1846.99	1846.99	1846.99	1846.99	1846.99
Cargo Weight(mt)	6,000	6,000	6,000	6,000	6,000
Misc. Weight(mt)	35	35	35	35	35
Deadweight(mt)	7,882	7,882	7,882	7,882	7,882
Lightship Wt(mt)	11,118	11,118	11,118	11,118	11,118
Operatg Pwr(%MCR)	90	90	90	90	90
Operating Pwr(MW)	86.04	86.04	86.04	86.04	86.04
Avg. Speed(kts)SS4	38	38	38	38	38
OW Voyage Dist(nm)	3383	3383	3383	3383	3383
OW Sea Time(hr)	89.02631579	89.02631579	89.02631579	89.02631579	89.02631579
CH Rate(Box/hr)	40	40	40	40	40
Add. Port Time(hrs)	7.9	7.9	7.9	7.9	7.9
OW Voyage Time(hr)	120.0032389	120.0032389	120.0032389	120.0032389	120.0032389
RT Voyage Time(hrs)	240.0064777	240.0064777	240.0064777	240.0064777	240.0064777
Oper.Time(days/yr)	350	350	350	350	350
RT Voyages per Yr	34.99905536	34.99905536	34.99905536	34.99905536	34.99905536
OW Voyages per Yr	69.99811071	69.99811071	69.99811071	69.99811071	69.99811071
Avg. Cargo Load(%)	90	80	70	90	80
Ann. Cargo Del.(mt)	276223.3138	245531.8345	214840.3552	276223.3138	245531.8345

Example of Microsoft Excel Spreadsheet (Page 2)

Hull Material	Steel	Steel	Steel	Steel	Steel
Hull Weight(mt)	7568	7568	7568	7568	7568
Hull Structure(\$)	22704000	22704000	22704000	22704000	22704000
Machinery Type	MS Diesel	MS Diesel	MS Diesel	MS Diesel	MS Diesel
Mach'y Weight(mt)					
Machinery(\$)	53523492	53523492	53523492	53523492	53523492
Outf't'g Weight(mt)					
Outfitting(\$)	27650000	27650000	27650000	27650000	27650000
Tot. Capital Cost(\$)	103877492	103877492	103877492	103877492	103877492
Target ROI(%)	15	15	15	20	20
Economic Life(Yrs)	25	25	25	25	25
	0.15469940	0.15469940	0.15469940	0.20211872	0.20211872
CRF	2	2	2	9	9
Ann. Capital Cost(\$)	16069786	16069786	16069786	20995587	20995587
Crew Size	20	20	20	20	20
Crew Cost(\$/per/yr)	66029	66029	66029	66029	66029
Manning(\$)	1320580	1320580	1320580	1320580	1320580
Fuel Price(\$/mt)	300	300	300	300	300
Fuel(\$)	29596762	29596762	29596762	29596762	29596762
M&R(\$)	3116325	3116325	3116325	3116325	3116325
Insurance(\$)	2077550	2077550	2077550	2077550	2077550
Cargo L/D(\$/Box)	200	200	200	200	200
Cargo Hndlg(\$)	12922728	12922728	12922728	12922728	12922728
Port Expenses(\$)	1329964	1329964	1329964	1329964	1329964
Ann. Oper. Cost(\$)	50363909	50363909	50363909	50363909	50363909
Mgmt&Admin(\$)					
Terminal Costs(\$)					
Ann. Sys. Cost(\$)					
Number Ships					
Tot. Ann. Cost(\$)	66433695	66433695	66433695	71359495	71359495
RFR(\$/mt-nm)	0.0711	0.0800	0.0914	0.0764	0.0859
RFR(\$/Box)	2284.82	2570.42	2937.62	2454.23	2761.01

Subtask 4.3 – Conclusions and Recommendations

It is concluded that the Commercial Express Containership Pentamaran Design and the Military Logistics Roll-on/Roll-off Pentamaran Design are both technically feasible. Additional technical design and engineering development work is needed in order to resolve certain issues and to bring the designs to the level of a Contract Design suitable for a shipyard to provide a firm price for a ship construction contract.

It is also concluded that both ships can be deployed in operational scenarios suitable for their successful utilization by commercial shipowners (such as Maresk) and military logistics operators (such as USTRANSCOM/MSC) respectively. Such ships can be either owned directly by their end user parties or leased/chartered from primary owners, as appropriate to each business case.

Additionally, it is concluded that the cost, both in acquisition and operation, of 40-knot ships is an expensive proposition for all concerned, particularly as fuel oil prices are at record levels and may continue to rise in the future. Clearly the requirements for such high speed ships must be clear and the ability to generate commercial/military shipper revenue and/or compensatory lease/charter rates to cover such costs and provide a profit commensurate with the risk is paramount.

Finally, it is recommended that CCDOTT and other sponsors fund the further technical development, operational assessment and economic analysis of innovative high speed ships such as the Pentamaran in order to encourage and facilitate the progress in this field of potential critical importance to the economic and national security of the United States.

Principal Attachments

1. Pentamaran Concept Design – ADX Containership
Preliminary Technical Specifications
Document NG518-070-51
September 29, 2005
2. Pentamaran Concept Design – Defense Logistics Ro/Ro
Preliminary Technical Specifications
Document NG518-070-54
December 9, 2005
3. Presentation: “Military Sealift Pentamaran Ship Design”
BMT SYNTEK Technologies, Inc.
November 10, 2005
4. NASSCO Letter dated February 20, 2006
5. BMT NGA E-mail dated February 24, 2006

Note: These Attachments were delivered earlier and are not included here for convenience.