Carderock Division
Naval Surface Warfare Center

Bethesda, MD 20817-5700

CDNSWC-TSSD-98-009 September 1998

Total Ship Systems Engineering Directorate
Technology Projection Report

HIGH-SPEED SEALIFT TECHNOLOGY
Volume 1

BY

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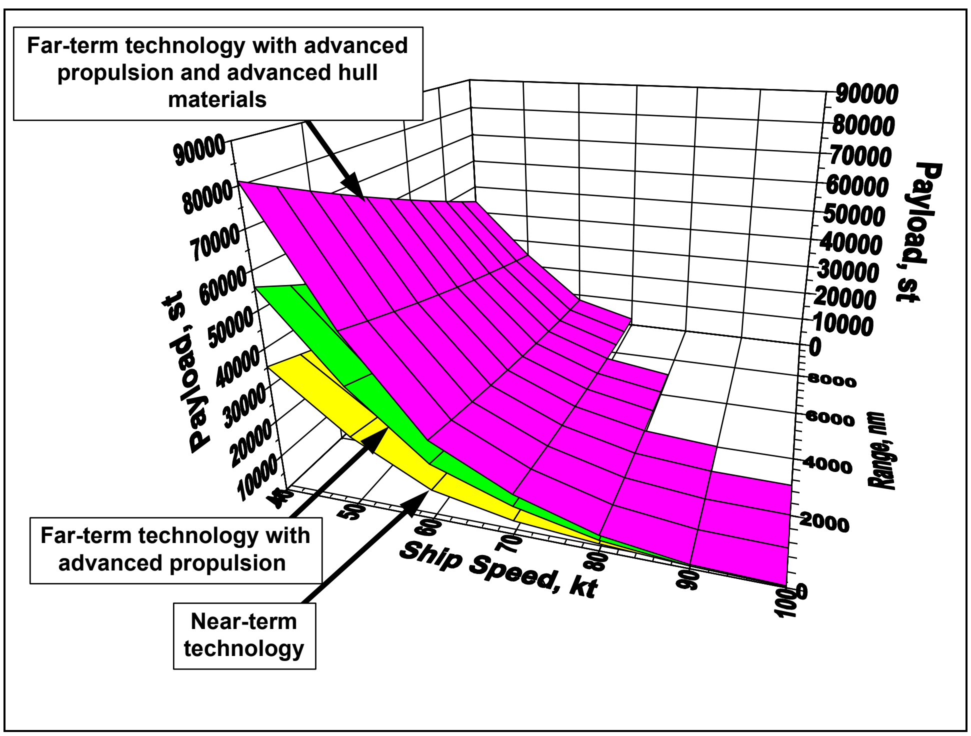

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1. REPORT DATE **SEP 1998**	2. REPORT TYPE	3. DATES COVERED **00-00-1998 to 00-00-1998**
4. TITLE AND SUBTITLE **High-Speed Sealift Technology Volume 1**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Surface Warfare Center,Carderock Division,Total Ship Systems Engineering Directorate,Bethesda,MD,20817-5700**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**71**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

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EXECUTIVE SUMMARY

This document summarizes the findings and conclusions from the High-Speed Sealift Technology Workshop, held at the Naval Surface Warfare Center, Carderock Division (NSWCCD), from 21-23 October 1997 and the subsequent post-workshop analysis that was briefed out on 25 March 1998. The workshop was sponsored by the US Transportation Command (USTRANSCOM) in partnership with the Center for the Commercial Deployment of Transportation Technologies (CCDoTT) and the Maritime Administration (MARAD), the US Navy, and the US Army. This document describes part of a process that has been initiated within the Department of Defense (DoD) and industry to help define the next generation of sealift ships. This document specifically examines the possibilities offered by technology to enhance the transport performance of high-speed commercial and military sealift ships, in advance of detailed design studies, in order to help define realistic future mission capabilities.

Technology projections made at the workshop are presented for both the near-term and the far-term, where the near-term and the far-term refer to technology that will be available in 5 years and 10 years, respectively. The impact of technology projections on transport performance properties is assessed quantitatively, and a tool has been developed to enable a user to assess near-term technology qualitatively. These assessments provide insight into the overall transport performance potential of hullforms and other technologies of interest.

The quantitative assessment uses a derivation of an empirical method[1] that provides basic parametric relationships between mission requirements expressed in terms of speed, range, and payload, and design characteristics expressed in terms of displacement, installed power, and fuel weight, to compare the various hullforms and other technologies of interest. Mission requirements of interest to both military and commercial operators were defined by the workshop as:

- Speed: 40 - 100 kt
- Range: 500 - 10,000 nm
- Payload: 500 - 5,000 ston

The results of the quantitative method were validated using a design tool based on first principle physics.[2] The qualitative assessment tool applies an established decision-making method to ascertain the relative capabilities and risks of hullforms and other technologies of interest for significant aspects of sea transport other than speed, range, and payload.

Realistic performance limits have been established, and, using these limits, the results of the quantitative analysis show that significant sealift capabilities, in terms of speed, range, and payload, are scientifically feasible for both near-term and far-term technology projections using:

- Advanced hull designs
- High-power, fuel efficient machinery
- Advanced structural designs using lightweight, high-strength materials

Full realization of these capabilities will require engineering development in supporting systems and construction techniques. In particular, the ability to package propulsion technology in advanced hulls while transmitting the power into the water is critical to achieving maximum transport capability for both near-term and far-term technologies. Engineering development will also be required to extrapolate existing ancillary systems to match these high-performance machinery plants.

The required mix of technologies depends on specific mission requirements such as speed, range, and payload. Determination of such mission requirements is expected during future phases of this process to allow the conduct of the design and cost studies necessary to enable technology investment decisions.

Commercial development can be expected to contribute to progress toward scientifically feasible performance, but Government investment may be required to realize specific military mission needs.

A website has been produced to provide all information from the workshop, including working group reports and briefout material. The qualitative analysis spreadsheet tool will be added to this website when available. The information posted on the website will be updated periodically.

URL: *ftp://web1.dt.navy.mil/pub/Hsstw97*

Both volumes of this High-Speed Sealift Technology Workshop Report will be posted on CCDoTT's web page:

URL: *http://www.ccdott.org*

ACKNOWLEDGMENTS

The authors wish to acknowledge, in particular, the contributions of:

- RADM R. Naughton (USTRANSCOM/TCJ5), RADM D. Sargent (US Navy/PEOCLA), and BG B. King (US Army/DCSLOG) as joint sponsors of the workshop and briefout.

- Representatives of CCDoTT for their contributions to the meetings held.

- Jack Offutt (NSWCCD, Code 22) for assistance with the compilation of the workshop, the briefout, and input into the many meetings held during the post-workshop analysis period.

- Brian Forstell and Chris Redmond, of Band, Lavis and Associates, for their lead role in automating the quantitative method, data searches, analysis, and presentation necessary during the post-workshop analysis period, including their contributions to the meetings.

- Howard Chatterton, of Band, Lavis and Associates, for the lead role in producing the qualitative assessment tool.

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RATIFICATION OF THIS DOCUMENT

This document presents the contributions from representatives of Government, Industry, and Academia regarding:

- The technology projections and methods of analysis generated at the workshop
- The post-workshop analysis results and conclusions presented at the briefout

In acknowledgment of the full participation of such representatives, and in ratification that the methods, technology projections, post-workshop analysis results, and conclusions are credible and comprehensive, the following personnel endorse the technical content of this document:

....	....
Dr. C. Kennell date	Mr. D. R. Lavis date
Naval Architect	Band, Lavis and Associates
NSWCCD	Senior Vice President of CDI Marine
....	....
Dr. D. Savitsky date	Mr. G. Ashe date
Professor Emeritus	Director
Stevens Institute of Technology	ABS Americas

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Section 1

ADMINISTRATIVE INFORMATION

The report of the High-Speed Sealift Technology Workshop consists of two volumes.

Volume 1 – **High-Speed Sealift Technology** provides a summary of:

- The workshop presentations
- The working group reports
- The post-workshop analysis methods and results
- The briefout presentation

Volume 2 – **High-Speed Sealift Technology Workshop Documentation** provides:

- The agenda and list of workshop attendees for the 21-23 October 1997 workshop
- The minutes and presentation handouts from the 21 October morning session
- The High-Speed Hullforms and Propulsor Technology working group report
- The High Density/Efficiency Propulsion/Prime Mover Technology working group report
- The Loads, Materials, and High-Strength, Lightweight Structures Technology working group report
- The Critical Ship/Port Interface (Load/Unload, C4I) Technologies working group report
- The Ship/System Concepts working group report
- The Shipbuilding/Manufacturing working group report
- The 25 March 1998 briefout presentation
- The 25 March 1998 briefout minutes

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Section 2

INTRODUCTION

2.1 BACKGROUND

Since the emergence of the New World Order, the US has been significantly reducing its overall military inventory, both equipment and personnel, but particularly that stationed overseas. Emphasis is shifting from maintaining the number of prepositioned ships and equipments to rapid power projection capability from the Continental United States (CONUS). To contribute to this power projection capability, an emerging transportation option is the potential use of reliable, strategic high-speed sealift ships. The present military sealift inventory, however, may not meet this future need. Therefore, the viability of new High-Speed Sealift (HSS) ships (oceangoing cargo vessels capable of at least 40 kt that are able to onload and offload military cargo in undeveloped ports and at sea) needs to be explored. Such HSS ships would form one part of the overall logistics chain.

Current budgetary pressures indicate that providing dedicated military sealift capability alone is unlikely, and a significant portion of the development must be leveraged from commercial advances. In view of both recent vigorous technological developments in the commercial fast-ferry markets, driven by competitive advantage, and DoD acquisition reform, which emphasizes greater utilization of commercial assets, military reliance on partnerships with industry for future HSS ships is the favored DoD option. The DoD is already exploring partnership options with initiatives such as the Voluntary Intermodal Sealift Agreement (VISA), the Maritime Security Program (MSP), and the National Defense Feature (NDF) Program to encourage commercial participation in military programs. Ideally, developments for future HSS ships will lead to designs that are both commercially viable and militarily useful.

2.2 PROCESS

DoD is in the early stages of a process to define its future strategic sealift requirements. Focus is being given to the logistics chain as a whole; i.e., from origin to destination, or “Fort to Foxhole,” by:

- Developing, where necessary, innovative options to support rapid deployment and movement of cargo

- Increasing inland, port, and terminal throughput and improving origin-to-destination movement.

Achieving both commercially viable and militarily useful transportation and infrastructure which, for military purposes, can load/unload cargo in underdeveloped ports and at sea, is dependent on desired transport performance requirements. The military needs to identify and evaluate desired warfighting capabilities, strategic mobility requirements, and associated benefits; and commercial shippers and operators must define the transportation and infrastructure characteristics in the middle market (high-value, time sensitive goods), or other profitable markets, to identify where military and commercial interests intersect. Definition of such requirements is, in part, driven by what is technically achievable. One of the ways in which USTRANSCOM, partnering with MARAD, is preparing to face the strategic mobility challenges of tomorrow, to include such emerging concepts as high-speed sealift and agile ports (APs), is through CCDoTT. CCDoTT was formed to enable DoD and other sponsors to:

- Leverage commercial technologies in addressing defense transportation infrastructure issues

- Conduct R&D for defense infrastructure initiatives

- Provide a technology transfer/dual use bridge between DoD and commercial sector

To assist in defining realistic transport performance requirements for the next generation of HSS ships by determining what is technically achievable, USTRANSCOM, US Navy/PEOCLA, and US

Army/DCSLOG jointly sponsored two HSS technology meetings, hosted by NSWCCD. Economic considerations were not introduced at this stage, inasmuch as the initial focus was on determination of technological feasibility without regard to cost of development or commercial viability. However, these were recognized as essential issues to be addressed in a subsequent phase of the process (see Figure 1). The first meeting, held in October 1997, took the form of a workshop, which was intended to identify, where necessary, innovative options to support rapid deployment and movement of cargo. This was achieved by characterizing current technology, predicting future capabilities, and determining the methods of analysis necessary to ascertain the transport improvement possible as a result of the technology projections. The second meeting, held in March 1998, was a briefout of the results of the post-workshop analysis.

Figure 1 pictorially represents the definition process and demonstrates how the information from the workshop and briefout is intended to assist the user community, both DoD and industry, in the identification of realistic mission requirements in advance of detailed design studies. Figure 1 also shows progress to date. The information contained in this document, in conjunction with the qualitative spreadsheet tool, will allow the user communities to define their mission capabilities of interest. In assisting the user community in defining realistic future transport requirements in advance of detailed design studies, it is the intention to produce a joint strategy to develop the critical technologies necessary to meet the future needs of both DoD and industry. Thus, this DoD-led process includes full participation with industry, and both the workshop and the briefout were attended by some 200 international participants from DoD, Industry, and Academia. Participants are listed in Volume 2.

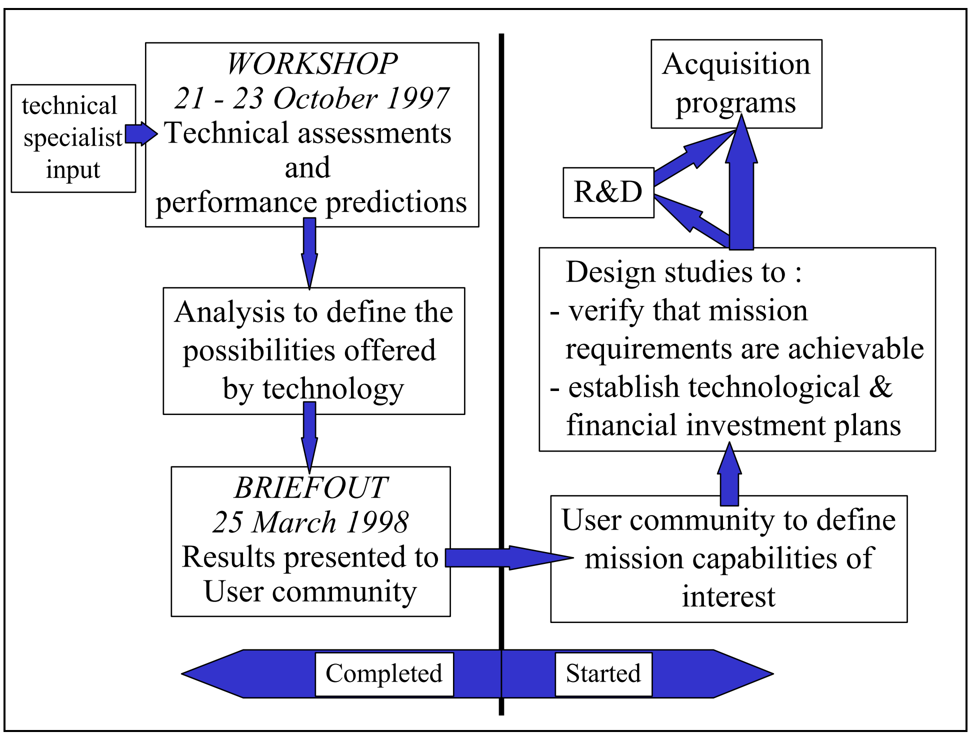

Figure 1 Process for Determination of Mission Capabilities of Interest and Technology Needs

Section 3

THE WORKSHOP

3.1 INTRODUCTION

The workshop was intended to identify, where necessary, innovative options to support rapid deployment and movement of cargo. The workshop focused on:

- Characterizing current technology
- Predicting future capability
- Determining the methods of analysis to be used to ascertain the transport improvements possible as a result of the technology projections

Expert opinion was solicited to address such subjects by forming working groups in six key areas, namely:

- Ship/system concepts
- Hullforms and propulsors
- Propulsion plant
- Cargo onload/offload and stowage
- Materials and ship structures
- Shipbuilding/manufacturing

3.2 AGENDA

The agenda for the workshop, held at NSWCCD from 21-23 October 1997, was as follows:

21 October 1997
am

• Introductions	Mr. R. Keane	NSWCCD
	Mr. K. Seaman	USTRANSCOM/TCJ5-SC
	BG B. King	US Army/DCSLOG
	Mr. J. Kaskin (on behalf of RADM D. Sargent)	OPNAV N42 (PEOCLA)
	RADM R. Naughton	USTRANSCOM/TCJ5
• Presentations	Lt. Col. F. Hillson, Joint Staff J-7	Joint Vision 2010
	Mr. K. Seaman, USTRANSCOM/TCJ5-SC	CCDoTT High Speed Sealift & Agile Port Program
	LTC R. Toguchi, US Army DCSOPS	Potential Military Utility for Fast, Decisive Strategic Lift

Dr. C. Kennell, NSWCCD	Overview of High Speed Sealift Technologies
Mr. J.A. Byrne, MARAD	Commercial Ships for Military Use
Mr. A. Hahn & Mr. J. Sterling, NCAMA	HSS Commercial Viability; Framing the Challenge

<u>21 October 1997</u>
<u>pm</u>

- Working group discussions

<u>22 October</u>

- Working group discussions

<u>23 October</u>
<u>am</u>

- Working group discussions

<u>pm</u>

- Working group presentations

3.3 SUMMARY OF PRESENTATIONS ON MORNING OF 21 OCTOBER

3.3.1 JOINT VISION 2010
Lt. Col. F. Hillson, Joint Staff J-7

An overview presentation of Joint Vision (JV) 2010 was given to provide background information regarding the envisaged implementation of US defense strategy and the role that future HSS ships might perform. JV2010 is the conceptual template for how US armed forces will channel the vitality and innovation of their personnel and leverage opportunities to achieve new levels of effectiveness in joint warfighting. JV2010 begins by addressing the expected continuity and changes in the strategic environment, including technology trends and their implications, for US armed forces. It recognizes the crucial importance of our current high-quality, highly trained forces and provides the basis for their further enhancement by proscribing how they will fight in the early 21st century.

The four operational concepts of JV2010 were described: Dominant Maneuver, Precision Engagement, Focused Logistics, and Full Dimensional Protection, including the implementation plan. It was emphasized that the JV2010 implementation plan incorporates the JV2010 concept into existing processes. The presentation material is reproduced in full in Volume 2, and further information is available at *http://www.dtic.mil/doctrine/jv2010*.

3.3.2 HIGH SPEED SEALIFT/AGILE PORT PROGRAM
Mr. K. Seaman, USTRANSCOM/TCJ5-SC

The purpose, mission, and objectives of CCDoTT, which is a consortium of public, academic, and private activities, undertaking a Congressionally sponsored program to identify and demonstrate advanced technologies, in partnership with USTRANSCOM and MARAD, were described as follows:

- Purpose - ". . . prototyping of AP facilities operating in combination with HSS and related rapid-deployment technologies and the enhancement of capabilities for cargo and personnel movement tracking and total asset visibility" in an integrated end-to-end environment.

  <u>Note</u>: The AP concept uses materiel, cargo-handling, and information system technologies to expand the ability of commercial terminals to accommodate military cargo. In improving terminal and port system operation and capability, the AP concept provides one mechanism to

identify common features for military and commercial requirements.[4]

- Mission - "Leverage commercial and national defense rapid deployment and logistics capabilities, facilitate national and international trade."

- Goal - "Improve military deployment effectiveness and the nation's productivity, competitiveness, and balance of trade."

- Objective - "Reduce time and cost of military deployments and commercial goods transport, especially critical items and high-value, time-sensitive goods."

CCDoTT's vision in support of USTRANSCOM and MARAD was outlined as a partnership with USTRANSCOM to improve the overall Defense Transportation System by:

- Enhancing DoD's global rapid response capabilities

- Leveraging Federal programs and commercial resources

- Developing innovative options to support rapid deployment/movement of cargo

- Increasing inland, port, and terminal throughput and improving origin-to-destination movement

CCDoTT's approach was described as follows:

- To demonstrate effective operations of AP systems in concert with HSS and rapid deployment technologies within 5 years.

- To work with attendant terminal, intermodal hub, highway, and rail infrastructures and information management systems.

- To partner with HSS/AP designers, builders, suppliers, owners, operators, and users to establish requirements and facilitate development of dual-use HSS/AP systems.

- To undertake demonstrations in support of both commercial and military cargo movement.

CCDoTT's future direction was described as follows:

- A proposed 5-year, $100 million program, at approximately $20 million per year.

- To apply technology to deliver prototypes, simulations, and demonstrations.

- To integrate rapid-movement technologies to the process of improving end-to-end delivery to customer.

- To facilitate AP/HSS and rapid deployment prototypes within 5 years.

- To use a total system approach to program development and implementation.

CCDoTT's High-Speed Sealift/Agile Port Operational Concept Document, dated April 97, was provided as a handout,[4] and is available for download from the internet:

URL: *http://heart.engr.csulb.edu/~ccdott/*

The formation of the workshop was supported by USTRANSCOM as a forum to provide expert guidance for emerging technologies that have HSS applications. The presentation material is reproduced in full in Volume 2.

3.3.3 POTENTIAL MILITARY UTILITY FOR FAST DECISIVE STRATEGIC LIFT
LTC R. Toguchi, US Army DCSOPS

The trend toward concentrating US armed forces on CONUS was discussed, and the importance of speed and power projection to prevent unnecessary escalation of conflicts and to provide disaster relief or humanitarian aid was demonstrated. General military parameters for fast, decisive sealift were proposed as follows:

- Speed: 40 - 100 kt
- Range: 5,000 - 10,000 nm
- Payload: 2,000 - 5,000 ston
- Payload: 75,000 - 150,000 ft^2
- Shallow draft/austere port/in-stream discharge capable

The presentation material is reproduced in full in Volume 2.

3.3.4 OVERVIEW OF HIGH-SPEED SEALIFT TECHNOLOGIES
Dr. C. Kennell, NSWCCD

An empirically based, quantitative 3-D parametric transport analysis method to compare various hullforms and other technologies of interest was presented.[1] The method provides uncomplicated parametric relationships between mission requirements, expressed in terms of speed, range, and payload, and overall ship design characteristics, expressed in terms of displacement, installed power, and fuel weight.

Use of this quantitative method was proposed to address the impact of technology projections on overall transport performance because the method allows significant insight into the overall transport potential of hullforms and other technologies of interest considerably in advance of detailed design studies. It would be possible to advise potential users of what is technologically possible, and how to get there.

It was proposed that the individual working groups categorize technology predictions in the near-term and far-term, where:

- The “near-term” refers to technology that will be available in 5 years.
- The “far-term” refers to technology that will be available in 10 years.

A demonstration of the quantitative method was given. The presentation material is reproduced in full in Volume 2.

3.3.5 COMMERCIAL SHIPS FOR MILITARY USE
Mr. J. A. Byrne, MARAD

A case for developing a commercial fleet of ships for military use in times of national emergency was presented. Recent Government/Industry partnership initiatives encouraging the development of commercially viable, militarily useful ships were described, including:

- The National Shipbuilding Initiative
- Title XI loan guarantees

- Maritime technology (MARITECH)

Recent developments in commercial shipping were used to demonstrate possible commercially viable, militarily useful ships. It was concluded that the time and cost of the entire sealift process could be improved, and that commercial assets should be part of the solution. The presentation material is reproduced in full in Volume 2.

3.3.6 HSS COMMERCIAL VIABILITY; FRAMING THE OPPORTUNITY/CHALLENGE Mr. A. Hahn/Mr. J. Sterling, NCAMA

A role for the National Center for Advanced Marine Applications (NCAMA) was defined.

The presentation conveyed the preliminary results of previous market and economic studies of the commercial viability of supporting HSS, and additionally suggested timeframes for commercial development and projected the likely future direction of market and economic studies.

It was concluded that there is a perceived market for HSS, and that there is justification for proceeding with cargo-carrying HSS technology development. The presentation material is reproduced in full in Volume 2.

3.4 SUMMARY OF WORKING GROUP TECHNOLOGY PREDICTIONS AND CONCLUSIONS

This section presents summaries of the main technology predictions and conclusions of the six working groups. It is worth noting that there were no predictions of technology breakthroughs, in the sense that the technology projections from the working groups were based on evolutions of current physics. The reports from each working group are reproduced in full in Volume 2.

3.4.1 SHIP/SYSTEM CONCEPT WORKING GROUP

This working group:

- Established the approach to evaluate the merits of the technology projections, provided by other working groups, for post-workshop analysis. The working group concurred that two methods of analysis were needed to examine the impact of technology projections on ship properties. The first method was a derivative of the quantitative method published by Dr. Kennell[1] as described in Section 3.3.4. The second method was a qualitative assessment to ascertain the relative capabilities for significant aspects of sealift transport other than speed, range, and payload. This method also included a means to measure the relative risks for hullforms and other technologies of interest.

- Formulated the method to capture the output from other working groups to enable the post-workshop analysis to be conducted.

- Considered the speed, range, and payload parameters of interest to both military and commercial operators, and defined the following set of parameters for use by the other working groups:

  - Speed: 40 - 100 kt

  - Range: 500 - 10,000 nm (see Section 3.3.3 for US military parameters of interest)

  - Payload: 500 - 5,000 ston (see Section 3.3.3 for US military parameters of interest)

  - Payload: 10,000 - 150,000 ft^2 (this was modified from the US military parameters of interest to be consistent with the payload change, at the same payload density)

- For military purposes, shallow draft/austere port/in-stream discharge capable.

- Determined that the post-workshop analysis should be limited to surface ships only. Solutions utilizing airship, wing in-ground effect (WIG), or submarine technology would not be considered.

- Concluded that conceptual ship designs and associated cost data would be required to adequately validate the post-workshop analysis results.

3.4.2 HULLFORMS AND PROPULSORS WORKING GROUP

This working group addressed hullform performance within the defined speed, range, and payload limits. This was achieved by considering displacement ships, dynamically supported ships, and power-supported ships in the following context:

- Historical origins

- Dominant physics

- Significant development milestones

- Current activities

- R&D needs/engineering challenges

- Enabling technologies

- Transport performance “state-of-the-art”

The performance claims of the projects of a number of working group participants were examined. Those performance claims that were deemed credible by this working group were used when defining state-of-the-art performance during the post-workshop analysis. The performance claims that required further substantiation, or were considered as being closer to basic research, were not considered as part of the post-workshop analysis, but these claims were acknowledged and recorded, awaiting demonstration. All such information is included in Table 9, noting that “Outlier” refers to those vehicles whose performance claims require either further substantiation or were considered as being closer to basic research.

The working group concluded that the following hullform types are contenders for the HSS role, and provided data to contribute to the definition of state-of-the-art performance:

- Displacement, semi-planing, and slender monohulls

- Displacement and semi-planing multihulls

- Small waterplane area twin hull (SWATH) and semi-SWATH

- Surface Effect Ships (SESs)

The working group concluded that the following types of craft are either unsuitable for the HSS role or the enabling technology requires demonstration, or advancement, to be considered as future HSS contenders:

- *Fully planing craft* - were not suitable for the sealift role because of their inherently low lift-to-drag ratio. Fully planing craft were categorized as having a volume Froude number of greater than 3.

- *Hydroski's* - consensus was that performance claims need to be substantiated before such craft can be considered further.

- *Hydrofoils* - the achievable lift-to-drag ratio was considered to be too low to achieve the required goals for speed, range, and payload. Discussion surrounding the Dynafoil™ concept concluded that the performance claims would need to be substantiated before the concept could be considered further.

- *Quadrimaran* - the concept was discussed, but adequate data to verify performance claims were not made available to warrant consideration at this stage.

- *Ekranocats* - the status of development was considered as being close to basic research.

- *Air lubricated multihulls (SES without seals) -* Although the concept has considerable merit, it has yet to be demonstrated at a scale that provides confidence that the sealift goals of speed, range, and payload are achievable.

There were no projections made regarding changes to the underlying physics controlling the lift-to-drag ratio, although several areas of fruitful research were identified; e.g., friction reduction studies.

The working group discussed propulsor configurations, and defined state-of-the-art performance. The working group concluded that waterjets were the propulsor of choice in the speed range of 40-60 kt, with propulsive efficiencies up to 0.75. No specific projections were made for near-term or far-term performance.

3.4.3 PROPULSION MACHINERY TECHNOLOGY WORKING GROUP

This working group covered prime mover development (gas turbines, diesel engines, and fuel cells) in terms of projected power ratings, specific fuel consumption, power-per-unit weight/volume, and approximate costs for development. Fuel flexibility and mechanical and electrical transmission systems were also examined. Power limits were established along with overall system data, including weight-per-unit power rating and volume-per-unit power rating. The working group assumed a minimum power level of 50,000 hp per propulsor. A summary of the working group information follows.

3.4.3.1 Gas Turbines

Approaches to obtaining higher power output and improved efficiency were considered. The development costs for a new engine were estimated as being in excess of $1 billion. Future development by modifying an engine derived for another application was the favored method. It was considered that the core of an existing aircraft engine could be used in the development of a 100MW, 0.3 lb/hp-hr specific fuel consumption (SFC), aero-derivative engine and that a market for such an engine exists. Given available funds, it was considered that such an engine could be developed for marine use in 5 years at a cost of $300 to $500 million.

Table 1 summarizes the gas turbine performance projections of the working group, where the "Defense Range" represents the maximum envisaged improvements that could be made in the near-term for Government funded development.

Key Parameters	Near-Term	Far-Term	Defense Range (near-term)
Power (hp)	70,000	125,000	80,000
SFC(lb/hp-hr)	0.33	0.26	0.33
lb/hp	1.0	1.0	1.0
ft^3/hp *	0.1	0.1	<0.1
Fuels	Distillate/Natural Gas	Distillate/Natural Gas	Distillate/Natural Gas
Emissions	meets standards	meets standards	meets standards
MTBO (hr)	12,500 – 25,000	12,500–25,000	1,000-2,000

* engine only

Table 1 Summary of Gas Turbine Performance Predictions

3.4.3.2 Diesel Engines

The working group considered that high-speed diesel engines, the largest of which is currently in the 4,000 hp range, would be impractical when considering a minimum requirement of 50,000 hp per propulsor. Slow-speed diesels could easily provide such power levels, but were considered too large and heavy to be of practical use.

Table 2 summarizes medium-speed diesel performance projections resulting from commercial evolution alone. Table 3 summarizes medium-speed diesel performance projections that might be expected given Government funding, estimated as being of the order of $300 to $500 million.

Key Parameters	Near-Term	Far-Term
Power (hp)	40,000-50,000	57,000-71,000
BMEP (psi)	400	500
BSFC (lb/hp-hr)	0.29	0.26
rpm	300-400	300-400
lb/hp*	25-30	20-25
ft^3/hp*	0.3-0.5	0.2-0.4
Fuels	All available	All available
Emissions	Meets standards. SFC may rise	Meets standards. SFC may rise
MTBO (hr)	10,000-20,000	10,000-20,000

* engine only

Table 2 Medium-Speed Diesel Engine Performance Predictions Resulting From Expected Commercial Evolution

Key Parameters	Near-Term	Far-Term
Power (hp)	no change from Table 2	80,000 – 100,000
BMEP (psi)	no change from Table 2	600-700
BSFC (lb/hp-hr)	no change from Table 2	0.24
rpm	no change from Table 2	500
lb/hp*	no change from Table 2	10-15
ft^3/hp*	no change from Table 2	0.2-0.4
Fuels	no change from Table 2	All available
Emissions	no change from Table 2	Meets standards. SFC may rise
MTBO (hr)	no change from Table 2	10,000-20,000

* engine only

Table 3 Medium-Speed Diesel Engine Performance Predictions Resulting From Government Funded Development

To realize the performance projections contained in Tables 2 and 3, the working group identified that technology advances would be necessary in several areas, principally:

- Turbocharger technology
- Improved materials and designs for components such as pistons, connecting rods, etc., to withstand the increased pressures associated with higher specific power outputs
- Improved bearing technology

By way of demonstration of what could be achieved with unlimited funding in the near-term, the working group focused on a specialty, military only, medium-speed diesel with a high power output but limited service life. Development would be required, in addition to that defined previously, for camless valve actuation. Performance parameters are given in Table 4. Funding levels were not defined.

Key Parameters	Near-Term
Power (hp)	60,000-70,000
BMEP (psi)	600
BSFC (lb/hp-hr)	0.30
rpm	300-400
lb/hp*	15-20
ft^3/hp*	0.2-0.4
Fuels	All available
Emissions	Meets standards. SFC may rise
MTBO (hr)	1,000 - 2,000

*engine only

Table 4 Military Only, High-Power Output, Medium-Speed Diesel Engine (Government Funded Development)

3.4.3.3 Fuel Cells

The principles of operation of fuel cell technology were described, and several development programs noted. Although fuel cells offer high fuel conversion efficiencies, quiet and clean operation, and produce electrical power directly, marine systems have yet to be constructed that can operate with logistically available fuels. Demonstration systems scheduled for the year 2000 are being designed as ship service units of 2.5MW. Propulsion sized systems (>50MW) were considered as being many years away, placing them, as candidate prime movers, in the far-term development category. Table 5 shows the far-term fuel cell characteristics considered achievable by the working group.

Type	SFC (lb/hp-hr)	lb/hp	ft^3/hp
PEM	0.34-0.31	4-9	0.14-0.22
SO (PLANAR)	0.31-0.22	7-10	0.21-0.60
SO (TUBULAR)	0.29-0.22	15-22	0.45-0.89
MCFC	0.33-0.24	30-45	0.73-1.57
PAFC	0.35-0.31	22-34	0.69-1.12

Table 5 Far-Term Fuel Cell Performance Characteristics

3.4.3.4 Transmission Systems

The working group concluded that propulsor speed is the key to delivering large amounts of power to the propulsor. Projected at 100-200 rpm, this requires large reduction ratios, particularly with gas turbine engines. The drive ratio governs the size of the equipment.

For mechanical drives, the lightest weight and smallest volume is obtained with epicyclic gears (sun and planet type), although the available capacity is typically limited to 20,000 hp. The working group considered that doubling the power transmission requirement would require a significant development effort.

Note By Ratifiers: post-workshop analysis has shown that waterjet speeds are likely to be higher than the 100-200 rpm assumed by this working group. Preliminary work suggests that waterjet speeds of the order of 400 rpm are not unreasonable.

The working group noted the increasing popularity of electrical transmission systems, specifically in commercial applications requiring arrangement flexibility and large transfers of electrical power between ship services and propulsion. High-output induction motors (44 MW on QE2) are large, heavy machines. Current developments with permanent magnet technology offer high power density, compact machines, but have yet to be demonstrated at propulsion-type power ratings. Other development areas were discussed. Table 6 summarizes the working group consensus on power density comparisons for each candidate prime mover and transmission system in the far-term.

Propulsion System	Mechanical Drive	Electrical Drive
Gas Turbine	10-12 lb/hp	18-20 lb/hp
Fuel Cell	N/A	20-23 lb/hp
Diesel	40 lb/hp	48 lb/hp

Table 6 Far-Term Propulsion System Power Density Comparisons

3.4.3.5 Fuel Flexibility

Fuel flexibility was considered in discussions of each prime mover. In summary, all prime movers could be operated using a variety of fuels, although fuel treatment and engine modifications could be extensive. The overriding issue with alternate fuel was identified as logistic supply and worldwide availability. To design a HSS ship, the fuel/prime mover/transmission should be considered as a total system.

3.4.4 LOADS, MATERIALS, AND HIGH-STRENGTH, LIGHTWEIGHT STRUCTURES WORKING GROUP

The working group examined the characteristics of seaway loading, the status of load prediction, and load reduction strategies. It highlighted that because structural weight can be up to one third of full-load displacement, the potential payoffs of weight savings for HSS applications could be substantial.

The status of seaway load prediction was considered. Validation of analytical techniques to date has largely been against conventional hullforms, and therefore was not considered to be sufficiently generalized to allow the design of a ship outside the current experience base without supporting model tests and technology demonstrators.

The working group concluded that the following load reduction strategies were worthy of future consideration:

- Improved hull geometry
- Sea train/articulated hull - because very long ships are penalized by primary hull girder bending, one approach might be to articulate a ship into several smaller linked hulls
- Pre-stressed methods

- Design for large deflections
- Feedback/active structures
- Isolation methods (foils, etc.)

The working group provided predictions for structural weight savings, and associated developmental and risk issues, for metallic and composite materials, and provided guidance information on application, limitations, and development needs. The following sections summarize their predictions.

3.4.4.1 Potential Weight Savings - Metals

Table 7 reproduces the working group predictions for weight savings in the near-term and far-term. All weight saving predictions are relative to ordinary steel [American Bureau of Standards (ABS) Grade A].

- Aluminum - Near-term applications for aluminum are limited to secondary structures and primary hull structures less than 100m in length. (Although aluminum hull structures greater than 100m have been built recently for commercial ferry service, there is insufficient evidence of their long-term structural performance, particularly within the operating environment and parameters projected for HSS, to confidently extend this near-term limit.) As more information about fatigue performance becomes available and joining technology improves, greater weight savings will be possible.

- Exotic metals - Some of the exotic metals have the potential for impressive weight and strength benefits as well as enhanced corrosion and fire protection characteristics. For these gains to be realized, performance of these materials in marine environments must be demonstrated and cost penalties overcome.

- Metallic sandwich **-** Such structures have demonstrated performance, weight, and cost benefits for secondary structures. As understanding of fatigue performance improves, far-term application for primary structures would result in further weight savings.

Material System	Near-Term	Far-Term
Aluminum	30% overall, limited to 100m LBP for primary structure	50% with improved joining technology
Exotic metals (Ti, Mg etc)	high risk	20-60% overall
Metallic Sandwich (LASCOR)	35-50% for secondary structure, 10% overall	45-60% for secondary structure, 20-30% overall

Table 7 Potential Weight Savings - Metals

3.4.4.2 Potential Weight Savings - Composites

Table 8 reproduces the working group predictions for weight savings in the near-term and far-term. Advantages and disadvantages, compared to metallic structures, were discussed. All weight saving predictions are relative to ordinary steel (ABS Grade A).

Ship Length	Near-Term	Far-Term
300 ft Primary Structure	20% Glass 40% Carbon	30% Glass 50% Carbon >65% new fibers and resins
800 ft Primary Structure	High Risk	50% Carbon >65% new fibers and resins
Secondary Structure	35-45% Glass	50% Glass/Carbon >65% new fibers and resins
All Structures		
300 ft	20-40%	35->65%
800 ft	8%	50->65%

Table 8 Potential Weight Savings – Composites

3.4.5 CRITICAL INTERFACE (LOAD/UNLOAD) TECHNOLOGIES WORKING GROUP

The working group noted that the selection of loading, storage, and unloading technologies is both mission and payload dependent. It was also noted that unique solutions for specific requirements are already available in the marketplace for other than in-stream onload and offload, but development work to adapt such solutions to the sealift case could be significant.

The working group identified measures of effectiveness, reviewed the state-of-the-art, and categorized applicable systems and technologies for future application. A variety of cargo types were considered, including containers, vehicles, pallets, and cassettes. Impacts on the port of entry and port of exit were considered, as were loading and unloading in an advanced port, an undeveloped port, and in situations where a port is not available. In the latter case, Joint Logistics Over The Shore (JLOTS) and in-stream operations were considered, noting that JLOTS development has demonstrated that the effort required to design a system to undertake in-stream operations in moderate seas is significant. Further enhancements to the required sea state for in-stream onload/offload will demand even greater development levels. The working group provided guidance and predictions for cargo loading, unloading, and storage options for incorporation at the design stage for future HSS ships.

3.4.6 SHIPBUILDING/MANUFACTURING WORKING GROUP

The working group:

- Evaluated anticipated HSS design parameters that potentially have the greatest impact on ship production.

- Considered the maturity of manufacturing processes to construct HSS ships incorporating such design parameters.

- Identified production issues and recommended areas of research and development to overcome such issues.

The working group assumed that HSS ships would be built to US commercial standards. Design parameters having the greatest impact on ship production were identified, and, for each parameter, various likely alternatives were identified.

The working group subsequently discussed required developments in manufacturing processes to support the production of HSS ships that incorporate near-term and far-term technology. Such developments are recorded below, noting that each development is technology specific; e.g., liquid natural gas (LNG) fuel-tank design recommendations will not be necessary if LNG technology is not used. Development requirements are considered as either high priority (HP) or low priority (LP).

- Design for construction of large high-stress structures in near-term (HP).

- Joining of large high-stress metal structures in near-term (HP).

- Erection and launching of large lightweight ships, particularly multihulls and SESs, in near-term (HP).

- Prototyping of new designs and shipbuilding/manufacturing processes in near-term (HP).

- Further development of CIM, including expansion of simulation-based design to simulation-based production (physics-based) in far-term (HP).

- Fabrication of stiffened aluminum plating in far-term (HP).

- Manufacturing of large-scale composites in far-term (HP).

- Scaling down of LNG fuel tank design and integration into ship structures in far-term (LP).

- Manufacture of lightweight high-strength castings in far-term (LP).

- Manufacture of lightweight high-strength shafting in far-term (LP).

- Production of high-strength steel shapes for shipbuilding in far-term (LP).

The working group concluded that, given sufficient investment and lead time, shipbuilding and manufacturing processes will be able to support production of all HSS ships envisioned at the workshop.

3.5 WORKING GROUP PRESENTATIONS

The working group presentation material is not presented separately because the content of the presentations is embodied within the individual working group reports, reproduced in full in Volume 2.

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Section 4

THE POST-WORKSHOP ANALYSIS METHODS

As stated in Section 3.4.1, the Ship System Concepts working group advocated two methods of post-workshop analysis:

- A quantitative analysis method, based on the empirical Transport Factor concept,[1] validated by the physics based design tool.[2] This method[1] provided uncomplicated parametric relationships between mission requirements (speed, range, and payload) and design characteristics (displacement, installed power, and fuel weight) to compare various hullforms and technologies of interest.

- A qualitative analysis method, which was considered necessary to analyze potential enhancements to transport capability in areas other than speed, range, and payload. This analysis method was based on the well-established "weighted sum" decision making tool used in DoD and industry, and is consistent with the quantitative method in that it provides a top-level screen of potential new ships and technologies, and identifies the most promising combinations in advance of detailed design studies. The qualitative analysis provides a comparative measure of the risk associated with those hullforms of interest.

4.1 THE QUANTITATIVE ANALYSIS METHOD

The quantitative analysis method used for the post-workshop analysis is outlined in this section, and includes a worked example. The mechanics of this method differ from those referred to in Section 3.3.4, but the concept and principles are similar. The changes made are briefly described in Section 4.1.3.

4.1.1 OUTLINE OF THE QUANTITATIVE ANALYSIS METHOD

The quantitative analysis method was based on the empirical Transport Factor (TF) concept.[1] The TF compares competing designs to relate the utility of each design when performing its transport task. In general, there is a unique non-dimensional characteristic called TF for each design, given by:

$$TF = (K \bullet W)/(SHP_{TI}/V_K) \quad (1)$$

where:

K = non-dimensionalizing constant

W = weight (full load displacement, cargo weight, etc.)

SHP_{TI} = total installed power (lift power + propulsion power for dynamically supported concepts)

V_K = average ship speed for a voyage (i.e., sustained or service speed)

Figure 2 presents graphically the TFs of a number of cargo carrying ships listed in Table 9. The data in Table 9 were compiled using information that was available at the time of the workshop. Figure 2 includes data for "actual" ships and "designs." The "designs" refer to mature design concepts whose performance claims, if discussed, were deemed plausible at the workshop by the Hullform and Propulsors working group. Data for "outliers" are also included for completeness. Outliers represent performance projections for hullform concepts that, as considered, either require further substantiation, or use technology that is close to the status of basic research, and thus are outside of the timeframe of interest.

The curve in Figure 2 defines the limit of realizable transport performance for this study and corresponds to the limit line of demonstrated capabilities of the ships and mature designs shown, as well as the results of point designs produced using a Design Synthesis Model (DSM).[2] The DSM was developed by Band, Lavis and Associates, on behalf of the Office of Naval Research, as a method of analyzing whole ship impact when incorporating future technologies, and is a high-fidelity parametric analysis tool based on first-principle physics. The DSM designs were produced specifically to define the upper limits of realizable performance for this analysis. It is worth noting that, should the performance claims of some, or all, of the outliers be fulfilled or new concepts introduced, the limit line in Figure 2 would be moved to accommodate such performance improvements. For information and interest, the limit line shown in Figure 2 is defined as:

$$TF = -7x10^{-5}(speed)^3 + 0.0238(speed)^2 - 2.6962(speed) + 108.22$$

with speed in kt

The limit line represents the highest TF value that is judged to be scientifically possible over this speed range for the ship concepts analyzed. As such, it represents the "edge of the envelope" for sealift transport. The limit line does not imply "edge of the envelope" performance can be achieved with all hullforms at all speeds. Instead, it implies that designs can be produced with at least one hullform that approaches this upper TF limit. The specific hullform(s) providing "edge of the envelope" performance is expected to vary for different design requirements. More extensive design studies addressing specific requirements are needed to determine the hullform(s) that produce these TF values.

Data for existing ships and mature designs in Figure 2 fall well below the "edge of the envelope" limit line. This implies that commercially viable ships need not be designed for maximum scientifically achievable TF performance. To the contrary, designs with extreme TF performance are expected to require heavy investment in technology development to support successful design and production.

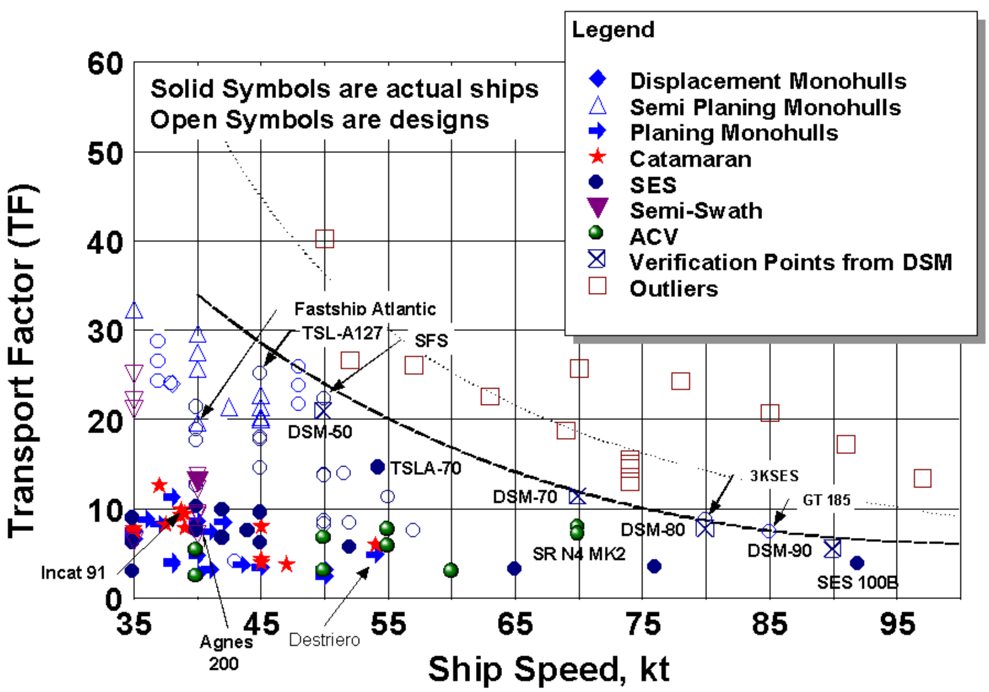


Figure 2 Vehicle Transport Factor

Ship	Ship Type	Ship (S) or Design (D)	Speed (kt)	Power (hp)	Full Load Disp (lton)	TF
CPC1C	Planing Monohull	S	41	6,370	72.45	3.21
PG84	Planing Monohull	S	40	13,950	242	4.77
PGG	Planing Monohull	S	38	24,750	390	4.12
BRAVE	Planing Monohull	S	54	12,750	100	2.91
FEROCITY	Planing Monohull	S	50	8,500	80	3.24
BRAVE UK	Planing Monohull	S	50	10,500	75	2.46
DARK UK	Planing Monohull	S	40	5,000	50	2.75
GRAY UK	Planing Monohull	S	40	5,000	50	2.75
JAGUAR	Planing Monohull	S	43.5	12,000	150	3.74
NASTY	Planing Monohull	S	45	6,200	69	3.44
GS BOAT	Planing Monohull	S	38	7,500	110	3.83
DESTRIERO	Planing Monohull	S	53.1	60,000	1,054	6.41
Design study	Semi-Planing Mono	D	42.5	400,000	29,314	21.41
Design study	Semi-Planing Mono	D	35	243,020	32,620	32.3
Design study	Semi-Planing Mono	D	40	385,326	38,518	27.49
Design study	Semi-Planing Mono	D	40	321,076	29,942	25.64
Design study	Semi-Planing Mono	D	40	438,075	47,254	29.66
Design study	Semi-Planing Mono	D	45	394,607	25,555	20.03
Design study	Semi-Planing Mono	D	45	353,823	23,158	20.25
Design study	Semi-Planing Mono	D	45	495,573	36,448	22.75
Design study	Semi-Planing Mono	D	45	349,271	22,904	20.29
Design study	Semi-Planing Mono	D	45	434,003	29,943	21.34
FastShip Atlantic	Semi-Planing Mono	D	40	420,000	30,000	19.64
INCAT K50	Multihull	S	45	29,283	418	4.4
INCAT K55	Multihull	S	45	29,283	377	4.0
B60	Multihull	S	54	44,117	710	6.0
Auto Express 82	Multihull	S	37.5	33,088	1,060	8.3
Condor 12	Multihull	S	38.7	29,502	1,100	9.9
CPS	Multihull	S	47	2,950	34	3.8
Fast-1	Multihull	S	45	3,000	78	8.0
INCAT 74	Wavepiercing Cat	S	35	20,735	650	7.5
INCAT 78	Wavepiercing Cat	S	35	23,823	773	7.8
INCAT 81	Wavepiercing Cat	S	38.7	30,330	1,100	9.6
INCAT 86	Wavepiercing Cat	S	39	39,049	1,165	8.0
INCAT 91	Wavepiercing Cat	S	39	39,043	1,400	9.6
INCAT 122	Wavepiercing Cat	D	37	35,845	1,778	12.6
Daewoo F-CAT 40	Foil-assisted Cat	D	38	5,515	113	5.3
AGNES 200	SES	S	40	8,610	246	7.9
SMYGE	SES	S	45	6,960	138	6.1
HCPC	SES	S	44	12,640	313	7.5
BES-16	SES	S	35	1,120	13.8	3.0
TSLA-70	SES	S	54.3	40,588	1,590	14.6
Mekat	SES	S	52	10,560	167	5.7
SES 100A-1	SES	S	65	14,000	100	3.2
SES 100A	SES	S	76	14,000	92.7	3.5
SES 100B	SES	S	92	15,360	93	3.8
SES 200-A	SES	S	40	6,590	244	10.2
26 Meter SES	SES	S	35	2,530	65	6.2
CIRR-105P (ex NORCAT)	SES	S	40	4,400	120	7.5
CIRR - 115 (EKWATA)	SES	S	42	4,038	137.5	9.8
CIRR-120P Class	SES	S	45	5,130	157	9.5
Wesamarin 4000	SES	S	45	8,744	180	6.4
Jet Rider	SES	S	42	5,336	123	6.7

Table 9 Cargo Ships Used for Definition of Vehicle Transport Factor Limit Line Shown in Figure 2

Ship	Ship Type	Ship (S) or Design (D)	Speed (kt)	Power (hp)	Full Load Disp (lton)	TF
Le Compte 27.1	SES	S	40	3,784	71	5.2
SWCM Sea Viking	SES	S	35	3,600	133	8.9
Designs +B20	SES	D	51.5	520,000	20,441	13.9
Designs +B20	SES	D	50	513,688	20,441	13.7
Designs +B20	SES	D	50	497,808	19,934	13.8
Designs +B20	SES	D	50	498,744	19,965	13.8
Designs +B20	SES	D	45	529,608	24,852	14.5
Designs +B20	SES	D	45	541,504	31,061	17.7
Designs +B20	SES	D	45	520,284	30,258	18.0
Designs +B20	SES	D	40	338,300	23,198	18.9
Designs +B20	SES	D	40	491,644	38,199	21.4
TSLA-127	SES	D	45	117,200	9,495	25.1
3K SES	SES	D	80	191,000	3,000	8.6
ITSL	SES	D	40	131,800	6,068	12.7
SFS	SES	D	50	300,000	19,455	22.3
PACSC	SES	D	40	220,000	14,074	17.6
SP SES	SES	D	52	73,977	1,714	8.3
US/G SES	SES	D	55	638,900	1,906	11.3
FR SES	SES	D	57	72,060	1,378	7.5
UK SES	SES	D	50	63,630	1,575	8.5
GT185	SES	D	85	35,000	440	7.35
Harley SES	SES	S	43	115	1.5	4.06
Samsung Ferry	SES	D	50	44,349	1,052	8.2
Stena HSS 900	Semi SWATH	S	40	46,874	1,620	9.5
Seajet 250	Semi SWATH	S	40.6	34,190	876	7.2
Stena HSS 1500	Semi SWATH	S	40	82,719	3,937	13.1
LMI design study	Semi SWATH	D	35	373,801	34,469	22.2
LMI design study	Semi SWATH	D	35	416,194	15,464	8.9
LMI design study	Semi SWATH	D	35	355,974	31,717	21.4
LMI design study	Semi SWATH	D	35	465,346	47,741	24.7
The Princess Margaret	ACV	S	50	15,202	295	6.7
LCAC	ACV	S	50	16,875	147	3.0
LCAC	ACV	S	40	16,875	147	2.4
SEDAM N500	ACV	S	70	16,000	261	7.8
AP 1-88	ACV	S	40	2,076	40	5.3
BH7 Mk 2	ACV	S	55	3,600	55	5.8
BH7 Mk 20	ACV	S	55	4,000	81	7.6
SRN4 Mk 2	ACV	S	70	13,600	200	7.1
Vca-36	ACV	S	60	5,000	35	2.9
Outliers	Outlier	Concept	97	560,304	11,254	13.39
Outliers	Outlier	Concept	91	560,304	15,395	17.19
Outliers	Outlier	Concept	85	560,304	19,890	20.74
Outliers	Outlier	Concept	78	560,304	25,385	24.29
Outliers	Outlier	Concept	74	1,430,670	40,935	14.55
Outliers	Outlier	Concept	74	1,430,670	43,740	15.55
Outliers	Outlier	Concept	74	381,800	11,240	14.98
Outliers	Outlier	Concept	74	1,430,670	36,725	13.06
Outliers	Outlier	Concept	70	560,304	29,906	25.68
Outliers	Outlier	Concept	69	381,800	15,107	18.77
Outliers	Outlier	Concept	63	381,800	19,909	22.58
Outliers	Outlier	Concept	57	381,800	25,399	26.07
Outliers	Outlier	Concept	50	525,000	67,000	43.86
Outliers	Outlier	Concept	52	381,800	28,465	26.65

Table 9 Cargo Ships Used for Definition of Vehicle Transport Factor Limit Line Shown in Figure 2 (Cont)

The weight of the ship can be considered as the sum of the parts corresponding to cargo, fuel, and ship weight, and can be expressed in TF terms as:

$$TF = TF_{cargo}+TF_{fuel}+TF_{ship} \qquad (2)$$

where: TF_{cargo} = TF based on weight of cargo

TF_{fuel} = TF based on weight of fuel

TF_{ship} = TF based on weight of empty ship

TF_{fuel} for a ship operating at constant weight depends primarily on range and the SFC rate of the machinery. These "constant draft" designs require seawater ballast to compensate for the weight of fuel burn-off. Such compensation is often necessary to maintain stability, provide acceptable propulsor performance, or attain other draft-related features. Many ships do not require compensation for burn-off. Powering reductions that occur as ship weight decreases for these "variable displacement" designs result in either reduced power at fixed speed or increased speed at constant power. Each of these reduces fuel consumption compared to a fixed draft design. Variable displacement designs were assumed for this study due to the major impact of TF_{fuel} on ship size and installed power for long-range ships. The effects of variable displacement operation on TF_{fuel} were included in the analysis through the use of the Breguet range correction, eqn 3. As a result, an additional term, TF_{fuel}/TF, becomes increasingly important as speed and range increase for these variable displacement designs. Unlike TF_{fuel}, TF is dependent on speed as shown in Figure 2. The resulting speed dependency of TF_{fuel}/TF was included in the analysis. Figure 3 shows the resulting variation in TF_{fuel} with range and SFC rate used in the analysis.

$$\frac{TF_{fuel}\text{ variable displacement}}{TF_{fuel}\text{ constant draft}} = \frac{1}{\ln(1/(1-TF_{fuel}/TF)/(TF_{fuel}/TF))} \qquad (3)$$

The behavior of TF_{fuel} for the variable displacement case is shown graphically in Figure 3.

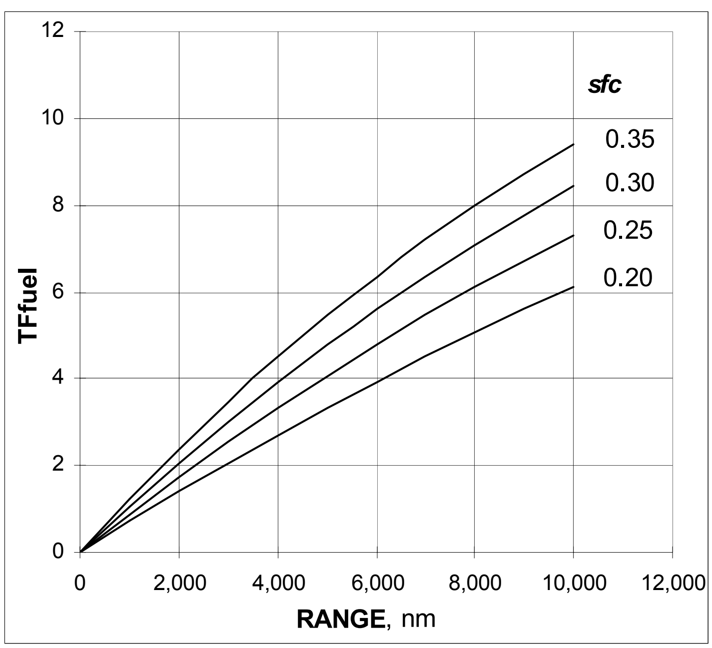


Figure 3 The Behavior of TF_{fuel}

The working group made predictions for structural weight reductions that may be realizable with improvements in structural materials and structural concepts. The effect of these weight reductions on empty ship weight are shown in Figure 4, in terms of the ratio of empty ship weight to full-load weight (which equates to the ratio of TF_{ship} to TF). Trend lines for near-term and far-term technologies are shown, and the data for various cargo carrying ships listed in Table 10 were used when deriving the trend lines. The data in Table 10 were limited to RO-RO and container cargo ships to exclude ships of differing cargo density, such as passenger ferries. The upper curve in Figure 4 shows the trend in ship empty weight fraction for ships with steel hulls using today's technology. The lower curve represents the effects of weight savings predicted for the far-term with advanced structural materials and concepts from Tables 7 and 8. No distinction is made, for far-term technology, between projected weight savings associated with metals and composites, as similar weight savings were predicted. The curves in Figure 4 were constructed as follows:

- For ships with displacements greater than 10,000 lton, the upper curve represents an average of the empty weight fraction for cargo carrying ships, and the lower curve incorporates far-term weight saving predictions.

- For ships with displacements of 5,000 lton or less, the lower curve incorporates far-term weight saving predictions over the contemporary aluminum hulls shown in the figure. The upper curve was calculated by assessing the empty weight ratio of such hulls if constructed out of steel using today's technology.

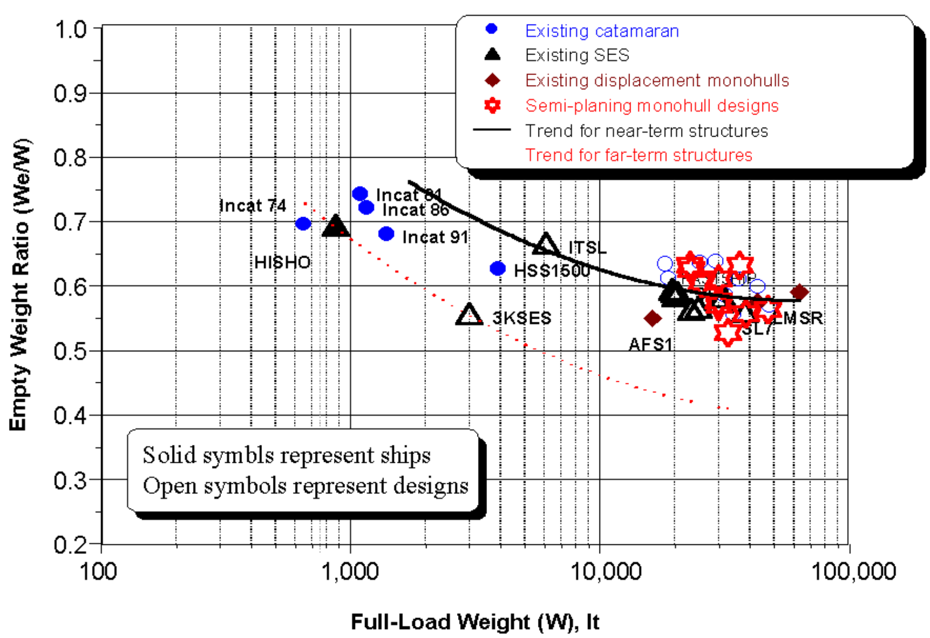


Figure 4 Empty Weight Trend

It is worth noting that both the upper and lower curves in Figure 4 reflect data produced by the DSM as well as data for existing designs. The curves in Figure 4 are defined as:

Lower curve: $We/W = 2.187 - (0.7245\log_{10}W) + (0.07327(\log_{10}W)^2)$

Upper curve: $We/W = 2.321 - (0.7264\log_{10}W) + (0.0757(\log_{10}W)^2)$

Ship	Ship Type	Ship (S) or Design (D)	Full Load Weight (lton)	Empty Weight (lton)	Weight Ratio
INCAT 74	Wavepiercing Cat	S	650	452	0.6950
INCAT 81	Wavepiercing Cat	S	1,100	817	0.7427
INCAT 86	Wavepiercing Cat	S	1,165	840	0.7210
INCAT 91	Wavepiercing Cat	S	1,400	950	0.6786
LMSR	Displacement Mono	S	62,945	37,160	0.5904
SL7	Displacement Mono	S	42,900	24,671	0.5751
AFS1	Displacement Mono	S	16,263	8,943	0.5499
HSS 1500	Multihull	S	3,937	2,461	0.6251
Design Study	Multihull	D	34,469	19,139	0.5553
Design Study	Multihull	D	31,717	18,570	0.5855
Design Study	Multihull	D	47,741	27,143	0.5685
Design Study	Multihull	D	18,872	11,540	0.6115
Design Study	Multihull	D	18,350	11,611	0.6364
Design Study	Multihull	D	29,127	18,536	0.6328
Design Study	Multihull	D	36,186	22,049	0.6093
Design Study	Multihull	D	25,318	16,073	0.6348
Design Study	Multihull	D	42,986	25,693	0.5977
HISHO	SES	S	1,590	1,097	0.6897
3KSES	SES	D	3,000	1,655	0.5517
SFS	SES	D	19,455	11,482	0.5902
ITSL	SES	D	6,068	4,013	0.6613
Design Study	SES	D	20,441	11,960	0.5851
Design Study	SES	D	19,934	11,701	0.5870
Design Study	SES	D	19,965	11,571	0.5796
Design Study	SES	D	24,852	13,969	0.5621
Design Study	SES	D	31,061	17,946	0.5778
Design Study	SES	D	30,258	17,253	0.5702
Design Study	SES	D	23,198	12,973	0.5592
Design Study	SES	D	38,199	21,248	0.5562
FastShip Atlantic	Semi-planing Mono	D	30,000	17,100	0.5700
Design Study	Semi-planing Mono	D	32,620	17,226	0.5281
Design Study	Semi-planing Mono	D	38,518	21,470	0.5574
Design Study	Semi-planing Mono	D	29,942	17,273	0.5769
Design Study	Semi-planing Mono	D	47,254	26,641	0.5640
Design Study	Semi-planing Mono	D	25,555	15,481	0.6058
Design Study	Semi-planing Mono	D	23,158	14,498	0.6260

Table 10 Cargo Ship Data Used to Define Empty Weight Trend Shown in Figure 4

Significant improvements in the power density of prime movers were projected at the workshop. The ability to package high-power propulsion machinery will determine the realistic limits that must be placed on ship performance. The empirical relationships shown in Figure 5 were derived to provide a measure of how much power can be sensibly installed in a hull (e.g., the physical ability to package the propulsion system and auxiliaries within the ship, install waterjets on the stern, etc.) and efficiently transmitted into the water. The lower line of Figure 5 represents realizable packaging of propulsion with near-term technology. The lower line was derived by examining the performance of real ships and mature design concepts as well as DSM data applying near-term propulsion performance projections. The upper line was similarly derived to embody far-term performance projections. It is recognized that development work will be necessary with both propulsors and power transmission systems to make the performance predictions shown in Figure 5 achievable. As a point of detail, all SES data used to derive Figure 5 exclude installed power for providing lift. (SES lift power was taken, on the basis of DSM design studies, to be 20 percent of installed power.) Although lift power for an SES reduces resistance to forward motion, it does not impact the ability to transmit propulsive power into the water. Table 11 shows the ship data used to produce the plot in Figure 5. The lines in Figure 5 are defined as:

Line through origin: $shp = 1{,}000 \cdot Displacement^{2/3}$

Near-term technology line: $shp = 227 \cdot Displacement^{2/3} + 200{,}834$

Far-term technology line: $shp = 227 \cdot Displacement^{2/3} + 418{,}404$

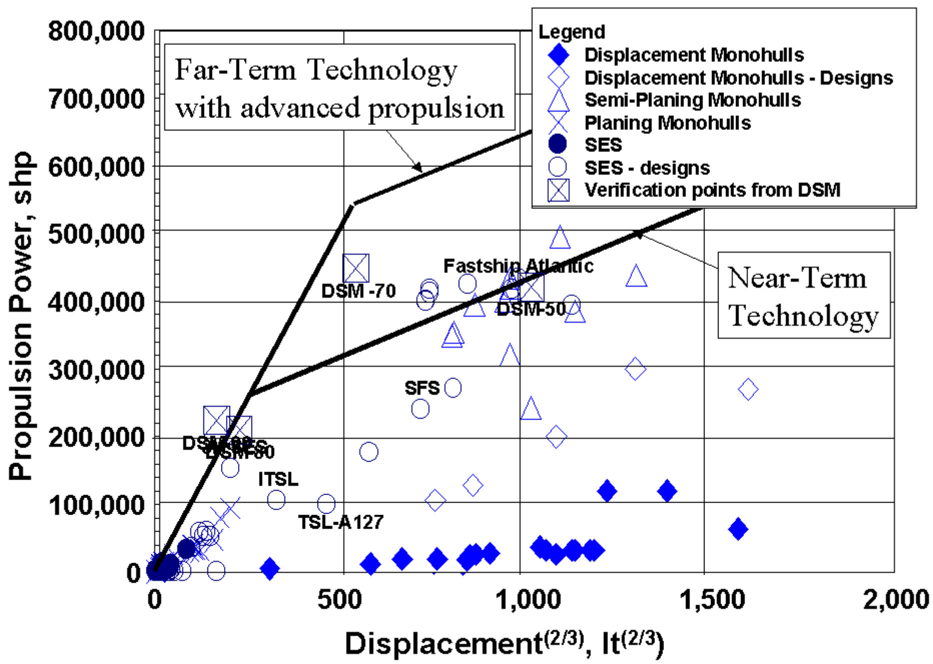


Figure 5 Propulsion Power Limits

Ship	Type	Ship (S) or Design (D)	Displacement (lton)	Propulsion Power(shp)
C6-M-F146a	Monohull (Container)	S	37,240	17,500
C6-S-F147a	Monohull (Container)	S	20,810	13,000
C9-M-132b	Monohull (Container)	S	40,000	16,500
C5-S-73b	Monohull (Container)	S	22,000	17,500
C5-S-77a	Monohull (Container)	S	24,150	11,000
C5-S-78a	Monohull (Container)	S	24,690	30,000
C6-S-69c	Monohull (Container)	S	25,050	24,000
C5-S-68d	Monohull (Container)	S	27,420	27,300
C8-S-81e	Monohull (Container)	S	41,200	32,000
C9-M-123b	Monohull (Container)	S	40,000	43,200
SL7	Monohull (Container)	S	51,815	120,000

Table 11 Ship Data Used to Determine Propulsion Power Limits Shown in Figure 5

Ship	Type	Ship (S) or Design (D)	Displacement (lton)	Propulsion Power (shp)
AOR3	Monohull	S	37,578	28,000
C4-S-67a	Monohull (RO-RO)	S	12,135	19,400
Cape I	Monohull (RO-RO)	S	33,770	37,000
Cape M	Monohull (RO-RO)	S	43,060	36,000
T-AKR	Monohull (RO-RO)	S	43,000	120,000
LMSR	Monohull (RO-RO)	S	62,945	64,000
Cape F	Monohull (Breakbulk)	S	37,870	32,000
Design study	Monohull	D	21,011	106,000
Design study	Monohull	D	25,349	128,000
Design study	Monohull	D	35,969	200,000
Design study	Monohull	D	47,104	300,000
Design study	Monohull	D	64,649	400,000
Design study	Semi-planing mono	D	29,314	400,000
Design study	Semi-planing mono	D	32,620	243,020
Design study	Semi-planing mono	D	38,518	385,326
Design study	Semi-planing mono	D	29,942	321,076
Design study	Semi-planing mono	D	47,254	438,075
Design study	Semi-planing mono	D	25,555	394,607
Design study	Semi-planing mono	D	23,158	353,823
Design study	Semi-planing mono	D	36,448	495,573
Design study	Semi-planing mono	D	22,904	349,271
Design study	Semi-planing mono	D	29,943	434,003
FastShip Atlantic	Semi-planing mono	D	30,000	420,000
CP1C	Planing Monohull	S	72	6,370
PG84	Planing Monohull	S	242	13,950
PGG	Planing Monohull	S	390	24,750
BRAVE	Planing Monohull	S	100	12,750
FEROCITY	Planing Monohull	S	80	8,500
BRAVE UK	Planing Monohull	S	75	10,500
DARK UK	Planing Monohull	S	50	5,000
JAGUAR	Planing Monohull	S	150	12,000
NASTY	Planing Monohull	S	69	6,200
GS BOAT	Planing Monohull	S	110	7,500
DESTRIERO	Planing Monohull	S	1,054	60,000
AGNES 200	SES	S	246	6,888
SMYGE	SES	S	138	5,568
HCPC	SES	S	313	10,112
HM527	SES	S	86	2,950
HM218	SES	S	28	877
BES-16	SES	S	14	896
TSLA-70	SES	S	1,590	32,470
BH-110	SES	S	137	3,200
Mekat	SES	S	167	8,448
SES100A	SES	S	100	11,200
SES100B	SES	S	93	12,288
TSL-A127	SES	S	9,495	100,000
3K SES	SES	D	3,000	152,800
ITSL	SES	D	6,068	105,440
SFS	SES	D	19,455	240,000

Table 11 Ship Data Used to Determine Propulsion Power Limits Shown in Figure 5 (Cont)

Ship	Type	Ship (S) or Design (D)	Displacement (lton)	Propulsion Power (shp)
PACSC	SES	D	14,074	176,000
Designs +B20	SES	D	20,441	416,000
Designs +B20	SES	D	19,934	398,250
Designs +B20	SES	D	24,852	324,690
Designs +B20	SES	D	31,061	433,200
Designs +B20	SES	D	30,258	416,227
Designs +B20	SES	D	23,198	270,640
Designs +B20	SES	D	38,199	393,315
DSM-50	SES	DSM verification point	32,591	420,834
DSM-70	SES	DSM verification point	12,754	448,197
DSM-80	SES	DSM verification point	3,476	209,859
DSM-90	SES	DSM verification point	2,178	224,019

Note : SES data excludes installed power for providing lift

Table 11 Ship Data Used to Determine Propulsion Power Limits Shown in Figure 5 (Cont)

The parametric relationships shown in Figures 2 through 5 were used to provide a broad identification of the levels of ship performance (in terms of speed, range, and payload) that are scientifically achievable in both the near-term and the far-term. In addition, overall design characteristics (full-load displacement, installed power, and fuel weight) were derived for the levels of ship performance identified, in the manner demonstrated in Section 4.1.2.

4.1.2 DEMONSTRATION OF THE QUANTITATIVE ANALYSIS METHOD

An example of the quantitative method is shown to demonstrate how the results discussed in Section 5 were generated.

This example will show the derivation of ship characteristics (displacement, installed power, and fuel weight) based upon defined requirements (speed, range, and payload) using near-term technology projections. TF performance up to the limit line shown in Figure 2 will be assumed. This example emphasizes that such derived ship characteristics do not determine the type of hullform at this stage - such definition will be deferred to detailed design studies. The limit line shown in Figure 2 therefore defines a maximum level of performance that can be expected, for a given ship speed, for one or more hullforms.

It is required to determine the payload that can be carried, using near-term technology, for a ship with a design speed of 55 kt and a range of 5,000 nm, with an SFC of 0.3 lb/hp-hr:

From Figure 2 at 55 kt: $TF = 20$

Because $TF = (K \bullet W)/(SHP_{TI}/V_K)$

then $SHP_{TI} = (K \bullet W)/(TF/V_K)$

or $SHP_{TI} = (2240 \bullet 1.6878/550) \bullet W \bullet (55/20)$

$= 18.9 \bullet W$

Figure 5 can be used to determine the propulsion power limits. For this example, we will assume that the maximum practicable propulsion power associated with near-term technology is required. As stated in Section 4.1.1, SES lift power has been taken to be, as a result of DSM design studies, 20 percent of installed power. There are, therefore, two propulsion power cases to be solved - one for SES and one for non-SES. The non-SES case, in this example, is given previously, and the SES case equates to:

$$\text{SES propulsion power} = 18.9 \bullet W \bullet 0.8$$

$$= 15.12 \bullet W$$

The near-term technology line associated with Figure 5 is given by:

$$\text{propulsion power} = 227 \bullet W^{2/3} + 200{,}834$$

This can be solved for both the non-SES and SES cases to find full load displacement and associated propulsion power, as follows:

$$\text{for the non-SES case,}\ \ 18.9 \bullet W = 227 \bullet W^{2/3} + 200{,}834$$

$$\therefore\ W = 19{,}255 \text{ lton, and}$$

$$\text{propulsion power} = 363{,}905 \text{ hp}$$

A comparison of SES and non-SES results is given in Table 12A.

	Full Load Displacement (lton)	Propulsion Power (hp)
Non SES	19,255	363,905
SES	26,690	403,550

Table 12A Propulsion Power Limits and Full Load Displacement for SES and Non-SES Vessels Using Near-Term Technology at 55 kt

From Table 12A, TF is equal to 20 in both cases because TF, by definition, is calculated using installed power; i.e.:

$$\text{non-SES:}\ \ TF = (2240 \bullet 1.6878/550) \bullet 19{,}255 \bullet 55/363{,}905 = 20$$

$$\text{SES:}\ \ TF = (2240 \bullet 1.6878/550) \bullet 26{,}690 \bullet 55/(403{,}550/0.80) = 20$$

Figure 4 will be used to determine the ratio of empty ship weight to full load displacement. For this example, we will assume that the minimum attainable empty ship weight associated with near-term technology is required. From the empty weight trend shown in Figure 4, it can be seen that the empty weight ratios for the non-SES case (full load displacement = 19,255 lton, from Table 12A) and the SES case are 0.598 and 0.589, respectively. The associated empty weight and disposable loads (i.e., cargo and fuel) are shown in Table 12B:

	Non-SES	SES
Full Load Displacement (lton)	19,255	26,690
Empty Weight ratio	0.598	0.589
Empty Weight (lton)	11,515	15,720
Disposable load (lton)	7,705	10,945

Table 12B Ship Empty Weight and Disposable Loads for SES and Non-SES Vessels Using Near-Term Technology at 55 kt

With an SFC of 0.3 lb/hp-hr and a range of 5,000 nm, TF_{fuel}, from Figure 3, is equal to 4.77. Fuel weight is therefore:

$$W_{fuel} = (SHP_{TI} \cdot TF_{fuel})/(K \cdot V_K)$$

noting that SHP_{TI} is the total installed power.

Finally: W_{cargo} = full load displacement - W_{fuel} - empty ship weight

W_{fuel} and W_{cargo} results are shown in Table 12C for both non-SES and SES cases.

	Non-SES	SES
W_{fuel} (lton)	4,590	6,365
W_{cargo} (lton)	3,150	4,605
W_{cargo} (ston)	3,530	5,160

Table 12C Fuel Weight and Cargo Weight for SES and Non-SES Vessels Using Near-Term Technology at 55 kt

4.1.3 DESCRIPTION OF CHANGES TO THE QUANTITATIVE ANALYSIS METHOD

The quantitative method,[1] as described in the opening presentation session of the workshop and as shown in Volume 2, was modified prior to starting the post-workshop analysis. The modification was twofold:

- The concept of the TF was retained, although the limit line was modified after the curve was benchmarked using the DSM.[2] As stated in Section 4.1.1, the benchmarking was used to provide confidence that the limit line was representative of realistic and realizable transport performance. The original limit line[1] is shown in Figure 6 (which includes the data points included at the workshop presentation). Figure 7, which superimposes the original and final limit lines, allows direct comparison of the change.

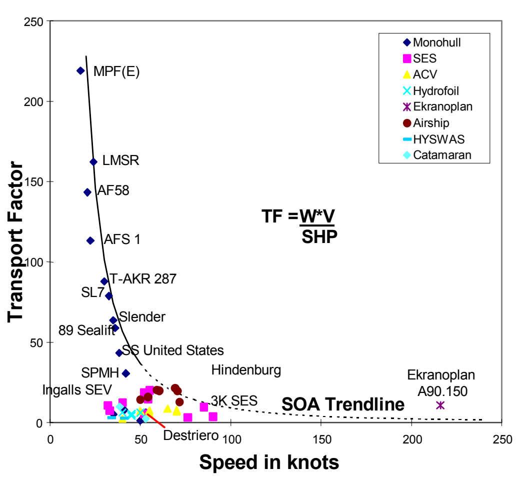


Figure 6 Original TF Curve Presented at Workshop

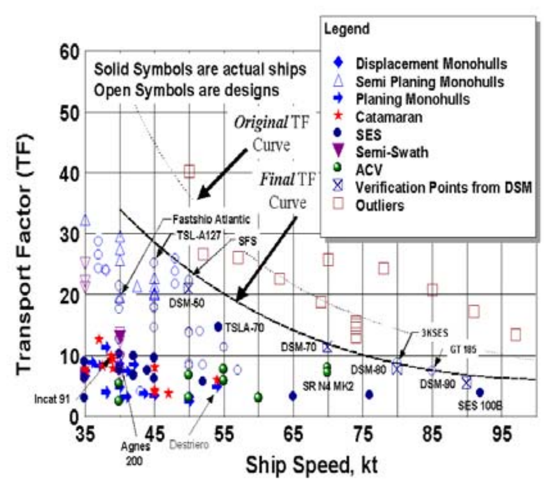


Figure 7 TF Curve Comparison

- Other modifications made to the method, such as the limits described in Figure 5, were intended to ensure scientifically achievable results and to allow a degree of automation when generating results, while affecting neither the results themselves nor the ability of engineers and scientists to place the results into perspective in terms of realism and achievability. This was proven by numerical comparison.

4.2 THE QUALITATIVE ANALYSIS METHOD

4.2.1 OUTLINE OF THE QUALITATIVE ANALYSIS METHOD

The wide range of hullform and technology alternatives addressed by the workshop represent potential enhancements to transport capability in areas other than speed, range, and payload. However, an adequate quantitative assessment of characteristics such as seakeeping, vulnerability, and cost could not be undertaken using simple approaches such as the TF process. As recommended by the Ship System/Concepts working group, a qualitative analysis method was therefore developed to allow a relative assessment of those important aspects of high-speed sealift not addressed by the quantitative analysis. The qualitative analysis is consistent with the quantitative analysis in that it provides a top-level screen of potential new ships and technologies and identifies the most promising technology combinations in advance of detailed design studies. The qualitative analysis also addresses the relative risk associated with the hullforms.

The qualitative analysis method will be made available to the user community as an interactive spreadsheet tool to assist with explorations of the effect of changing mission priorities on ship characteristics using near-term technology. When available, the spreadsheet tool can be downloaded from the internet via URL *ftp://web1.dt.navy.mil/pub/Hsstw97*, and it will be operated interactively from a PC (and not across an internet connection). User assistance will be available in the form of a spreadsheet page and an accompanying document that describes the method of analysis and how to use the spreadsheet tool.

The qualitative assessment method is based on the well-established "weighted sum" decision making method. The first step in the screening process is to rate the ship types in terms of their inherent capability to:

1. Carry the desired payloads.
2. Achieve the desired speed and operate at high speed in open ocean.
3. Perform cargo-handling operations in port, off the beach, and over the beach.
4. Avoid detection, absorb damage, and recover from damage.

The spreadsheet rates the various ship types in terms of their inherent:

5. Capability to sustain structural loads and adaptability to multiple-design materials and propulsion components
6. Producibility
7. Cost

Thirty-eight attributes are rated within these 7 categories. Both the categories and the attributes are defined in Table 13. Users are able to assign numerical weighting factors to each of the attributes shown in Table 13 within the spreadsheet, according to their perception of each attribute's relative importance to the overall mission.

Ship types within the spreadsheet include those considered by the Hullform and Propulsors working group as being credible contenders for the sealift role:

- Displacement Monohull
- Displacement Multihull
- Trimaran
- SWATH
- Semi-SWATH
- SES

Each of the 38 attributes of each hullform of interest is assigned a capability rating using the rigid criteria shown in Table 14. These criteria, and the capability ratings, have been developed by specialists and cannot be modified by the user.

The product of the spreadsheet is a ranking of ship types based on the user's specification of the importance of specific sealift-related attributes. By modifying the numerical weighting factors of the attributes, the user can explore how changing mission priorities influences the choice of preferred hullform.

The qualitative analysis tool also contains an assessment of risk. This is expressed in terms of the likelihood of an adverse outcome and the corresponding consequence associated with that occurrence for each hullform of interest. The assessment of likelihood of an adverse outcome is made by the user using the rigid criteria shown in Table 15. The consequences of failure are also rated against rigid criteria as shown in Table 16. The level of likelihood and related level of consequence for each attribute are combined to assign a risk rating of Low, Medium, or High to that attribute for each hullform of interest using the scheme shown in Table 17.

Another spreadsheet could be developed in which the attribute values for capability, likelihood of a problem occurrence, and consequence of a problem are adjusted to reflect the judgment of the workshop participants for far-term technology. Identical mission/requirement weightings applied to both spreadsheets would then indicate how the preferred choice of ship type might change over time. The results would also allow the user to identify the mission emphasis and the technology developments that created the change. If such a development is required, the user should contact the authors of this document.

Payload Capacity:

- Weight 500 ston
- Weight 5,000 ston
- Space 10,000 ft^2
- Space 150,000 ft^2

Performance:

- Seakeeping:
  - Very High Speed (> 60 kt)
  - High Speed (> 50 kt)
  - Cruise Speed (40 kt)
- Speed/Powering:
  - Very High Speed (> 60 kt)
  - High Speed (> 50 kt)
  - Cruise Speed (40 kt)
- Range (500 to 10,000 nm):
  - High Speed Maneuvering
  - (Collision avoidance)

Loading Interface:

- Navigational draft
- Maneuvering in port
- Air Draft
- Cargo handling at Pier
- Cargo handling in-stream
- Cargo handling by Beaching

Ship Survivability:

- Susceptibility to detection/being hit
- Vulnerability to damage from a hit
- Ability to recover after damage

Feasibility:

- Structure
- Hydrodynamic loads
  - Slamming loads
  - Whipping loads
- Materials
- Structural concept
- Propulsion components
- Prime mover availability
- Transmission availability
- Propulsor availability

Ability to Manufacture:

- Processes are established
- Facilities are available for:
  - Construction
  - Maintenance
  - Dry-docking

Cost of Ownership:

- RDT&E cost
- Acquisition cost
- Operating cost
- Maintenance cost
- Fuel cost
- Crew cost

Table 13 Attributes Included in Qualitative Analysis

Level		when the requirement: or,	the attribute: or,	the component or facility: or,	the cost:
5	High	is a threshold requirement or exceeds a threshold requirement and is within the capability of the Platform, and that capability has been demonstrated at sea	is consistent with platform performance demonstrated at the desired scale, at sea	has demonstrated capacity, capability, or performance at the required scale	for R&D has already been invested OR established from the estimating relationships for acquisition is well established OR for the item or element is low, and has a predictable history
4	Mod High	is a threshold requirement that has been demonstrated in a prototype, but not at the required scale, or at sea	has been extrapolated from a prototype or a physical model but has not been demonstrated at the required scale, at sea	has extrapolated capacity, capability, or performance based on the attributes of a prototype or physical model and is highly compatible with the ship type	for R&D <$2M and time < 1 year OR determined from the estimating relationships for 90% of the acquisition is well established OR of the element is moderate and has a predictable history
3	Mod	is a threshold requirement that can be accommodated in the platform with some minor degradation in performance OR exceeds a threshold requirement but can be accommodated in the platform with some significant degradation of performance	has been shown to be achievable using physics-based calculations but has not been demonstrated by a physical model or a prototype	has extrapolated capacity, capability, or performance based upon physics-based calculations but has not been demonstrated by a physical model or prototype and can be fitted to the ship type with attention needed during design	for R&D between $2-5M and the time is between 1-2 years OR determined from the estimating relationships for 75% of the acquisition is well established OR of the element is moderate and has a variable history
2	Mod Low	is a threshold requirement that cannot be accommodated in the platform without some significant degradation in performance or a significant improvement in some technology element of the design	has been shown to be feasible using semi-empirical methods but the theory and physical basis are not well understood	has extrapolated capacity, capability, or performance based upon semi-empirical calculations but has not been demonstrated by a physical model or prototype and can be fitted to the ship type with considerable effort required	for R&D is between $5-10M and the timeframe is between 2-4 years OR determined from the estimating relationships for 50% of the acquisition are well established OR of the element is unknown cost and is difficult to estimate
1	Low	is a threshold requirement that cannot be accommodated in the platform without major degradation in performance or a technology breakthrough	is believed to be feasible based upon broad parametric data or theory unsupported by experimental data	is believed to have desired capacity, capability, or performance based upon broad parametric data or theory unsupported by experimental data and will require innovation to be fitted to the ship type	for R&D >$10M and the time is more than 4 years OR determined from the estimating relationships for less than 50% of the acquisition are well established OR of the element is unknown and is difficult to estimate
0		Incompatible	Incompatible	Incompatible	

Table 14 Ranking Scheme to Determine Hullform Capability

Level	Likelihood:	when the design: or,	the materials: or,	the technology:
5	High	involves a new type of component for which limited experience or no previous experience exists	are untried in this application, production technique, or functional design	is not well known or well defined; extrapolation from available data is uncertain and might produce substantial errors
4	Moderately High	involves a new subsystem or component whose performance must be proven; design guidance is limited to analytical methods	are new, or depend upon new production techniques or functional design concepts; requires extrapolation from basic research, experimental models, and prototypes	involves an area that is not known with any certainty; extrapolation from known data is not fully supported by first principle calculations. Theory is not fully understood
3	Moderate	involves a new subsystem or component whose performance must be proven; design guidance is available from prototypes or model data.	are new, or depend upon new production techniques or functional design concepts; guidance is available from basic research, experimental models, and prototypes; there is reasonable assurance of meeting design goals	involves an area that is not known with any certainty; however, extrapolation from known data is supported by first principle calculations and is unlikely to cause a major error
2	Moderately Low	involves the use of existing components whose performance is known, but has not yet been demonstrated at sea, under conditions equal to, or more severe, than those expected for the new design	use production techniques or design concepts that are well known, but have not been demonstrated at sea, under conditions equal to, or more severe than, those expected for the new design.	is well known, physics based, but has not been demonstrated at sea under conditions equal to, or more severe, than those expected for the new design
1	Low	involves the use of existing components whose performance is well known, documented, and demonstrated at sea, under conditions equal to, or more severe, than those expected for the new design	use production techniques or design concepts that are well known, documented, and demonstrated at sea under conditions equal to, or more severe than, those expected for the new design	is well known, physics based, and demonstrated at sea under conditions equal to, or more severe, than those expected for the new design

Table 15 Ranking Scheme to Determine the Likelihood of an Adverse Outcome

Level	Impact	if the technical performance impact is: or,	the schedule: or,	the cost impact is: or,	the impact on other teams is:
5	High	unacceptable; fails to meet basic top level requirement (TLR)	cannot achieve a key milestone	>10%	unacceptable
4	Moderately High	acceptable; meets TLR but without margins	causes a slip in key milestone or a critical path event is impacted by more than the slip of this element	7-10%	a major work disruption; change in approach required
3	Moderate	acceptable; meets TLR with significant reduction in margin	causes a slip in a key milestone event or a critical path event equal to the slip in this element; unable to meet dates	5-7%	the cause of work disrupted, but the basic approach remains the same
2	Moderately Low	acceptable; meets TLR with some reduction in margin	causes additional resources to be required; able to meet dates.	<5%	some rework required
1	Low	minimal or no impact	has minimal or no impact	minimal, or has no impact	no impact

Table 16 Ranking Scheme to Determine the Consequence of an Adverse Outcome

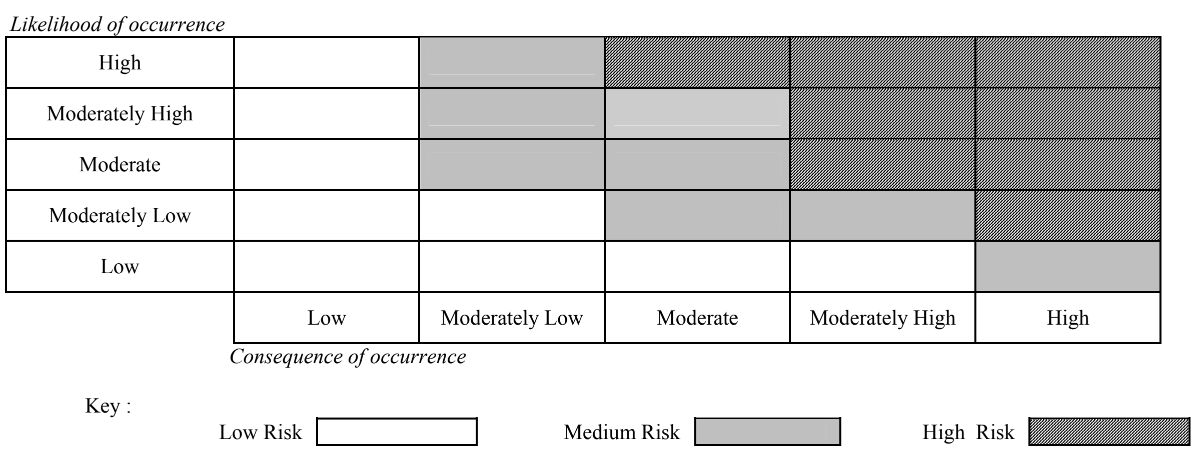


Table 17 The Assessment of Risk

4.2.2 LIMITATIONS OF THE QUALITATIVE ANALYSIS METHOD

The simple linear analysis scheme adopted treats each of the 38 attributes as an independent variable. As a result, changes in the weighting of attributes are evaluated without consideration of the cascading impacts on the ship type. For example, if greater emphasis is placed on speed, there are implications for hull structural loads, material properties, structural weight, propulsion plant size and weight, and fuel requirements. The simple linear analysis scheme adopted does not include modeling for such interactions. Results from the qualitative analysis are not presented in this document because they are dependent on the user's choice of mission priorities.

4.2.3 DEMONSTRATION OF THE QUALITATIVE ANALYSIS METHOD

The results of the qualitative analysis are dependent upon the user's choice of mission priorities. It is emphasized that the demonstration contained in this section is not intended to advocate any hullform or technology, and is solely intended to demonstrate the method.

This demonstration follows the spreadsheet format of the qualitative analysis tool. The spreadsheet consists of 20 pages:

- Page 1 - **General Information**, contains general administrative information about the spreadsheet.

- Page 2 - **Methodology**, contains a quick reference to the analysis methodology and use of the spreadsheet.

- Page 3 - **Analysis Results**, contains the results of an analysis for a given set of user-selected weightings. The information on the Analysis Results page lists the ship types analyzed, and provides the unweighted and weighted performance ratings associated with each ship type. The page displays the rank order of each ship type based upon the weighted ranking. It also displays the number of attributes rated as High, Medium, and Low risk for each ship type. (A weighted ranking of zero appearing in this table indicates that some attribute for that ship type was judged incompatible with the fast sealift mission. The attribute can be identified on the Hullforms page.) A truncated sample of this spreadsheet page is given in Table 18.

FAST SEALIFT HULLFORM EVALUATION PROGRAM

SUMMARY HULLFORM EVALUATION

Hullform	Type	Total Unweighted Rating	Total Weighted Rating	Rank	Risk		
					Low	Medium	High
Monohull	Displacement	138	675	5	13	11	14
Catamran	Displacement	144	729	1	10	10	18
Planing Cat	(Semi-)Planing	142	706	3	10	9	19
Trimaran	Trimaran	116	575	9	5	8	25
SWATH	SWATH	121	580	8	8	7	23
Semi-SWATH	Semi-SWATH	142	711	2	9	6	23
SES	SES	133	668	6	13	12	13
Slender Mono	Slender Mono	126	608	7	10	8	20

Sort Hullforms
CLICK HERE TO UPDATE

Excel 97 users click on the button above to update the results. Excel 5.0 users click on Tools, then on Macro. In the dialog box, run the SortHullform macro to update the results.

HULLFORM RANKING ORDER		
Rank	Hullform	Rating
1	Catamaran	729
2	Semi-SWATH	711
5	Monohull	675
6	SES	668
7	Slender	608
8	SWATH	580
9	Trimaran	575

Table 18 Sample of "Analysis Results" Spreadsheet Page (Truncated)

- Page 4 - **User Weightings**, is the user interface page. The user inputs numerical information to provide numerical weighting factors to the 38 attributes in the 7 categories, as defined in Table 13.

  The user's first step is to establish an overall weighting value for each of the seven major categories. The magnitude of the sum of all the weighting values is entirely the user's choice and should reflect the relative importance of each major category to the sealift mission.

  The user's next step is to assign weighting values to the sub-categories under each major category (replacement weight values should be adjusted until the subtotal matches the target subtotal).

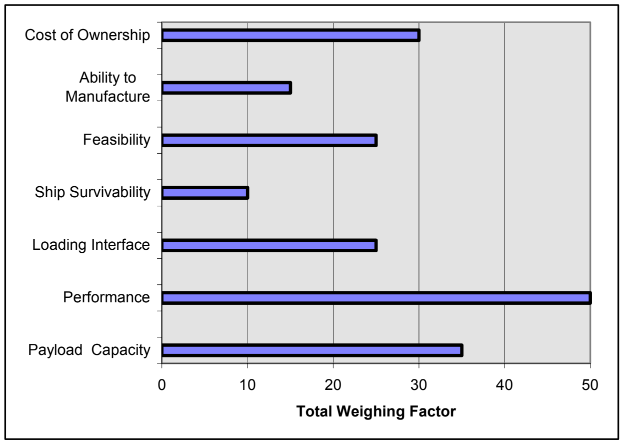
  The user's third step is to review the sub-categories and determine which of those attributes, if any, must be provided by the ship type to be a viable concept. Any ship type that does not have capability in a key sub-category will receive a zero total rating. A truncated sample of this spreadsheet page is given in Table 19 (the column headed "Key" provides the key sub-category requirement just described).

USER-SELECTED WEIGHTING FACTORS

DETAILED CATEGORIES		Target Values	Key
PAYLOAD CAPACITY			
Weight 2000 tons	**11**		1
Weight 5000 tons	**7**		
Space 75,000 sq ft	**10**		
Space 150,000 sq ft	**7**		
Total	35	35	
PERFORMANCE			
Seakeeping			
Very High Speed (> 60kt)	**5**		
High Speed (>50kt)	**4**		
Cruise Speed (40kt)	**4**		
Speed/Powering			
Very High Speed (> 60kt)	**10**		
High Speed (>50kt)	**7**		
Cruise Speed (40kt)	**5**		1
Range (5-10000 NM @ 40 kt)	**10**		1
Hi Speed Maneuvering (Collision avoidance)	**5**		
Total	50	50	
LOADING INTERFACE			
Channel depth	**4**		
Maneuvering in port	**4**		
Air draft	**4**		
Cargo handling at pier	**6**		
Cargo handling in stream	**3**		
Cargo handling by beaching	**4**		
Total	25	25	
SHIP SURVIVABILITY			
Susceptibility to detection/being hit	**4**		
Vulnerability to damage from a hit	**3**		
Ability to recover after damage	**3**		
Total	10	10	
FEASIBILITY			

SUMMARY OF USER-SELECTED WEIGHTING FACTORS

Chart 1 - MAJOR CATEGORIES



USER-SELECTED WEIGHTING FACTORS

Table 1 - MAJOR CATEGORIES

Payload Capacity	35
Performance	50
Loading Interface	25
Ship Survivability	10
Feasibility	25
Ability to Manufacture	15
Cost of Ownership	30
Total	190

Table 19 Sample of "User Weightings" Spreadsheet Page (Truncated)

- Page 5 - **Weighting Ref**, provides an annotated example of an assignment of weighting values and represents a sample of ratings developed by a fictitious user. The purpose of this page is to provide some insight to the thought process behind the setting of ratings. Numbers on this page are illustrative and do not impact the analysis.

- Page 6 - **Rating Definitions**, contains the criteria used to rate:

  - The inherent capability of each ship type, in each sub-category (Table 14)

  - The likelihood of a problem occurring in each sub-category (Table 15)

  - The consequence of a problem in each sub-category (Table 16)

- Page 7 - **Consequences**, describes the impact of a problem in an individual sub-category. This page of the spreadsheet describes the consequence rating assigned to each sub-category, and a short description of the rationale for that rating. A sample of this spreadsheet page is given in Table 20.

EVALUATION OF THE CONSEQUENCE OF A PROBLEM (INDEPENDENT OF PLATFORM TYPE)
(Values in cells with yellow shading have been assigned by technical specialists and are protected values)

PAYLOAD CAPACITY	Consequence of a problem	Rationale
Weight 2000 tons	5	Failure to meet a minimum TLR
Weight 5000 tons	4	Failure to meet a desired TLR; Decrease in margin or desired capacity
Space 75,000 sq. ft	5	Failure to meet a minimum TLR
Space 150,000 sq. ft	4	Failure to meet a desired TLR; Decrease in margin or desired capacity
Seakeeping		
> 60 Knots	4	Failure to meet a desired TLR; Decrease in margin or desired speed
50-60 Knots	4	Failure to meet a desired TLR; Decrease in margin or desired speed
40-50 Knots	5	Failure to meet a minimum TLR
Speed/Powering		
> 60 Knots	4	Preferred TLR
50-60 Knots	4	Preferred TLR
40-50 Knots	5	Essential (minimum) TLR
Range (5-10000 NM @ 40 kt)	5	Essential TLR
Hi Speed Maneuvering/Collision Avoid	3	Not critical but should be good enough for safe navigation at high speed (Collision avoidance)
LOADING INTERFACE		
Navigational Draft	5	Critical for access to undeveloped areas
Maneuvering in port	3	Important in places where assistance (tug boat) will not be available
Air draft	3	Can be a problem for access up rivers , under bridges
Cargo handling at pier	5	Essential capability for a sealift mission
Cargo handling in stream	3	Not a major TLR (rather a nice to have capability)
Cargo handling by beaching	3	Not a major TLR (rather a nice to have capability)
SHIP SURVIVABILITY		
Susceptibility to detection/being hit	4	Important to reduce potential of damage
Vulnerability to damage from a hit	5	Critical to contain damage & complete mission
Ability to recover after damage	4	Important to complete mission
FEASIBILITY		
Structural Design		
Hydro Loads	4	Important to minimize deadweight/maximize cargo
Slamming Loads	4	Important to minimize deadweight/maximize cargo
Whipping Loads	5	Knowledge is vital to achieve TLR performance
Materials	5	Knowledge is vital to achieve TLR performance
Structures Technology	4	Important hull fatigue and service life issue
Propulsion Components		
Prime Mover Availability	5	Vital to achieve TLR performance
Transmission Availability	5	Vital to achieve TLR performance
Propulsor Availability	5	Vital to achieve TLR performance
ABILITY to MANUFACTURE		
Processes are Established	3	Impacts construction efficiency & cost
Facilities available for:		
Construction	4	Impact on acquisition cost if new facilities must be developed
Maintenance	4	Impact on life cycle cost if new facilities must be developed
Drydocking	4	Impact on life cycle cost if new facilities must be developed
COST of OWNERSHIP		
RDT&E Cost	4	Impacts ability to deliver systems required to achieve performance
Acquisition Cost	4	Impacts ability to secure support to initiate program

Table 20 Sample of "Consequences" Spreadsheet Page

- Page 8 - **Hullforms**, summarizes the rating assigned to each sub-category, for each ship type. It displays the weight to be assigned to that rating, and whether the sub-category is considered to be "key." If a ship type should score zero on the Summary page, the user can review the Hullform page to determine which key sub-category for the ship type caused the zero value. A truncated sample of the "Hullforms" spreadsheet page is given in Table 21.

Summary of Weighted and Unweighted Mission Capability Values

Values in green were assigned by the User on the "User Weightings" page
Values in yellow are assigned by technical specialists and are protected
Values represent assessment for the Near Term

Summary of Weighted and Unweighted Mission Capabilities.	Hullform		Displacement Monohull			Slender Mono Monohull			(Semi-)Planing Monohull	
Capabilities	Weight	Essential	Unweighte	Weighted	Keyed	Unweighte	Weighted	Keyed	Unweighte	Weighted
PAYLOAD CAPACITY										
Weight 2000 tons	11	1	5	55	0	4	44	0	4	44
Weight 5000 tons	7	0	5	35	0	3	21	0	3	21
Space 75,000 sq. ft	10	0	4	40	0	3	30	0	5	50
Space 150,000 sq. ft	7	0	3	21	0	2	14	0	3	21
PERFORMANCE										
Seakeeping										
> 60 Knots	5	0	1	5	0	1	5	0	2	10
50-60 Knots	4	0	1	4	0	3	12	0	2	8
40-50 Knots	4	0	3	12	0	3	12	0	3	12
Speed/Powering										
> 60 Knots	5	1	0	0	1	1	5	0	3	15
50-60 Knots	4	1	0	0	1	2	8	0	3	12
40-50 Knots	4	1	3	12	0	3	12	0	3	12
Range (5-10000 NM @ 40 kt)	10	1	4	40	0	3	30	0	2	20
Hi Speed Maneuvering/Collision Avoid	5	0	3	15	0	3	15	0	4	20
LOADING INTERFACE										
Navigational Draft	4	0	3	12	0	3	12	0	4	16
Maneuvering in port	4	0	3	12	0	2	8	0	3	12
Air draft	4	0	3	12	0	3	12	0	3	12
Cargo handling at pier	6	0	4	24	0	3	18	0	4	24
Cargo handling in stream	3	0	3	9	0	3	9	0	3	9
Cargo handling by beaching	4	0	2	8	0	2	8	0	3	12
SHIP SURVIVABILITY										
Susceptibility to detection/being hit	4	0	4	16	0	4	16	0	4	16
Vulnerability to damage from a hit	3	0	4	12	0	3	9	0	4	12
Ability to recover after damage	3	0	4	12	0	4	12	0	4	12
FEASIBILITY										
Structural Design										
Hydro Loads	3	0	4	12	0	4	12	0	4	12
Slamming Loads	4	0	4	16	0	4	16	0	3	12
Whipping Loads	2	0	4	8	0	2	4	0	4	8
Materials	2	0	5	10	0	5	10	0	4	8
Structures Technology	2	0	5	10	0	4	8	0	4	8
Propulsion Components										
Prime Mover Availability	4	0	5	20	0	4	16	0	4	16
Transmission Availability	4	0	4	16	0	4	16	0	4	16
Propulsor Availability	4	0	3	12	0	3	12	0	4	16
ABILITY to MANUFACTURE										

Table 21 Sample of "Hullforms" Spreadsheet Page (Truncated)

- Pages 9-20 - **Ship Type Pages**, detail the ratings assigned to the inherent capability and likelihood of a problem, for each sub-category, for a specific ship type. A short description of the rationale for these ratings is provided. Technical specialists, experienced in the design and analysis of high-performance vehicles, have assigned these ratings. These values are protected and may not be changed by the user. A truncated sample of the "Monohull" spreadsheet page is given in Table 22.

Parameters	Capability Rating	Rationale for Rating	Likelihood of Problem	Consequence of Problem	Risk Ranking Low	Hi	Med
	Displacement Monohull		Values in cells shaded yellow have been assi[gned] by technical specialists and are protected				
PAYLOAD CAPACITY							
Weight 2000 tons	5	Excellent ability to carry payload	1	5	0	0	1
Weight 5000 tons	5	Excellent ability to carry payload	1	4	1	0	0
Space 75,000 sq. ft	4	Good capability up to a certain point	1	5	0	0	1
Space 150,000 sq. ft	3	Somewhat limited in space (narrow decks)	1	4	1	0	0
PERFORMANCE							
Seakeeping							
> 60 Knots	1	High accelerations can be expected	5	4	0	1	0
50-60 Knots	1	High accelerations can be expected	5	4	0	1	0
40-50 Knots	3	Acceptable seakeeping possible	5	5	0	1	0
Speed/Powering							
> 60 Knots	0	Powering requirements are prohibitive	5	4	0	1	0
50-60 Knots	0	Powering requirements are prohibitive	5	4	0	1	0
40-50 Knots	3	Likely to achieve with slender hulls	4	5	0	1	0
Range (5-10000 NM @ 40 kt)	4	Within monohull range capability	3	5	0	1	0
Hi Speed Maneuvering/Collision Avoid	3	Acceptable capability - less capable than other types	1	3	1	0	0
LOADING INTERFACE							
Navigational Draft	3	Acceptable draft is expected	1	5	0	0	1
Maneuvering in port	3	Acceptable performance (needs bow-thrusters)	1	3	1	0	0
Air draft	3	No inherent requirement for tall structures	1	3	1	0	0
Cargo handling at pier	4	Good capability, compatible with existing infrastructure	1	5	0	0	1
Cargo handling in stream	3	Not best due to roll motions	1	3	1	0	0
Cargo handling by beaching	2	Requires shallow draft forward	4	3	0	0	1
SHIP SURVIVABILITY							
Susceptibility to detection/being hit	4	Adaptable to stealth technology	1	4	1	0	0
Vulnerability to damage from a hit	4	Can use well known design practices	1	5	0	0	1
Ability to recover after damage	4	Can survive damage to a certain point (limited by dama	2	4	0	0	1
FEASIBILITY							
Structural Design							
Hydro Loads	4	30+ knot large monohulls now in operation	1	4	1	0	0
Slamming Loads	4	30+ knot large monohulls now in operation	2	4	0	0	1
Whipping Loads	4	30+ knot large monohulls now in operation	3	5	0	1	0
Materials	5	Many materials can be used. Better use HTS ?	2	5	0	1	0
Structures Technology	5	Design technologies are available, service proven	3	4	0	1	0
Propulsion Components							
Prime Mover Availability	5	Accepts a wide variety of prime movers	1	5	0	0	1
Transmission Availability	4	Accepts a wide variety of transmissions	3	5	0	1	0
Propulsor Availability	3	Requires modifications to accept waterjets	4	5	0	1	0
ABILITY to MANUFACTURE							
Processes are Established	5	Processes are well defined	1	3	1	0	0
Facilities available for:							
Construction	5	Facilities and experienced trade skills are available	1	4	1	0	0
Maintenance	5	Facilities and experienced trade skills are available	1	4	1	0	0
Drydocking	5	Facilities and experienced trade skills are available	1	4	1	0	0
COST of OWNERSHIP							

Table 22 Sample of "Monohull" Spreadsheet Page (Truncated)

Results from the qualitative analysis are not presented because they are dependent upon the user's choice of mission priorities.

Section 5

QUANTITATIVE ANALYSIS RESULTS AND DISCUSSION

Near-term and far-term performance projections are based on the limit line shown in Figure 2. It is interesting to note that existing ships and mature designs fall well below the trend line shown in Figure 2. The absence of viable designs near the limit line suggests that such ships may not be economically viable. This indicates that it is not necessary to provide the maximum scientifically achievable transport capability to produce economically viable ships. More detailed design studies specific to mission requirements are required to support the cost and economic analyses needed for such concepts.

As far as near-term and far-term performance projections are concerned, it is not surprising that certain technology predictions dominate the results; therefore, results are presented for those technology predictions having greatest impact on transport performance irrespective of the cost of development or economic viability (i.e., prime movers with high power density, low specific fuel consumption, and lightweight structures). Implicit in the former is the ability to package machinery and to efficiently transmit the power into the water.

Near-term technology results reflect the impact of:

- 60,000 hp gas turbines
- Waterjet propulsors
- Hulls manufactured from advanced steels with advanced structural design concepts

Far-term technology results include the impact of:

- 125,000 hp main engines (type unspecified, because the specific weights and specific fuel consumptions for a gas turbine propulsion system and a fuel cell propulsion system were predicted as being similar - see Tables 1 and 6, respectively)
- Waterjet propulsors
- Hulls manufactured from advanced materials (note that weight saving predictions for both advanced aluminum and composites are similar for the far-term, averaging at 50-percent savings over contemporary steel technology - see Tables 7 and 8, respectively).

Near-term results are shown in Table 23. Results for the combination of near-term structures and far-term machinery are shown in Table 24. Finally, results for far-term structures and far-term machinery are shown in Table 25. The relative impact of the technologies can be seen by comparing the data in these tables. Tables 23, 24, and 25 are worthy of some explanation:

- First, the results for installed power are separated into propulsive and lift components for speeds of 50 kt and over. As noted in Section 4.1.1, SES lift power was, on the basis of DSM design studies, taken to be 20 percent of installed power. This distinction is made because the limit line, shown in Figure 2, for speeds of more than 50 kt is indicative of SES performance, as confirmed by the DSM.
- Second, the results include payload levels well beyond the stated range of required payload (500 to 5,000 ston; see Section 3.4.1) because it is of interest to determine what maximum payload is scientifically achievable for each combination of speed and range.
- Third, it is evident that ship size and installed power are large in many cases. Such large, high-powered vessels indicate that, while expected performance, as defined by the trend line in Figure 2, may be scientifically achievable, it may be neither desirable nor economic. It is

reasonable to conclude that ship performance that approaches the TF limit line of Figure 2 could entail both higher risk and cost.

	Speed, kt						
	40	50	60	70	80	90	100
Range,nm	***Payload, st***						
500	33,870	18,420	7,650	3,455	1,675	590	200
1,000	32,565	17,615	7,140	3,100	1,405	430	105
2,000	30,010	16,050	6,180	2,435	910	145	
3,000	27,540	14,560	5,280	1,825	475		
4,000	25,145	13,135	4,435	1,275	90		
5,000	22,830	11,770	3,640	770			
6,000	20,585	10,470	2,900	315			
7,000	18,410	9,225	2,205				
8,000	16,305	8,035	1,555				
9,000	14,265	6,900	955				
10,000	12,290	5,820	400				
Disp, lt	*74,620*	*41,015*	*18,240*	*9,255*	*5,260*	*2,495*	*1,290*
Propulsion Pwr, shp	*603,175*	*470,805*	*358,140*	*300,910*	*269,480*	*183,955*	*118,620*
Lift Pwr, shp	-	*117,700*	*89,535*	*75,225*	*67,370*	*45,990*	*29655*

Table 23 Results for Near-Term Technology

	Speed, kt						
	40	50	60	70	80	90	100
Range, nm	***Payload, st***						
500	53,780	31,655	14,545	7,145	2,560	590	200
1,000	51,675	30,275	13,625	6,465	2,175	430	105
2,000	47,565	27,605	11,870	5,200	1,475	145	
3,000	43,585	25,060	10,225	4,050	860		
4,000	39,735	22,620	8,685	3,000	320		
5,000	36,000	20,295	7,240	2,040			
6,000	32,385	18,070	5,890	1,170			
7,000	28,885	15,945	4,625	395			
8,000	25,495	13,915	3,440				
9,000	22,215	11,980	2,340				
10,000	19,035	10,130	1,335				
Disp, lt	*120,135*	*70,055*	*33,275*	*17,595*	*7,430*	*2,495*	*1,290*
Propulsion Pwr, shp	*971,080*	*804,170*	*653,240*	*571,965*	*380,825*	*183,955*	*118,620*
Lift Pwr, shp	-	*201,040*	*163,310*	*142,990*	*95,205*	*45,990*	*29,655*

Table 24 Results for Far-Term Propulsion and Near-Term Structures

	Speed, kt						
	40	50	60	70	80	90	100
Range,nm	***Payload, st***						
500	78,945	45,920	21,070	10,490	3,915	1,025	415
1,000	76,840	44,540	20,150	9,810	3,530	860	325
2,000	72,735	41,875	18,395	8,545	2,830	575	165
3,000	68,755	39,325	16,750	7,395	2,215	335	30
4,000	64,900	36,890	15,210	6,340	1,675	135	
5,000	61,170	34,565	13,765	5,385	1,210		
6,000	57,555	32,340	12,415	4,515	825		
7,000	54,055	30,215	11,150	3,740	610		
8,000	50,665	28,185	9,965	3,075			
9,000	47,380	26,245	8,870	2,575			
10,000	44,205	24,400	7,860	2,405			
Disp, lt	*120,135*	*70,055*	*33,275*	*17,595*	*7,430*	*2,495*	*1,290*
Propulsion Pwr, shp	*971,080*	*804,170*	*653,240*	*571,965*	*380,825*	*183,955*	*118,620*
Lift Pwr, shp	-	*201,040*	*163,310*	*142,990*	*95,205*	*45,990*	*29,655*

Table 25 Results for Far-Term Propulsion and Far-Term Structures

Figures 8 through 12 are based on the results shown in Tables 23, 24, and 25.

- Figure 8 shows in 3-D space the impact on mission performance of near-term and far-term technology projections. The lower surface represents near-term technology performance predictions (from Table 23), the middle surface represents the performance allied with far-term propulsion and near-term structures (from Table 24), and the upper surface represents far-term technology performance predictions (from Table 25).

- Figure 9 shows a 2-D plot of payload versus speed possibilities for the minimum range of interest (500 nm). Significant payload capability exists at this short range for the speeds of interest using near-term and far-term technologies. In particular, the maximum payload of interest (5,000 ston) is scientifically achievable at high speeds. The effects of incorporating far-term propulsion and far-term structures are evident, as is the impact of increasing speed.

- Figure 10 shows a similar 2-D plot of payload versus speed possibilities at the maximum range of interest (10,000 nm). The figure shows that designs with 5,000 ston payload capability are scientifically feasible, using near-term technology, for speeds well in excess of existing sealift ships. Use of advanced technologies extends the speed capability to higher levels. The comparison between Figures 9 and 10 shows the impact of increasing range as a function of ship speed and technology.

- A comparison of the payload capacity achievable, using near-term technology, with contemporary military sealift and airlift capacity is shown in Figure 11. Figure 11 shows the potential performance gains possible in the near-term alone, which are impressive.

- Whereas Figures 8 through 11 present results in terms of mission variables, Figure 12 compares the ship size and propulsive power associated with near-term and far-term technology limits with contemporary state-of-the-art cargo ships. Figure 12 reinforces the observation that, within the desired cargo limits of 500 to 5,000 ston, propulsive power for high-performance sealift ships will be significantly greater than that of existing ships. Although these high-performance ship concepts are scientifically feasible, they may be neither desirable nor economic.

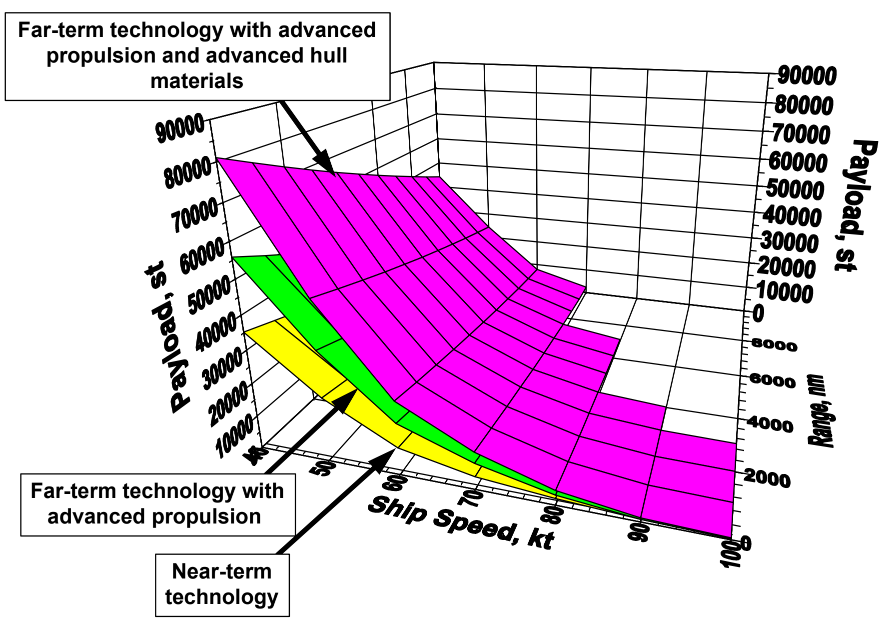


Figure 8 Predicted Impact of Technology on Ship Performance

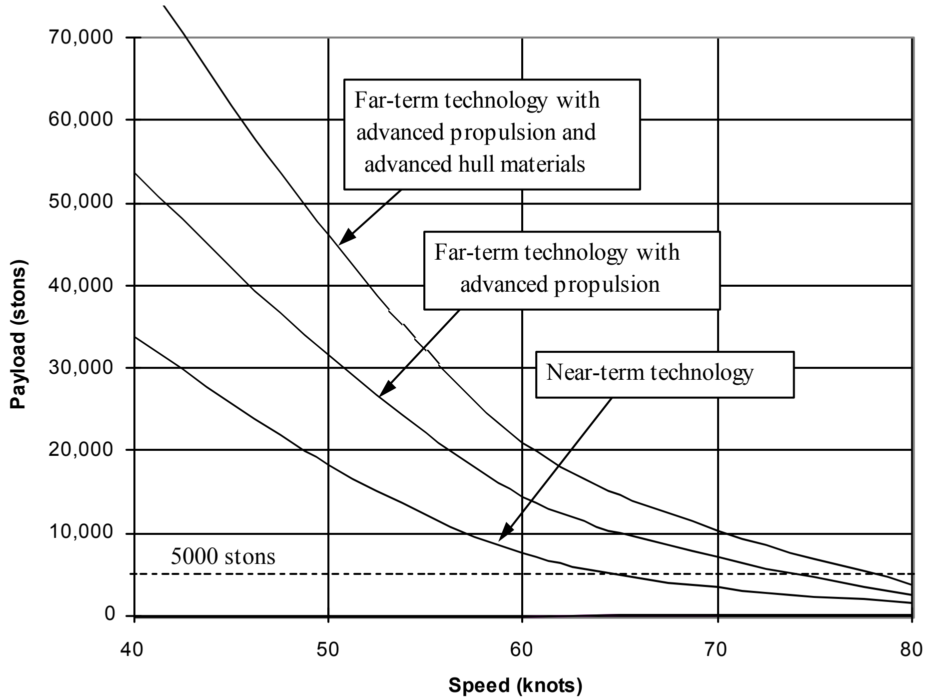


Figure 9 Payload vs Speed for 500 nm Range

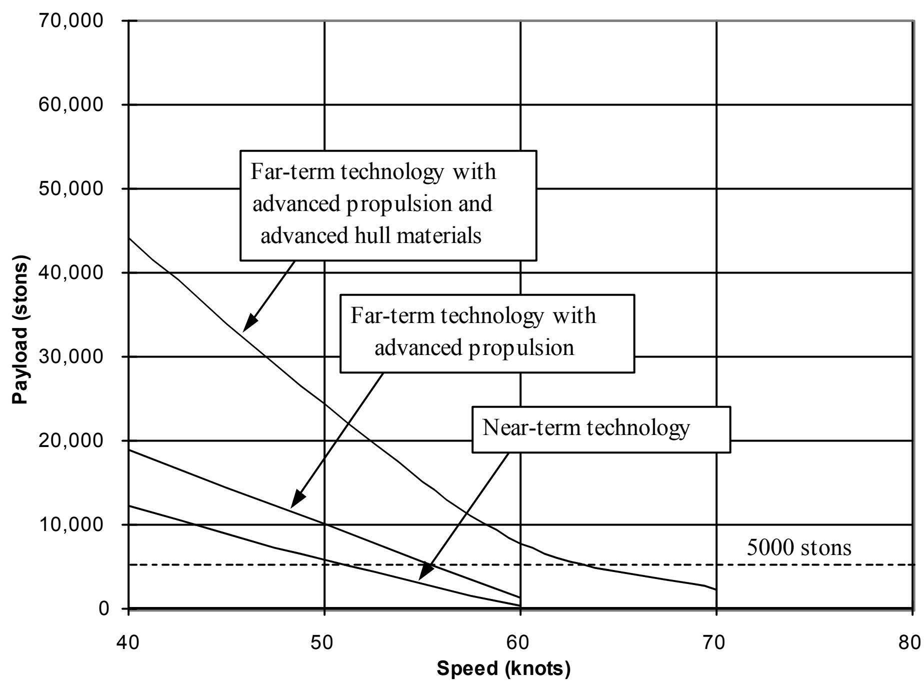


Figure 10 Payload vs Speed for 10,000 nm Range

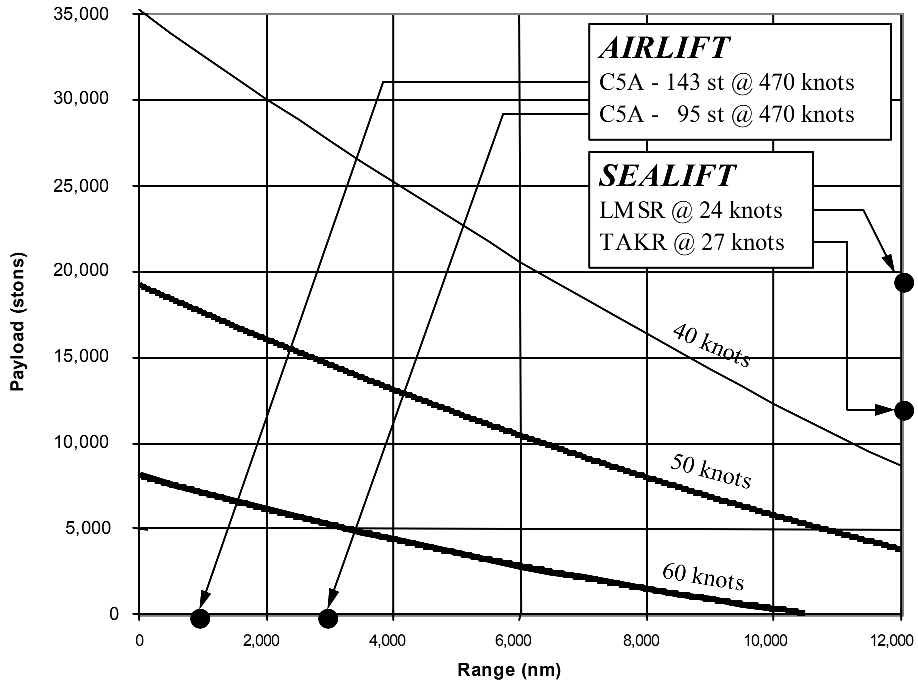


Figure 11 Near-Term Performance Predictions Compared with Contemporary Military Sealift and Airlift Capability

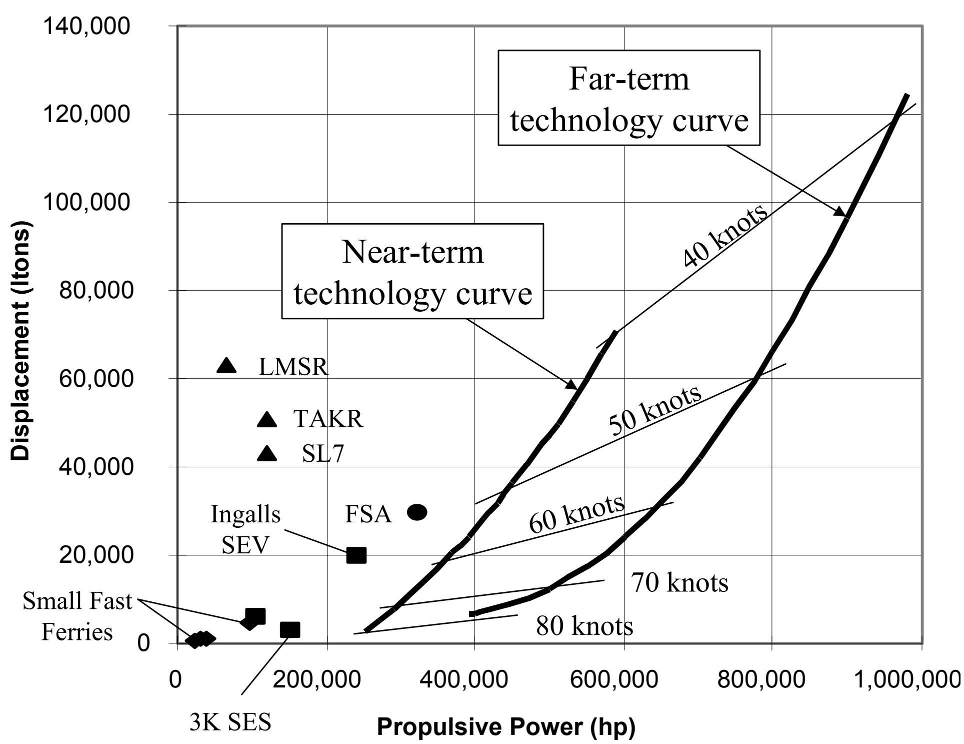


Figure 12 Comparison of Predicted Ship Characteristics with Contemporary Ships

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Section 6

THE BRIEFOUT

6.1 INTRODUCTION

The objective of the overall technical process was to quantify the speed, range, and payload projections of future high-speed sealift transports. The results of the individual workshop working groups were analyzed and integrated. Projections of the speed, range, and payload were made in the post-workshop interval and briefed in March 1998.

6.2 SUMMARY OF PRESENTATIONS

6.2.1 NSWCCD

The meeting was opened by Mr. R. Metrey, Technical Director, NSWCCD. Mr. Metrey welcomed the attendees back to Carderock and thanked them for all the hard work done during the October workshop and afterwards. Mr. Metrey's welcome was followed by opening comments from each of the workshop sponsors.

6.2.2 PEOCLA

Workshop sponsor RADM D. Sargent of PEOCLA remarked that a primary goal of the workshop was to determine the latest technology available throughout the world that could be utilized to accomplish HSS. He also mentioned that the conference served as an initial step towards building budget justification for HSS.

6.2.3 USTRANSCOM

USTRANSCOM was represented by RADM R. Naughton, who noted that the briefout identified where we need to go in regards to technology in order to accomplish HSS. He also noted that, although we have fewer bases around the world, we have become involved in more actions. Therefore, studying how we get to these actions has become increasingly important.

6.2.4 US ARMY

Col. C. Hall from the Department of the Army recognized the value of the input from workshop attendees, in that they were from a wide range of areas such as Academia, Industry, Government, etc. He remarked that this workshop on HSS was one of the first steps towards moving our forces around the world in a shorter period of time.

6.2.5 USTRANSCOM

Mr. K. Seaman of USTRANSCOM gave an overview of the workshop and briefout. He talked about the origin of the HSS workshop. He stated that the conference's focus on technology was in response to the need to go beyond viewgraphs to identify implementable technology. He emphasized that the end-to-end transportation process must be considered. The goal of HSS should be to enhance the DoD's ability to deploy, and looking at current technology identifies where to invest money. Finally, Mr. Seaman remarked that it is imperative that we keep together the consortia that developed from this effort to ensure that we are all working in the same direction.

6.3 POST-WORKSHOP ANALYSIS BRIEF

Dr. C. Kennell of NSWCCD and Mr. D. Lavis of Band, Lavis and Associates gave the post-workshop analysis and technical projections brief. The presentation material is reproduced in full in Volume 2.

6.4 CLOSING STATEMENTS

A summary statement was given by each sponsor of the workshop. They reiterated that we must look at the end-to-end process and focus on commercially viable platforms.

6.5 TECHNICAL BRIEF

A brief was held to present a technical explanation of the tools used for the quantitative and qualitative assessments. There was an opportunity for dialogue between the presenters and the briefout attendees. The minutes of this brief are reproduced in full in Volume 2.

Section 7

CONCLUSIONS

High-speed sealift capabilities have been defined for mission parameters of interest that reflect the technological characterizations produced by the international body of experts assembled for the workshop hosted by NSWCCD. These capabilities reflect consensus assessments of near-term and far-term technology projections and represent aggressive technological goals.

Significant high-speed sealift capabilities have been found to be scientifically, although not necessarily economically, feasible using both the near-term and far-term technology projections for:

- Advanced hull designs
- High-power, fuel-efficient machinery
- Advanced structural designs using lightweight, high-strength materials

Full realization of these capabilities is expected to require engineering development in supporting systems and construction techniques. In particular, the ability to package propulsion technology in advanced hulls while efficiently transmitting the power into the water is critical to achieving maximum transport capability for both near-term and far-term technologies. Engineering development work will also be required to extrapolate existing ancillary systems to match these high-performance machinery plants.

Achieving the highest feasible levels of sealift capability results in ships with very high installed power. Advanced technology reduces both ship size and power requirements relative to near-term technology for given mission parameters. However, issues of ship size and power raise questions regarding economic viability. Resolution of these issues requires design/cost studies for specific missions that are beyond the scope of current analyses. Such studies are expected during the next phase of the ongoing sealift requirements determination process.

R&D investment is likely to be required to design and build ships with the sealift capabilities required for the future. Progress toward scientifically feasible performance can be expected through normal commercial development, but additional Government investment may be required to realize specific military mission needs.

A wide range of options was identified by the workshop. The impact on transport capability of the more significant of these technologies has been defined. The required mix of technologies and their expected cost depend on specific mission requirements such as speed, range, and payload. The detailed design/cost studies needed to make the technology investment selections are expected during future phases of the sealift requirements determination process.

The spreadsheets that can be developed using the qualitative analysis will be useful for identifying those ship types that are candidates for sealift missions, and in assessing the sensitivity of the results to changes in emphasis on mission capability and developments in selected technologies. Some ship types will show capability with modest risk, with risk reducing as technology advances. Some ship types will show low capability, insensitive to changes in technology, and these can be eliminated from consideration. Some ship types may show high capability with very high risk. Ship types that are considered candidates for sealift missions should then be evaluated using design studies to verify feasibility. A programmatic choice will then be required to pursue technologies supporting a ship type that meets threshold goals at low to moderate risk, or technologies supporting a ship type providing a higher level of capability at a greater development risk.

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Section 8

FURTHER INFORMATION AND WEBSITES

A website has been produced to provide all information from the workshop, including working group reports and briefout material. The qualitative analysis spreadsheet tool will be added to this website when available.

URL: *ftp://web1.dt.navy.mil/pub/Hsstw97*

The information posted on the website will be updated periodically.

CCDoTT's High-Speed Sealift/Agile Port Operational Concept Document is available for download on the internet.

URL: *http://heart.engr.csulb.edu/~ccdott/*

Both volumes of this High-Speed Sealift Technology Workshop Report will be posted on CCDoTT's web page:

URL: *http://www.ccdott.org*

Section 9

REFERENCES

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2. LAVIS, D.R., and GOUBAULT, P., "Physics-Based Ship-Design Synthesis," presented at the 6th International Marine Design Conference, University of Newcastle-upon-Tyne, England, 23-25 June 1997.

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4. REMUS, T.A., et. al., "Study to Accompany High-Speed Sealift/Agile Port Operational Concept Document," Center for the Commercial Deployment of Transportation Technologies, August 1997.

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Section 10

NOMENCLATURE

ABS	American Bureau of Standards
AP	Agile Port
BMEP	Brake Mean Effective Pressure
BSFC	Brake Specific Fuel Consumption
CCDoTT	Center for the Commercial Deployment of Transportation Technologies
CIM	Computer Integrated Manufacturing
CONUS	Continental United States
DoD	Department of Defense
DCSLOG	Deputy Chief of Staff for Logistics
DSM	Design Synthesis Model
hp	Horsepower
HP	High Priority
hr	Hour(s)
HSS	High-Speed Sealift
HYSWAS	Hydrofoil Small Waterplane Area Ship
JLOTS	Joint Logistics Over the Shore
JV	Joint Vision
kt	Knot(s)
LASCOR	Laser Corrugated Core
lb	Pound(s)
LBP	Length Between Perpendiculars
LMI	Logistics Management Institute
LNG	Liquid Natural Gas
LP	Low Priority
lton	Long Ton(s) 2,240 lb
MARAD	Maritime Administration

MARITECH	MARAD’s Maritime Technology Shipbuilding Investment Program
MCFC	Molten Carbonate Fuel Cell
Mg	Magnesium
MSP	Maritime Security Program
MTBO	Mean Time Between Overhaul
NCAMA	National Center for Advanced Marine Applications
NDF	National Defense Feature
nm	Nautical Mile(s)
NSWCCD	Naval Surface Warfare Center Carderock Division
OPNAV	Office of Chief of Naval Operations
PAFC	Phosphoric Acid Fuel Cell
PEM	Proton Exchange Membrane
PEOCLA	Program Executive Officer for Carriers, Littoral Warfare, and Auxiliary Ships
psi	Pound(s) per Square Inch
R&D	Research and Development
RDT&E	Research, Development, Technology, and Engineering
RO-RO	Roll-On, Roll-Off
rpm	Revolutions per Minute
SES	Surface Effect Ship
SFC	Specific Fuel Consumption
SHP	Shaft Horsepower
SO	Solid Oxide
ston	Short Ton(s) 2,000 lb
SWATH	Small Waterplane Area Twin Hull
TF	Transport Factor
Ti	Titanium
TLR	Top Level Requirement
USTRANSCOM	United States Transportation Command

V	Velocity
VISA	Voluntary Intermodal Sealift Agreement
W	Weight
WIG	Wing In-Ground Effect

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