In the United States Court of Federal Claims

No. 12-484C

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FASTSHIP, LLC,

Plaintiff,

v.

UNITED STATES,

Defendant.

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Post-trial decision in a patent case; U.S. Patent Nos. 5,080,032 and 5,231,946; 28 U.S.C. § 1498(a); infringement; non-obviousness; enablement; reasonable and entire compensation

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Andrew P. Zager, Trial Attorney, Commercial Litigation Branch, Civil Division, United States Department of Justice, Washington, D.C., for defendant. With him on the briefs and at trial were Scott Bolden and Lindsay Eastman, Trial Attorneys, Commercial Litigation Branch, Civil Division, United States Department of Justice, Washington, D.C. Also with him on the briefs were Benjamin C. Mizer, former Principal Deputy Assistant Attorney General, and Gary Hausken, Director, Commercial Litigation Branch, Civil Division, United States Department of Justice, Washington, D.C.

OPINION AND ORDER[1]

LETTOW, Judge.

This post-trial opinion addresses plaintiff's claims for damages attributable to alleged infringement of patents pertaining to large ships with a semi-planing monohull design and

[1]Because this order might have contained confidential or proprietary information within the meaning of Rule 26(c)(1)(G) of the Rules of the Court of Federal Claims ("RCFC") and the protective order entered in this case, it was initially filed under seal. The parties were requested to review this order and to provide proposed redactions of any confidential or proprietary information. The resulting redactions are shown by brackets enclosing asterisks, e.g., "[***]."

waterjet propulsion. Plaintiff, FastShip, LLC ("FastShip"), alleges that the United States, acting through the United States Navy ("Navy" or "government"), has infringed upon its patents, United States Patent Nos. 5,080,032 ("the '032 patent") and 5,231,946 ("the '946 patent"), both entitled "Monohull Fast Sealift or Semi-Planing Monohull Ship."

The Navy instituted the Littoral Combat Ship ("LCS") program to develop large, fast ships for combat operations in shallow waters. After years of development by the Navy and its contractors, the first ship in the Freedom class variant of the LCS program, LCS-1 (USS Freedom), was launched on September 23, 2006. LCS-1 has a semi-planing, double-chine monohull and is propelled by waterjets that are powered by gas turbines and diesel engines. FastShip alleges that LCS-1 infringes Claims 1 and 19 of the '032 patent and Claims 1, 3, 5, and 7 of the '946 patent, and seeks $44 million in damages for the alleged infringement. The government responds that no infringement has occurred and also contends that the '032 and '946 patents are invalid due to obviousness and lack of enablement. Further, the government argues that even if LCS-1 infringes the '032 and '946 patents, FastShip would only be entitled to a reasonable royalty of $900,000, plus delay damages.

A ten-day trial was held in Washington, D.C., commencing on October 3, 2016 and ending on October 17, 2016. Following post-trial briefing, the court heard closing arguments on February 21, 2017. The case is now ready for disposition.

FACTS[2]

A. The '032 and '946 Patents

David Giles is the inventor of the '032 and '946 patents. See PX 23 (the '032 patent); PX 29 (the '946 patent); Tr. 29:24 to 30:6 (Test. of David Giles).[3] Plaintiff is the current assignee of both patents. See PX 225 (Assignment for the Patents in Suit from Thornycroft, Giles & Company, Inc. ("Thornycroft Giles" or "TGC") to FastShip, LLC (July 31, 2012)); Tr. 832:8 to 833:12 (Test. of Howard Brownstein).[4]

[2]This recitation of facts constitutes the court's principal findings of fact in accord with RCFC 52(a). Other findings of fact and rulings on questions of mixed fact and law are set out in the analysis.

[3]Mr. Giles has degrees in classics and English literature from Winchester College and New College Oxford. Tr. 30:18-22 (Giles). He is a naval architect who has worked in the field since the 1970s. See Tr. 32:24 to 33:3 (Giles).

Citations to the trial transcript are cited as "Tr. __." Citations to plaintiff's exhibits are identified as "PX __," defendant's exhibits are denoted as "DX __," and plaintiff's demonstrative exhibits are marked as "PDX__."

[4]Mr. Giles initially assigned the '032 and '946 patents to Thornycroft Giles in 1993. See PX 584 (Assignment for the Patents in Suit from David Giles to Thornycroft, Giles & Company, Inc. (June 2, 1993)) at G503567-68. Peter Thornycroft and Mr. Giles founded Thornycroft Giles

Mr. Giles filed a United Kingdom patent application on October 11, 1989, setting that date as the priority date for the '032 and '946 patents. See '032 patent, Foreign Application Priority Data; '946 patent, Foreign Application Priority Data; Tr. 132:5-7 (Giles). He filed a U.S. patent application on May 18, 1990, which issued as the '032 patent on January 14, 1992, and he filed a continuation of the application on January 13, 1992, which issued as the '946 patent on August 3, 1993. See '032 patent; '946 patent; Pl.'s Post-Trial Br. at 6, ECF No. 155. Both patents expired on May 18, 2010. See FastShip, LLC v. United States, 122 Fed. Cl. 71, 73 (2015) ("FastShip II").

The '032 and '946 patents are directed to "a monohull fast sealift (MFS) or semi-planing monohull (SPMH) ship and, more particularly, to a fast ship whose hull design in combination with a waterjet propulsion system permits, for ships of about 25,000 to 30,000 tons displacement with a cargo carrying capacity of 5,000 tons, transoceanic transit speeds of up to 40 to 50 knots in high or adverse sea states." '032 patent, col. 1, lines 6-13; '946 patent, col. 1, lines 10-17.[5] The patent depicted this ship design as follows:

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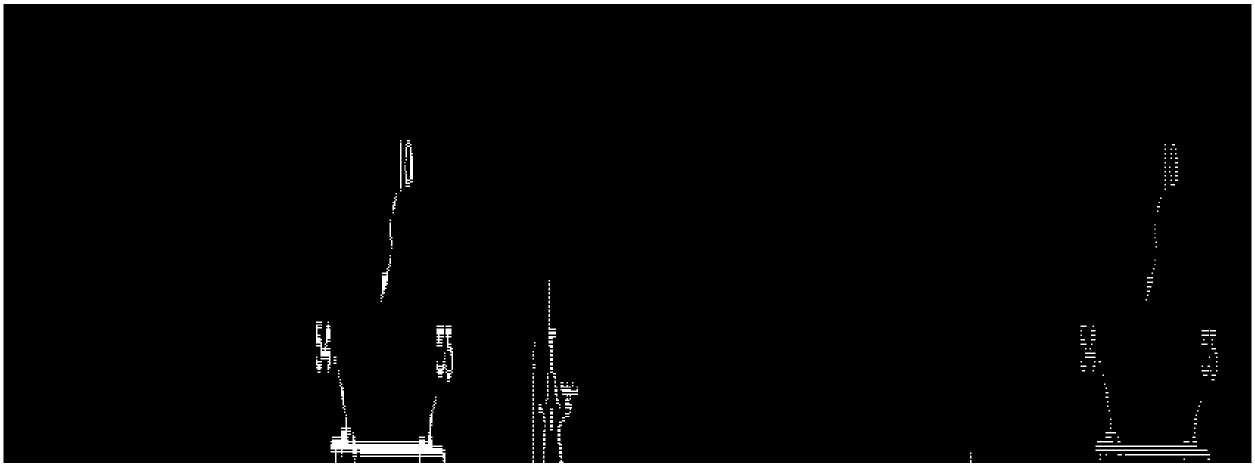
for the purpose of "explor[ing] the possibilities of enlarging semi-planing hulls," later leading to the ship designs embodied in the '032 and '946 patents. See Tr. 37:22-23 (Giles). Mr. Giles founded FastShip Atlantic for the purpose of commercializing these designs. See Tr. 132:16-22 (Giles); Tr. 844:8-10 (Test. of Roland Bullard, former director, President and CEO of FastShip, Inc.) ("FastShip Atlantic's role was to undertake the building of a transportation network between Europe and the United States utilizing the patents of TGC."). To accomplish that goal, Thornycroft Giles licensed its technology, including the '032 and '946 patents, to FastShip Atlantic in 1994. PX 30 (Amended and Restated License Agreement between Thornycroft Giles and FastShip Atlantic, (July 21, 1994)). FastShip, Inc. was created in 1997 as a holding company for both Thornycroft Giles and FastShip Atlantic. Tr. 843:18-21, 844:1-2 (Bullard).

FastShip, Inc., Thornycroft Giles, and FastShip Atlantic declared bankruptcy in 2012. See Tr. 957:17-24 (Bullard). Pursuant to the liquidation plan for the bankruptcy, FastShip, LLC was created as a separate entity that is entirely owned by the Brownstein Corporation, the trustee of the liquidating trust of FastShip, Inc., Thornycroft Giles, and FastShip Atlantic. Tr. 824:19 to 825:1 (Brownstein); see also PX 582 (Liquidating Trust Agreement, In re FastShip, Inc., No. 12-10968 (Bankr. D. Del. July 12, 2012)). Thornycroft Giles assigned the '032 and '946 patents to FastShip, LLC on July 31, 2012 for purposes of this litigation and any subsequent litigation related to these patents and/or the FastShip entities. See PX 225; Tr. 832:8-13 (Brownstein).

[5] The specifications of the '032 and '946 patents are identical; therefore, subsequent references to either specification will only cite to the '032 patent.



‘032 patent at 1.

The ‘032 patent consists of twenty claims and the ‘946 patent consists of eight claims. Of these claims, Claims 1 and 19 of the ‘032 patent and Claims 1, 3, 5, and 7 of the ‘946 patent are at issue in this case. Claim 1 of the ‘032 patent and Claims 1 and 3 of the ‘946 patent are “vessel” claims, and Claim 19 of the ‘032 patent and Claims 5 and 7 of the ‘946 patent are “vessel conveying method” claims. All of the claims at issue contain common limitations and have the same specification, and thus will be considered together through a representative claim, which the parties have designated as Claim 1 of the ‘032 patent. See Def.’s Post-Trial Br. at 15-16, ECF No. 165.

Claim 1 of the ‘032 patent recites:

> A vessel comprising:
>
> a hull having a non-stepped profile which produces a high pressure area at the bottom of the hull in a stern section of the hull which intersects a transom to form an angle having a vertex at the intersection and hydrodynamic lifting of the stern section at a threshold speed without the hull planing across the water at a maximum velocity determined by a Froude Number, the hull having a length in excess of 200 feet, a displacement in excess of 2000 tons, a Froude Number in between about 0.42 and 0.90, and a length-to-beam ratio between about 5.0 and 7.0;
>
> at least one inlet located within the high pressure area;
>
> at least one waterjet coupled to the at least one inlet for discharging water which flows from the inlet to the waterjet for propelling the vessel;
>
> a power source coupled to the at least one waterjet for propelling water from the at least one inlet through the waterjet to propel the vessel and to discharge the water from an outlet of the waterjet; and wherein

> acceleration of water into the at least one inlet and from the at least one waterjet produces hydrodynamic lift at the at least one inlet which is additional to the lifting produced by the bottom of the hull in the high pressure area which increases efficiency of the hull and reduces drag.

'032 patent, col. 13, line 68 to col. 14, line 29.[6]

B. The Navy's Littoral Combat Ship Program

1. The Focused Mission High-Speed Ship Study.

The Navy began exploring the concept that later became the LCS program in the early 2000s, seeking new ships that could be used for "focused missions" at high speeds. Tr. 1416:21-24, 1417:17-19 (Test. of Susan Tomaiko, Director, Undersea Systems Contracts Division, Naval Sea Systems Command). The Navy commissioned its initial study of focused mission high-speed ("FMHS") ships in 2002. Tr. 1416:21-23 (Tomaiko). In its request for proposals ("RFP"), the Navy asked offerors to develop ship concepts that covered seven naval warfare tasks and mission areas: cost, speed and agility, manned and unmanned vehicles, war fighting capability, hull configuration, propulsion and engineering systems, and smart systems. DX 65 (Lockheed Martin, Ship Concept Study for a Focused Mission Ship, Contract No. N00024-03-C-2303, Concept Final Report (Feb. 6, 2003)) at G012391; DX 66 (Gibbs & Cox, Ship Concepts Study Final Report, Contract No. N00024-03-C-2301 (Feb. 6, 2003)) at G011863. The Navy received eighteen proposals and made six contract awards for FMHS studies, which it later used to "develop[] [its] requirements for the littoral combat ship . . . program." Tr. 1421:21 to 1422:4, 1423:6-7 (Tomaiko).

Lockheed Martin Corporation and Gibbs & Cox, Inc., two government contractors that ultimately worked together on a team to design, develop, and construct LCS-1, each received individual FMHS contract awards for the initial ship study. DX 65; DX 66. Lockheed Martin proposed the "VariCat," a ship with a "variable displacement hullform" that combined features of a small-waterplane-area twin hull ("SWATH") and a catamaran hull, and incorporated waterjet propulsion. DX 65 at G012378. Gibbs & Cox proposed a ship with an aluminum semi-planing monohull that was to be propelled by waterjets as well. DX 66 at G011846-48. Lockheed Martin was a member of the Gibbs & Cox FMHS team in addition to submitting its own proposal, as was Donald L. Blount & Associates, another subcontractor that ultimately worked on the LCS program. Id. at G011860.

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[6]Froude numbers are dimensionless figures representing "the ratio of a ship's speed in knots to the square root of its length in feet and [are] used to understand drag by describing the physics of a ship's speed relative to its size. [They are] analogous to the use of mach numbers to describe aviation speed." FastShip, LLC v. United States, 114 Fed. Cl. at 499, 502 n.3 ("FastShip I") (citing Tech. Tutorial 18:24 to 19:11, ECF No. 28).

2. LCS RFP and contract awards.

Following the award and evaluation of the FMHS proposals, the Navy issued its first RFP for the LCS program on February 28, 2003. DX 73 (Contract No. N00024-03-C-2311) at G008455. Based on the knowledge gleaned from the FMHS program, the RFP laid out preliminary performance parameters for the Navy's desired littoral combat ship, including, among other requirements, ideal distance range at sprint and economical speeds, performance in different sea states, hull service life, crew size, and cost. See id. at G008770. The Navy specifically sought a ship with a sprint speed of at least 40 knots, ideally reaching 50 knots. Id. Within these parameters, the Navy did not specify a particular hull form for the ship, nor did it include size or weight requirements. See id.; Tr. 1460:24 to 1461:12 (Tomaiko) (explaining that the Navy provided offerors with desired LCS performance specifications and "left it up to the contractors to figure out how to design the ship to get to the key performance parameters that the Navy wanted it to have").

For the LCS proposal, Lockheed Martin abandoned its FMHS VariCat design and became the prime contractor with Gibbs & Cox on the semi-planing monohull proposal. See DX 68 (Littoral Combat Ship, Volume I, Technical Volume (Apr. 14, 2003)) at G025271; Tr. 1426:7 to 1427:5 (Tomaiko). Lockheed Martin served as program manager, while Gibbs & Cox was "responsible for platform design, naval architecture, and ship systems integration." DX 68 at G025273-74. Other subcontractors on the Lockheed Martin and Gibbs & Cox team included Marinette Marine and Bollinger Shipyards for ship design and construction, and Donald L. Blount & Associates, Fincantieri, and Navatek as design specialists. Id. at G025274-78.

While Lockheed Martin and Gibbs & Cox were preparing their LCS proposal, Mr. Giles met with representatives of both companies to discuss FastShip's potential contributions to the team. See PX 282 (David Giles, Report on Meeting with Lockheed-Martin and Gibbs & Cox (Feb. 26, 2003)). On February 26, 2003, Mr. Giles gave a presentation about the Prelude, FastShip's large semi-planing monohull design that the company had been developing for commercial purposes. Id. at FS0032776; PX 337 (PowerPoint Presentation: "PRELUDE (LCS CONCEPT): Agenda for 2/26/03"); Tr. 162:18-22 (Giles). [***]. See PX 282; Def.'s Post-Trial Br. at 8. In his presentation, Mr. Giles described the science behind and the benefits of the Prelude's semi-planing monohull design. See generally PX 337. He also explained FastShip's experience in installing and operating waterjets and that FastShip could provide validation of earlier performance, tank, and seakeeping tests that it had conducted on models of its semi-planing monohull design. See PX 282 at FS0032776. During this meeting, the Lockheed Martin and Gibbs & Cox representatives emphasized key features of their proposed littoral combat ship, including low-speed stability features, sprint speeds of 40 to 50 knots over 1,000 nautical miles, "[l]ow electronic signature," and price. Id. at FS0032776-77. Following the presentation, the representatives told Mr. Giles that it was "unlikely that [the team and FastShip] could enter into a direct arrangement for the hull design being provided by [FastShip]" because of the companies' preexisting relationship with Donald L. Blount & Associates, but they would be willing to explore the possibility of adding FastShip to the team for "certain design aspects." Id. at FS0032777.

On the same day that Mr. Giles met with the Lockheed Martin and Gibbs & Cox LCS team, FastShip and Gibbs & Cox entered into a confidentiality agreement regarding FastShip's "technical package," covering patents, technical drawings, and other information provided to Gibbs & Cox for FastShip's potential involvement with the LCS program. See PX 71 (Confidentiality Agreement (Feb. 26, 2003)); Tr. 940:8-21 (Bullard). Several weeks earlier, FastShip had also entered a non-disclosure agreement with Lockheed Martin regarding technical information FastShip shared with Lockheed Martin during their discussions about the LCS program. PX 64 (Proprietary Information Non-Disclosure Agreement (Feb. 4, 2003)); Tr. 938:11-18 (Bullard).

On March 17, 2003, Lockheed Martin and FastShip signed a term sheet related to FastShip's potential participation on the LCS team. PX 79 (FastShip, Inc. Involvement in Littoral Combat Ship Program). It extended a 2001 memorandum of understanding between the companies "relating to cooperation with respect to commercialization of vessels to be built to a patented designed developed by FastShip, Inc." Id. at FS0116533.[7] According to this term sheet, "Lockheed Martin ha[d] determined that a variant of the TG 770 patented design and expertise developed by FastShip, Inc. in high speed ships may be applicable to the Littoral Combat Ship." Id. The "TG 770 patented design" is the FastShip commercial vessel covered by the '032 and '946 patents. Tr. 942:11-15 (Bullard). The term sheet made provision for information sharing between the LCS team and FastShip, subject to the aforementioned non-disclosure and confidentiality agreements. PX 79 at FS0116533. It did not, however, specify FastShip's role, if any, on the Lockheed Martin and Gibbs & Cox LCS team. See id.

The Navy divided the LCS RFP into two phases. Phase I constituted the preliminary design of core systems. See DX 83 (Source Selection Advisory Counsel, Best Value Recommendation: LCS Flight 0 Contracts, Final System Design, and Detail Design and Construction, Phase II) at G344348. The Navy made contract awards for Phase I to the Lockheed Martin and Gibbs & Cox team, a team led by General Dynamics, and a team led by Raytheon. Id. at G344353-54. The period of performance for the Phase I contracts was seven months, from July 2003 to February 2004, and each Phase I contract included an option for Phase II, final system design. Id. at G344348.

The Phase I proposal from the Lockheed Martin and Gibbs & Cox LCS team adopted the semi-planing monohull from Gibbs & Cox's FMHS proposal. See DX 68 at G025366-68. The proposed ship was to be 95.5 meters (approximately 313 feet) long with a full load displacement of 1,640 metric tons and a full load sprint speed of 50 knots. Id. at G025366. The hull would be constructed from aluminum and propelled by gas turbines and waterjets. Id. at G025366, G025370. The proposal describes the semi-planing monohull as "based on the highly successful design of the Destriero," a yacht with a 67 meter, 1,000 metric ton semi-planing hull designed by Donald L. Blount & Associates and Fincantieri. Id. at G025367-68. The proposed LCS ship

[7]The original memorandum of understanding between FastShip and Lockheed Martin defined Lockheed Martin's role as a subcontractor on FastShip's development of a transatlantic cargo route. See PX 45 (Memorandum of Understanding (Nov. 12, 2001)). It also denoted potential future work for "military transport applications." Id. at FS0116256.

would fit in terms of size and displacement between the Destriero and the Jupiter ferry designed by Fincantieri. Id. According to the proposal, FastShip's role on the team was to "contribute hydrodynamic test data and loiter speed roll-reducing technologies." Id. at G025278. These data were deemed to "provide[] a valuable independent check on the [t]eam's analysis to ensure all requirements [were] met." Id. The proposal also identified FastShip's development of "an advanced 40,000 ton, 42-knot semi-planing cargo ship" as part of the company's qualifications and expertise. Id.

The Lockheed Martin and Gibbs & Cox team advanced to Phase II. At that stage, the team substantially revised its design to propose a larger, sturdier, heavier ship, with an "advanced semi-planing (double chine) monohull design constructed of steel with an aluminum superstructure" that would achieve sprint speeds of 45 knots. DX 83 at G344353. The forward portion of the hull had the appearance of a conventional displacement hull, but the aft portion had a flattened shape more characteristic of a semi-planing hull. Tr. 336:10 to 337:17 (Test. of Dr. Richard Garwin); see also infra, at 21 (reproducing the lines plan of the hull). The team changed the hull material from aluminum to steel because the steel structure would be simpler to build and would "reduce stress concentrations which [would] lower the risk of fatigue during service and the risk of catastrophic failure due to battle damage." PX 146 (LCS Preliminary Design CDRL D.10 Hull Form Development Report (Oct. 29, 2004)) at G026993. More shipyards also had experience with building and repairing steel monohulls as compared to aluminum monohulls. Id. The change to steel significantly increased the weight of the vessel, and the hull was also lengthened to 115 meters (approximately 377 feet). See id.

In light of these changes and the resulting Phase II proposal as a whole, the Navy's Source Selection Advisory Counsel adjudged that the Lockheed Martin and Gibbs & Cox team had the highest rated technical/management proposal, presented the lowest risk, and offered the lowest-cost proposal. DX 83 at G344367-68. The Navy ultimately awarded two contracts for final system design of the LCS program, one to the Lockheed Martin and Gibbs & Cox team and the other to the General Dynamics team. See DX 84 (Decision of the Source Selection Authority, LCS Flight 0 (May 25, 2004)) at G345136. According to the Navy, "two designs would provide the Navy with alternative combat system designs as well as emphasize different off-board organic vehicle launch and recovery operations." Tr. 1483:22-25 (Tomaiko). In addition, "the award of two contracts would maintain a competitive environment to encourage both contractors to control cost and schedule during performance of the contract." Tr. 1483:25 to 1484:3 (Tomaiko).

After the teams executed their final system designs, the Navy exercised its option for both contractors for "detail design and construction of the first ship" following final critical design review. See Tr. 1439:1-8, 1440:15 to 1441:21 (Tomaiko). On May 27, 2004, the Navy selected the Lockheed Martin and Gibbs & Cox team to build LCS-1, the first ship in the Freedom class variant of the LCS program. PX 476 (USS Freedom (LCS 1) Timeline) at FS0165496. After receiving the contract award, construction commenced on LCS-1 on February 8, 2005 at Marinette Marine Corporation in Marinette, Wisconsin. Id. at FS0165496-97. The ship was launched on September 23, 2006, and was commissioned by the Navy on November 8, 2008. Id. at FS0165497-98.

C. Testing of Lockheed Martin's LCS Design

1. Model-scale tank testing.

In December 2003, the Naval Sea Systems Command ("NAVSEA"), in conjunction with the Lockheed Martin and Gibbs & Cox team, published a report of preliminary smooth water tests of an LCS model that were performed at the Naval Surface Warfare Center, Carderock Division ("Carderock"). See PX 127 (Dominic S. Cusanelli, Lockheed Martin Littoral Combat Ship (LCS), Series A: Preliminary Smooth Water Resistance Tests, Model 5623 (Dec. 2003)). The model used in these tests, designated Model 5623, was based on the then-current Lockheed Martin and Gibbs & Cox LCS hullform design at a 1:22 model scale. Id. at 3. The tests included an evaluation of "[t]hree different stern hull-bottom inserts" to test "the effect of different buttock angle configurations." Id. One was a straight buttock "similar to that of the parent NTUA series," and the other two were "hooked" buttocks. Id.[8] "Hook 1" was ultimately used on LCS-1. See id. at 12; Tr. 346:12-14 (Test. of Dr. Richard L. Garwin).[9]

In January 2006, NAVSEA published a report of bare hull calm water resistance tests on a model of LCS-1, also performed at Carderock. See PX 155 (Kenneth M. Forgach, Bare Hull Resistance Experiments with Model 5640, Representing the Lockheed Martin Littoral Combat Ship, LCS 1, USS FREEDOM (Jan. 2006)). The main reason for these tests was to assess "[p]owering performance at heavier displacements." Id. at G045724. These tests were performed on Model 5640, which was based on the LCS-1 double-chine, semi-planing monohull at a 1:18 model scale. See id. at G045725-26.[10] The model was in a bare hull condition for these

[8]"NTUA" refers to the National Technical University of Athens, whose ship designers had developed the so-called "Athens hull form," a semi-planing type. Tr. 469:17 to 470:22 (Test. of Dr. Christopher McKesson).

[9]A "hook" at the stern or buttocks of a ship is a "partial concavity," Tr. 270:14 (Giles), designed to produce lift or pressure at the bottom of the hull and lift the "whole back end" of the ship, Tr. 266:20 to 267:25 (Giles).

By contrast, a "rocker" is a convex-shaped stern, used on traditional warships such as cruisers, destroyers, and frigates. Tr. 335:6-11 (Garwin). A rocker stern at high speeds provides "a suck-down at the stern, and that gives a bow-up trim moment, down at the stern, up at the bow." Tr. 335:9-11 (Garwin); see also Tr. 665:24 to 667:17 (McKesson) (addressing models of existing naval cruisers, destroyers, and frigates of "traditional full-displacement high-speed monohull" design, with "transom stern[s]," i.e., ones that have rocker characteristics but are "whacked off" and not "canoe" shaped).

[10]A "chine" is a spray rail, kink, or edge on the side of a ship or boat, Tr. 264:3-7 (Giles), notably used in planing boats, such as PT boats and MTBs in World War II, id. A chine or spray rail reduces drag because it serves to prevent wetting as much of the hull as would otherwise occur by "caus[ing] the water to break off cleanly and carry on straight." Tr. 462:23-24 (McKesson); see also Tr. 463:5-7 (McKesson) ("I don't need a rail back aft, but I do need the rail up forward. . . ."). As to whether a chine provides lift, the experts indicate that it provides a

tests, which meant that its stabilizing fins and thruster nozzles were removed, and the waterjet inlets and openings into the hydrodynamic transom were sealed. Id. at G045725. As configured, "[t]he model was tested at six displacements over an extended speed range (speed-length ratio of 0.28 to 3.88)." Id.[11]

Model 5640 was later reconfigured for tank tests of LCS-3.[12] In 2009 and 2010, the Lockheed Martin and Gibbs & Cox team and NAVSEA performed resistance experiments at

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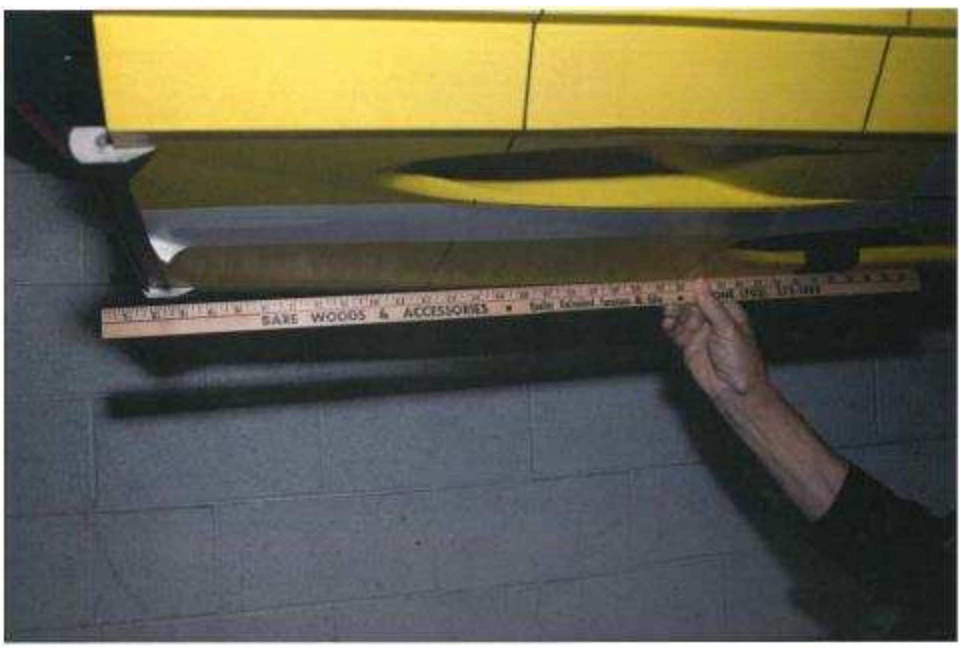
bit of lift at the bow, but not at the stern. Compare Tr. 265:11-14 (Giles) ("I think that this spray rail can create a certain amount of lift as well."), with Tr. 460:14 (McKesson) ("[T]he water sheet that is coming up off the bow knocks into th[e] rail and is deflected horizontally sideways. Th[e] rail is acting exactly like a waterski and producing exactly a waterskiing force lifting the bow of the ship up. . . .").

[11]The parties and the court observed Model 5640 in its current condition during their site visit to Carderock on September 7, 2016. Upon inspection, Model 5640 appeared as follows:



PX 712 (photo taken during Carderock inspection (Sept. 7, 2016)). As this photo shows, Model 5640 appeared to have a convex "rocker" stern rather than a hooked stern. See Tr. 2275:19 to 2279:3 (Garwin). However, the lines and body plans of LCS-1 show a hooked stern rather than a convex stern. See id. A convex stern would create low pressure at speeds over 40 knots, while a hooked stern would create high pressure at such speeds. See Tr. 2319:16 to 2320:12 (McKesson). The court concludes that the stern of Model 5640, as inspected, does not accurately represent the stern of LCS-1; the totality of evidence shows that LCS-1 has a hooked stern rather than a convex stern, which generates high pressure and hydrodynamic lift.

[12]Although LCS-3 is no longer at issue as a potentially infringing vessel in this case, see FastShip II, 122 Fed. Cl. at 86, the testing performed by the Navy on models of LCS-3 is

Carderock on the reconfigured Model 5640. See PX 210 (Bryson J. Metcalf, Resistance Experiments Conducted with Model 5640 Representing the LCS 3 Littoral Combat Ship (Jan. 2011)). Model 5640 was outfitted with a "modified transom in accordance with the Lockheed Martin Hull-2 geometry" to represent the redesigned hullform of LCS-3. Id. at G035055-57. These tests included both calm water and irregular head seas resistance tests, as well as tests on "the influence of appendages." Id. at G035055. The tests also incorporated different model configurations, including different "ballast and trim conditions, roll fin deployment, and interceptor immersion." Id.

In April 2011, NAVSEA published the results of propulsion experiments performed at Carderock on the LCS-3 model. See DX 104 (Bryson J. Metcalf, Propulsion Experiments Conducted with Model 5640 Representing the LCS 3 Littoral Combat Ship (Apr. 2011)). These tests used the same model as the previous LCS-3 tank tests, except that the model was self-propelled through the testing tank rather than towed. See id. at G035193. To propel the model, testers outfitted it with "[s]urrogate waterjet pumps" used "in conjunction with scaled inlet geometries and nozzle diameters." Id. at G035193, G035197. The model also had roll fins installed for these tests and its interceptors were fully immersed. Id. at G035194. The model was tested in calm water and in irregular sea states. Id. at G035193.

2. Full-scale vessel testing.

The builder's trials of the full-scale LCS-1 began in Lake Michigan on July 28, 2008. PX 476 at FS0165498; see also PX 279 (video of high-speed builder's trials (Aug. 2-3, 2008)). During these trials, Lockheed Martin performed Builder's Dock Trials, Builder's Sea Trials, and Acceptance Trials. PX 187 (USS Freedom LCS-1 Trials Report (June 10, 2009)) at 1. During the Builder's Sea Trials, LCS-1 [***]. Id. at 55, 59, 64, 66.[13]

In 2010, the Navy performed calm water trials on LCS-1 off the coast of San Clemente Island, California. See PX 208 (Douglas B. Griggs, et al., USS Freedom (LCS 1) Performance and Special Trials Results Volume I (Apr. 2012)) at G029423-24. These tests were "designed to evaluate the speed/power relationship of the hull and propulsion plant at a range of speeds up to full power using multiple propulsion configurations." Id. at G029428. The Navy was unable to test the retractable fins and interceptors during these trials due to mechanical problems. Id. at G029423, G029427. During the trial, LCS-1 [***]. Id. at G029461.

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relevant to assessing the characteristics and performance of LCS-1 because the hullform did not significantly change between these iterations of the ship, see Tr. 355:13-15 (Garwin); Tr. 443:15-18, 545:22-25 (McKesson) ("We can tell [the model is] the [LCS-]3 because . . . these outboard waterjets have been moved aft relative to the inboard waterjets, but we understand the hull to be basically the same.").

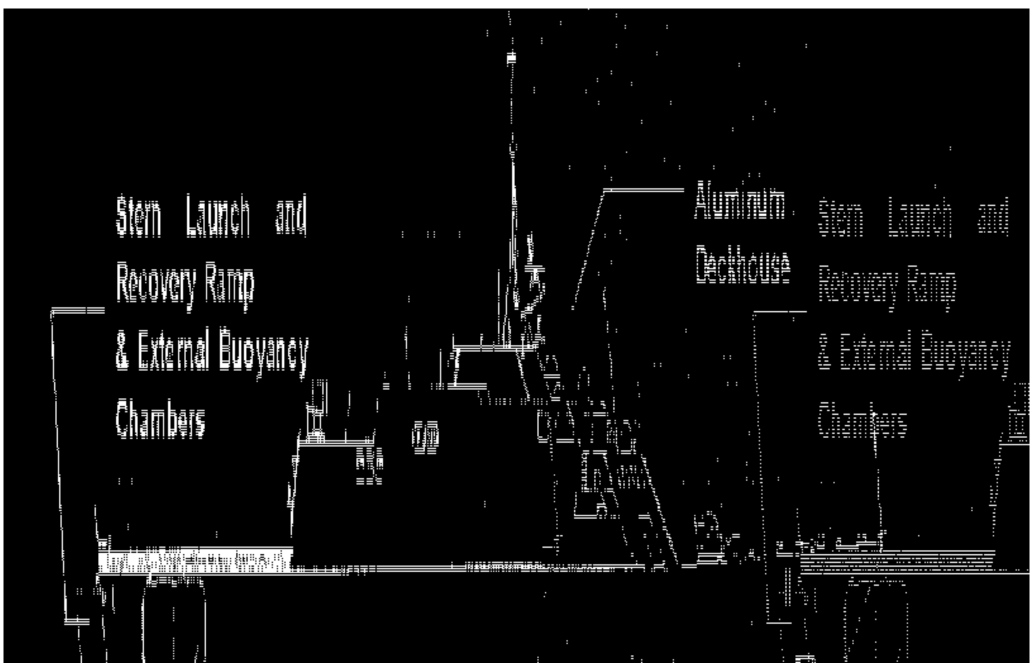
[13]"CODAG" refers to "Combined Diesel and Gas (Turbine)," i.e., signifying that both types of power are being employed.

The Navy also performed full-scale trials on LCS-3 off the coast of San Clemente Island, California. PX 239 (Stephen T. Minnich & Matthew W. Marquardt, USS Fort Worth (LCS 3) Fuel Economy and Tactical Performance Trial Results (May 2014)). During these trials, LCS-3 [***]. Id. at G343508.

D. Specifications for and Key Features of LCS-1

In its final form, LCS-1 has a "double-chine, semi-planing monohull form, propelled by waterjets driven by a CODAG power plant." DX 129 (Lockheed Martin, et al., Final System Design Summary Report, Revision D (Nov. 7, 2011)) at G054758.[14] Lockheed Martin represents that the hull design is based on Destriero, the Jupiter ferry, and "the work done by Donald L. Blount & Associates and Fincantieri." Id. at G054784. The monohull form and steel construction "increases survivability and reduces the likelihood of fatigue issues with the structure." Id. at G054758. This hullform is also "inherently scalable, with flexibility to accommodate emerging requirements without extensive redesign." Id. For propulsion, LCS-1 has two outboard waterjets for steering and reversing, and two inboard "boost" waterjets that generate forward thrust. Id. at G054790; see also PX 138 (Littoral Combat Ship Waterjet Propulsor Specification).

LCS-1 is 118.8 meters (389.76 feet) long, with a 17.65 meter (57.90 foot) beam and a full-load displacement of 3,305 metric tons. DX 129 at G054763. Its hull contains the following features:



DX 129 at G054770. According to the final system design report, LCS-1 [***]. DX 129 at G054758. The later-published technical manual states, however, that LCS-1 [***]. PX 231

[14]The LCS Final System Design Summary Report "reflects the [LCS-1] as delivered to the U.S. Navy in September 2008." DX 129 at G054759.

(Technical Manual: LCS-1 USS Freedom, Revision I (Oct. 15, 2012)) at G327840; see also PX 328 (National Geographic, The Freedom Flies (video), available at http://channel.nationalgeographic.com/explorer/videos/the-freedom-flies/) (stating that LCS-1 is designed to go "40-plus knots" and has achieved speeds of 47 knots).

In its final form, LCS-1 appears as follows:

PX 208 at G029415.

PROCEDURAL HISTORY

FastShip filed suit in this court on August 1, 2012, alleging that the Navy infringed Claims 1 and 19 of the '032 patent and Claims 1, 3, 5, and 7 of the '946 patent through the development, construction, and use of LCS-1 and LCS-3, and seeking compensation for this allegedly infringing use. See generally Compl.[15] The court entered a protective order in this case on March 6, 2013, ECF No. 14, which was subsequently modified on April 2, 2014, ECF

[15]Prior to filing suit in this court, FastShip, Inc. and Thornycroft Giles filed an administrative claim with the Navy alleging that LCS-1 infringed the '032 and '946 patents. See PX 200 (Letter from Thomas P. Hilliard, Esq., Section Head, Intellectual Property Law Section, Office of the General Counsel, Naval Sea Systems Command to Donald B. Stout, Esq. (Apr. 28, 2010)). Following an investigation into the allegations, the Navy denied this claim on April 28, 2010. See id.

No. 45, April 11, 2014, ECF No. 48, and March 9, 2017, ECF No. 175. The parties submitted briefs on claim construction in August and September 2013, conducted a technological primer for the court on August 27, 2013, and presented arguments at a Markman hearing held on September 13, 2013. See FastShip I, 114 Fed. Cl. at 503-04. The court then issued its construction of eight salient claim terms on October 9, 2013. Id. at 504-12.

Thereafter, the government moved for partial summary judgment, arguing that LCS-3 and the subsequent ships in the Freedom class "were not 'manufactured' by or for the government within the meaning of 28 U.S.C. § 1498 prior to the expiration of the patents-in-suit," and therefore could not serve as the basis for FastShip to recover. FastShip II, 122 Fed. Cl. at 72. This court granted the government's motion, leaving only LCS-1 at issue as the basis for FastShip's potential recovery. Id. at 86.

After the parties completed discovery, and prior to trial, the court and the parties conducted site visits at Fincantieri Marinette Marine Shipyard in Marinette, Wisconsin and at Carderock in West Bethesda, Maryland. A ten-day trial began on October 3, 2016.[16] Following post-trial briefing and closing argument, the case is ready for disposition.

STANDARDS FOR DECISION

A. Patent Infringement under 28 U.S.C. § 1498

Pursuant to 28 U.S.C. § 1498(a), the United States has waived sovereign immunity and vested in this court exclusive jurisdiction to adjudicate patent infringement claims against the federal government "[w]henever an invention described in and covered by a patent of the United States is used or manufactured by or for the United States without license of the owner thereof or lawful right to use or manufacture the same." 28 U.S.C. § 1498(a). Section 1498 provides in relevant part that "the use or manufacture of an invention described in and covered by a patent of the United States by a contractor, a subcontractor, or any person, firm, or corporation for the [g]overnment and with the authorization or consent of the [g]overnment, shall be construed as use or manufacture for the United States." Id.

The government's unauthorized "use or manufacture" under Subsection 1498(a) is analogous to a taking of property under the Fifth Amendment of the United States. See Motorola, Inc. v. United States, 729 F.2d 765, 768 (Fed. Cir. 1984); see also Hughes Aircraft Co. v. United States, 29 Fed. Cl. 197, 208 (1993). The government "takes" a non-exclusive and compulsory license to a United States patent "as of the instant the invention is first used or manufactured by the [g]overnment." Decca Ltd. v. United States, 640 F.2d 1156, 1166 (Ct. Cl. 1980). And, because the government has waived sovereign immunity only for a compulsory taking of a non-exclusive patent license, the basis for recovery under 28 U.S.C. § 1498 differs

[16]Before trial began, FastShip filed four motions in limine and the government filed two motions in limine; all but one of these motions sought to exclude evidence from trial. This court denied the parties' motions, except for plaintiff's motion for leave to file for admission of designated deposition testimony, subject to the government's counter-designations. See Order of Sept. 23, 2016, ECF No. 124.

from that in patent litigation between private parties under 35 U.S.C. § 271 in the following respects:

> [S]ection 1498 is a waiver of sovereign immunity only with respect to a direct governmental infringement of a patent. Activities of the [g]overnment which fall short of direct infringement do not give rise to governmental liability because the [g]overnment has not waived its sovereign immunity with respect to such activities. Hence, the [g]overnment is not liable for its inducing infringement by others, for its conduct contributory to infringement of others, or for what, but for section 1498, would be contributory (rather than direct) infringement of its suppliers. Although these activities have a tortious ring, the [g]overnment has not agreed to assume liability for them.

Decca, 640 F.2d at 1167 (footnotes omitted) (emphasis added).

The government directly infringes a patent when it uses or manufactures the patented invention without a license. See Decca, 640 F.2d at 1167 n.15. In evaluating a patent infringement dispute under Section 1498, the court applies a two-step analysis that parallels the infringement analysis applied to disputes between private parties. See Lemelson v. United States, 752 F.2d 1538, 1548-49 (Fed. Cir. 1985); Casler v. United States, 15 Cl. Ct. 717, 731 (1988), aff'd, 883 F.2d 1026 (Fed. Cir. 1989). The court first construes the claims of the patent, and then compares the construed claims to the characteristics of the accused infringing product or process. See JVW Enters., Inc. v. Interact Accessories, Inc., 424 F.3d 1324, 1329 (Fed. Cir. 2005). Claim construction is a question of law to be determined by the court, whereas the comparison between the claims and the accused product or process involves questions of fact. Markman v. Westview Instruments, Inc., 517 U.S. 370, 388-90 (1996). In making such a comparison, the plaintiff has the burden of proving that every limitation in a patent claim is also present in the accused infringing product or process, either literally or through the doctrine of equivalents. See Lemelson, 752 F.2d at 1551 ("[E]ach element of a claim is material and essential, and . . . in order for a court to find infringement, the plaintiff must show the presence of every element or its substantial equivalent in the accused device.") (citations omitted); Prochroma Techs., Inc. v. United States, 60 Fed. Cl. 614, 617 (2004) (noting that plaintiffs must demonstrate evidence that the government "literally or equivalently" infringed the claim by meeting all of the claim's limitations) (citations omitted). This standard is commonly described as the "all elements" rule. See TDM Am., LLC v. United States, 92 Fed. Cl. 761, 768 (2010), aff'd, 471 Fed. Appx. 903 (Fed. Cir. 2012); see also Warner-Jenkinson Co. v. Hilton Davis Chem. Co., 520 U.S. 17, 29 (1997). Ultimately, the plaintiff has the burden of proving direct infringement, literally or under the doctrine of equivalents, by a preponderance of the evidence. Lemelson, 752 F.2d at 1547; Hughes Aircraft Co. v. United States, 717 F.2d 1351, 1361 (Fed. Cir. 1983); Cormack v. United States, 122 Fed. Cl. 691, 701-07 (2015) (concluding that the accused device, a mail sorting machine, did not infringe claims of the patent at issue).

B. Available Defenses

Under Subsection 1498(a), "[i]n the absence of a statutory restriction, any defense available to a private party is equally available to the United States." Motorola, 729 F.2d at 769 (quoting 28 U.S.C. § 1498, Revisor's Notes) (alterations in original). Thus, the invalidity defenses available to private parties involved in patent disputes under 35 U.S.C. § 282(b) are also available to the government. See, e.g., Messerschmidt v. United States, 29 Fed. Cl. 1, 17-40 (granting the government's cross-motion for summary judgment on plaintiff's patent infringement suit and invalidating plaintiff's patent on the basis of anticipation and obviousness), aff'd, 14 F.3d 613 (Fed. Cir. 1993). Nonetheless, because an issued patent is presumed valid, see 35 U.S.C. § 282(a), the government must prove invalidity by clear and convincing evidence, Microsoft Corp. v. i4i Ltd. P'ship, 564 U.S. 91, 95 (2011). This burden of persuasion remains on the government throughout a pending action. Stratoflex, Inc. v. Aeroquip Corp., 713 F.2d 1530, 1534 (Fed. Cir. 1983).

A patent is invalid due to obviousness when "the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains." 35 U.S.C. § 103(a) (2006).[17] The obviousness determination is a "legal conclusion," but is "based on underlying facts." Allergan, Inc. v. Sandoz Inc., 726 F.3d 1286, 1290 (Fed. Cir. 2013) (citing Graham v. John Deere Co. of Kansas City, 383 U.S. 1, 17 (1966)). The factual underpinnings include: (1) the scope and content of the prior art, (2) the difference between the prior art and asserted claims, (3) the level of ordinary skill in the relevant art, and (4) the objective evidence of non-obviousness. Graham, 383 U.S. at 17-18; see also KSR Int'l Co. v. Teleflex Inc., 550 U.S. 398, 406-07 (2007). The party raising the obviousness defense has the burden of proving, by clear and convincing evidence, "that a skilled artisan would have had reason to combine the teaching of the prior art reference to achieve the claimed invention, and that the skilled artisan would have had a reasonable expectation of success from doing so." PAR Pharm., Inc. v. TWI Pharm., Inc., 773 F.3d 1186, 1193 (Fed. Cir. 2014) (quoting In re Cyclobenzaprine Hydrochloride Extended-Release Capsule Patent Litig., 676 F.3d 1063, 1068-69 (Fed. Cir. 2012) (in turn quoting Procter & Gamble Co. v. Teva Pharm. USA, Inc., 566 F.3d 989, 994 (Fed. Cir. 2009))) (internal quotation marks omitted). The court may also consider evidence of secondary considerations indicating non-obviousness. *KSR Int'l*, 550 U.S. at 406 (citing Graham, 383 U.S. at 17-18); see also Transocean Offshore Deepwater Drilling, Inc. v. Maersk Drilling USA, Inc., 699 F.3d 1340, 1349-54 (Fed. Cir. 2012) (considering commercial success, industry praise, unexpected results, copying, industry skepticism, licensing, and long-felt but unsolved need in the court's analysis of secondary indicia of non-obviousness).

A patent is also invalid if it fails to satisfy the enablement requirement, which is set forth in 35 U.S.C. § 112:

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[17] Section 103 of the patent laws was amended by Section 3 of the Leahy-Smith America Invents Act ("AIA"), Pub. L. No. 112-29, 125 Stat. 284, 287 (2011). Subparagraph 3(n)(1) of the AIA makes the change to Section 103 applicable to any patent application filed 18 months after September 16, 2011, i.e., subsequent to March 16, 2013. See id. at 293. As the patent applications for the '032 and '946 patents were filed in 1990 and 1992 respectively, well before the applicable date of the AIA, the pre-AIA version of Section 103 applies to this case. See, e.g., ClassCo Inc. v. Apple, Inc., 838 F.3d 1214, 1218 n.2 (Fed. Cir. 2016).

> The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same, and shall set forth the best mode contemplated by the inventor of carrying out his invention.

35 U.S.C. § 112, Paragraph 1 (2006).[18] A patent is invalid due to lack of enablement when the party contesting the patent's validity demonstrates, by clear and convincing evidence, that "a person of ordinary skill in the art would not be able to practice the claimed invention without 'undue experimentation.'" Alcon Research, 745 F.3d at 1188 (citing In re Wands, 858 F.2d 731, 736-37 (Fed. Cir. 1988); Johns Hopkins Univ. v. CellPro, Inc., 152 F.3d 1342, 1360 (Fed. Cir. 1998)). The enabling disclosure must be in the specification of the patent at the time the patent application was filed. MagSil Corp. v. Hitachi Glob. Storage Techs., Inc., 687 F.3d 1377, 1382 (Fed. Cir. 2012). Enablement is a question of law, but the court's analysis may be based on findings of fact. Alcon Research, 745 F.3d at 1188. Determining whether the necessary experimentation is "undue" requires the court to weigh "many factual considerations" and apply a standard of reasonableness, with consideration given to "the nature of the invention and the state of the art." Wands, 858 F.2d at 737 (citations omitted).

C. Compensation under 28 U.S.C. § 1498

If the government directly infringes the plaintiff's patent, the plaintiff is entitled to recover the "reasonable and entire compensation" for the government's acquisition of a compulsory non-exclusive patent license. 28 U.S.C. § 1498(a); see Decca, 640 F.2d at 1167. "Generally, the preferred manner [for calculating reasonable and entire compensation] is to require the government to pay a reasonable royalty for its license as well as damages for its delay in paying the royalty." Standard Mfg. Co. v. United States, 42 Fed. Cl. 748, 758 (1999), abrogated in other respects by Uniloc USA, Inc. v. Microsoft Corp., 632 F.3d 1292 (Fed. Cir. 2011); see also Wright v. United States, 53 Fed. Cl. 466, 469 (2002). In determining such a royalty, the court considers the "supposed result of hypothetical negotiations between the plaintiff and defendant." Rite-Hite Corp. v. Kelley Co., 56 F.3d 1538, 1544 (Fed. Cir. 1995) (en banc) (citing Hanson v. Alpine Valley Ski Area, Inc., 718 F.2d 1075, 1078 (Fed. Cir. 1983)). In this hypothetical negotiation, the court must "envision the terms of a licensing agreement reached as the result of a supposed meeting between the patentee and the infringer at the time infringement began," id., which is deemed to be the date of first use or manufacture, Brunswick Corp. v. United States, 36 Fed. Cl. 204, 210 (1996), aff'd, 152 F.3d 946 (Fed. Cir. 1998). To supplement the court's analysis of a reasonable royalty in the context of a hypothetical negotiation, the court may rely on the factors provided in Georgia-Pacific Corp. v. United States Plywood Corp., 318 F. Supp. 1116, 1120 (S.D.N.Y. 1970), modified and aff'd, 446 F.2d 295 (2d

[18]Section 112 of the patent laws was amended by Subsection 4(c) of the AIA. See AIA, 125 Stat. at 296. Subsection 4(e) of the AIA makes the change to Section 112 applicable to any patent application filed on or after September 16, 2012. Accordingly, the court looks to the pre-AIA version of Section 112 as the legal basis for its decision. See Alcon Research Ltd. v. Barr Labs., Inc., 745 F.3d 1180, 1183 n.1 (Fed. Cir. 2014); Hitkansut LLC v. United States, 130 Fed. Cl. 353, 367 n.11 (2017), appeals filed, Nos. 17-1853 & 17-1856 (Fed. Cir. 2017).

Cir. 1971). See Maxwell v. J. Baker, Inc., 86 F.3d 1098, 1109-10 (Fed. Cir. 1996). The factors are:

> (1) current, established royalty rates under the patent at issue; (2) royalty rates for comparable technology; (3) scope, exclusivity, and restrictiveness of a retroactive license; (4) the patent holder's established licensing and marketing practices; (5) commercial/competitive relationship of licensor and licensee; (6) derivative/convoyed sales of unpatented, accompanying materials by patentee and competitors; (7) duration of patent and license terms; (8) profitability and commercial success of invention; (9) utility and advantages of invention over prior art; (10) nature, character, and benefits of use; (11) extent and value of infringing use; (12) allocation of a portion of profits or sales for use of invention; (13) portion of realizable profits creditable to the invention alone; (14) expert testimony on royalty rates; and (15) the totality of other intangibles impacting a hypothetical negotiation between a willing licensor and licensee.

Brunswick Corp., 36 Fed. Cl. at 211 (citing Georgia-Pacific Corp., 318 F. Supp. at 1120). However, the court is not "constrained" by these factors and need not consider factors that are "inapposite or inconclusive." Id. at 211-12. Ultimately, the court's reasonable royalty analysis is "highly case-specific and fact-specific" and involves "mixed considerations of logic, common sense, justice, policy and precedent." Boeing Co. v. United States, 86 Fed. Cl. 303, 311 (2009) (internal quotation marks and citations omitted).

ANALYSIS

FastShip filed suit against the government under 28 U.S.C. § 1498(a), alleging that LCS-1 directly and literally infringes Claims 1 and 19 of the '032 patent and Claims 1, 3, 5, and 7 of the '946 patent. Pl.'s Post-Trial Br. at 15-40. The government asserts that LCS-1 does not infringe any of the asserted claims, and also contests the validity of the '032 and '946 patents on grounds of obviousness and lack of enablement. Def.'s Post-Trial Br. at 16-43. Additionally, if the government is found to have infringed the '032 and '946 patents, FastShip claims that its "reasonable and entire compensation" would total $44 million, Pl.'s Post-Trial Br. at 42-60, whereas the government states that FastShip would only be entitled to approximately $900,000 plus delay damages, Def.'s Post-Trial Br. at 43-59. In resolving this dispute, the court's initial task is to determine whether LCS-1 directly infringes the foregoing claims in the '032 and '946 patents.

I. INFRINGEMENT

The parties agree that Claim 1 of the '032 patent is a representative claim that encompasses every limitation of each claim at issue in this case. As such, the court's analysis focuses on the claim limitations as stated in Claim 1. To prove literal infringement, FastShip must demonstrate that LCS-1 embodies each and every element in Claim 1. See ZMI Corp. v. Cardiac Resuscitator Corp., 844 F.2d 1576, 1578 (Fed. Cir. 1988). If the language provided in Claim 1 reads directly on LCS-1, "the court may disregard additional components or elements of the accused device if those additions do not produce a radically different result." Judin v. United

States, 27 Fed. Cl. 759, 784 (1993); see also Becton Dickinson & Co. v. C.R. Bard, Inc., 922 F.2d 792, 797 (Fed. Cir. 1990).

The parties do not dispute that LCS-1 embodies the following limitations of Claim 1: "a hull having a non-stepped profile;" "the hull having a length in excess of 200 feet, a displacement in excess of 2000 tons, a Froude Number in between about 0.42 and 0.90, and a length-to-beam ratio between about 5.0 and 7.0;" "at least one waterjet coupled to the at least one inlet for discharging water which flows from the inlet to the waterjet for propelling the vessel;" and "a power source coupled to the at least one waterjet for propelling water from the at least one inlet through the waterjet to propel the vessel and to discharge the water from an outlet of the waterjet." '032 patent, col. 14, lines 1, 8-12, 15-21; see Pl.'s Post-Trial Br. at 13-15; Def.'s Post-Trial Br. at 16-17. However, the government contends that FastShip has failed to show infringement of every element set forth in Claim 1, Def.'s Post-Trial Br. at 19-33, as detailed in the government's objections below:

A. High Pressure and Hydrodynamic Lifting

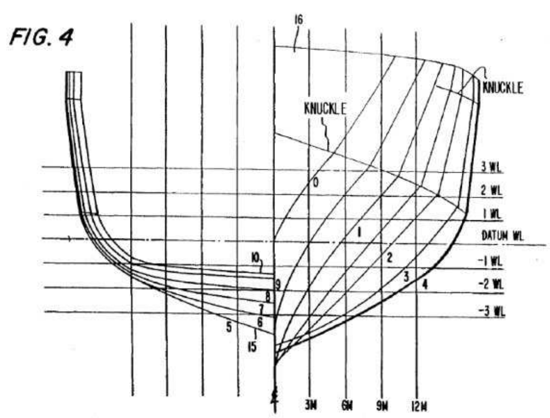
1. "[A] hull . . . which produces a high pressure area at the bottom of the hull in a *stern section of the hull" and "hydrodynamic lifting of the stern section at a* threshold speed without the hull planing across the water at a maximum velocity determined by a Froude Number."

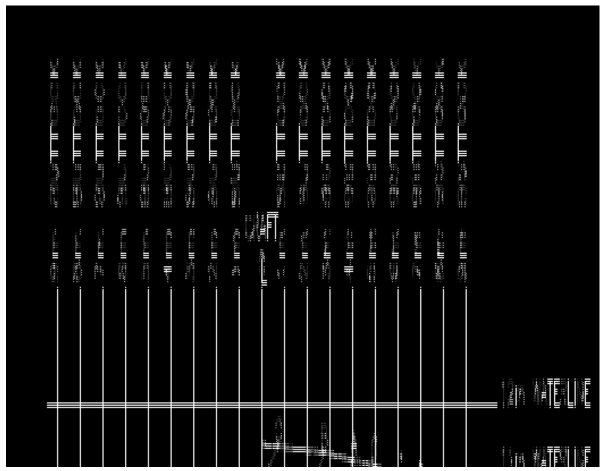
These two sections of the representative claim must be considered together because the presence of a high pressure region beneath the hull at the stern, in the absence of waterjets or other appendages, would create hydrodynamic lift. See Pl.'s Post-Trial Br. at 17; Tr. 545:11-15 (McKesson).[19] Further, according to the patent, "[i]t is this hull configuration which produces at a threshold speed a hydrodynamic lift under the aft section." '032 patent, col. 9, lines 23-25. The court construed "high pressure area" to mean "an area with hydrodynamically generated pressure sufficient in magnitude to produce an upward rather than a downward force vector," FastShip I, 114 Fed. Cl. at 506, and "hydrodynamic lifting" to mean "generating an upward force vector by hydrodynamic means," id. at 508. FastShip argues that the hooked stern of LCS-1 causes high pressure and therefore causes hydrodynamic lifting of the stern as the ship gains speed. Pl.'s Post-Trial Br. at 17, 22-28. The government argues, on the other hand, that

[19]Dr. McKesson, an expert testifying for plaintiff, is the co-director of the graduate studies program in naval architecture and marine engineering at the University of British Columbia. PX 419 (Expert Report of Chris B. McKesson, Ph.D. (Mar. 4, 2016)) at 12; Tr. 405:18-25 (McKesson). He holds a bachelor's degree in naval architecture and marine engineering from the University of Michigan, and a master's degree and Ph.D. in naval architecture and marine engineering from the University of New Orleans. PX 419 at 12. He is also licensed as a professional engineer in the State of Washington and the Province of British Columbia. Id. Dr. McKesson was accepted by the court as an expert in naval architecture, including waterjet propulsion. Tr. 441:4-6, 447:16-17. His expert reports were admitted into evidence. PX 419; PX 420 (Expert Report of Chris B. McKesson, Ph.D. (Mar. 31, 2016)); PX 421 (Expert Report of Chris B. McKesson, Ph.D. (Apr. 15, 2016)).

hydrodynamic lifting of the stern would only occur at speeds above which LCS-1 has been shown to achieve. Def.'s Post-Trial Br. at 22-27.

Consistent with the claim language, the hull shape of LCS-1 creates a high pressure region under the stern. According to the specification, a semi-planing hull has a "traditional displacement hull shape with a keel in the forward section and a flattened bottom in the aft section." '032 patent, col. 9, lines 13-17. Both the patented hullform and LCS-1 have this shape, according to their lines plans:





'032 patent, Figure 4 (at left); DX 141 (Drawing 0403-1-801-001 Rev. A) at DB0000188 (at right). These diagrams both show flattened buttocks lines in the aft section of the ship, consistent with the semi-planing hullform as defined by the patent. See also Tr. 2256:4 to 2258:12 (Test. of Robert T. Waters, Branch Head, Full-Scale Trials Branch, Surface Ship Hydromechanics Division, Naval Architecture and Engineering Department, Naval Surface Warfare Center) (explaining that the lines plan of LCS-1 depicts a "stern hook"). A hull with this shape can operate in the semi-planing range of Froude numbers, approximately 0.4 to 0.9. See Tr. 33:25 to 34:3 (Giles). In this Froude range, high pressure causes the stern section of a vessel to rise and therefore reduce its trim, thus causing it go from bow-up to bow-down or relatively less bow-up. See Tr. 1631:4-9 (Test. of Donald Blount).[20] For a vessel of the waterline length of LCS-1, speeds within the semi-planing range would be 25 to 54 knots. See Tr. 541:23 to 542:3, 543:25 to 544:11 (McKesson). The parties do not dispute that LCS-1 was designed to operate and can achieve speeds within this range.

[20]Mr. Blount, an expert testifying for defendant, is the president of Donald L. Blount & Associates, a wholly-owned subsidiary of Gibbs & Cox. DX 42 (Expert Report of Donald L. Blount (Mar. 3, 2016)), Ex. B at 44; Tr. 1585:10-17 (Blount). He has a bachelor's degree in mechanical engineering from George Washington University, and he is a licensed professional engineer in the State of North Carolina and the Commonwealth of Virginia. DX 42, Ex. B at 45; Tr. 1586:2-18. Mr. Blount was accepted by the court as an expert in high-speed hydrodynamics and waterjet propulsion. Tr. 1612:14-16. His expert reports were admitted into evidence. DX 42; DX 61 (Expert Response Reports of Mr. Blount (Apr. 14, 2016)).

Tank tests of the LCS-1 models show that the bare hull of LCS-1 generates high pressure and lifts the stern at speeds between 35 and 40 knots. In the 2006 test of Model 5640, which modeled the bare hull of LCS-1 including the hooked buttock design, tests of the model at different operating conditions show that the ship's rise at the aft perpendicular (i.e. at the stern of the ship) increased at speeds between 35 knots and 40 knots. See PX 155 at G045736-38, G045755-57. Because such lift is created by high pressure, these tests show that high pressure was generated under the stern at a threshold speed between 35 and 40 knots. LCS-1 achieved speeds above 35 knots in multiple tests, see, e.g., PX 208 at G029461; PX 187 at 55, 59, 64, 66, which shows that the full-sized ship operates within the speed range required for hydrodynamic lifting of the stern. The government argues that the trim angle of the ship (i.e. its bow-up positioning) still increased at this speed, providing an indication that the stern was not hydrodynamically lifted. See Def.'s Post-Trial Br. at 23-27.[21] Notably, however, both the stern and bow are lifted at this speed. See PX 155 at G045755-57. The chines at the bow and the flattened hull shape with hook at the aft portion of the ship both have an effect on lift and trim. Nonetheless, the bow is lifted at a greater degree than the stern, which causes the increase in trim angle between 35 and 40 knots. See id. Even so, the patent claims are only directed to hydrodynamic lifting of the stern, rather than the overall trim angle of the ship. Because the rise of the stern of LCS-1 increases between 35 and 40 knots, it satisfies the "hydrodynamic lifting" element of the claim.

The amount of high pressure under the stern was not quantifiably measured during the full-scale or model tests of LCS-1. However, pressure taps used in bare-hull model tests of LCS-3 showed consistent positive pressure under the stern. PX 210 at G035071-72; Tr. 545:21 to 546:10 (McKesson). As LCS-1 and LCS-3 have essentially the same hull structure, aside from the positioning of the waterjets, this measurement indicates that both ships generate an area of high pressure under the stern, which, as previously explained, causes hydrodynamic lifting of the stern.[22]

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[21]The government cites to the full-scale trials of LCS-1 to support its position that the trim angle of the ship increases bow-up at speeds between 35 and 40 knots. See Def.'s Post-Trial Br. at 23 (citing PX 208 at G029438, G029444). These trials measured trim angle without measuring ship rise or heave at the aft perpendicular, as was done in the tank tests. It is therefore improper to extrapolate the trim angle data from the full-scale trials to determine if there was hydrodynamic lift in the stern region at particular speeds.

[22]The government mistakenly relies upon the computation fluid dynamics calculations of its expert witness, Dr. Stern, in arguing that the hull of LCS-1 does not generate a high pressure area under the stern that causes hydrodynamic lift. Dr. Stern's calculations, which model a bare-hull, sub-scale model of LCS-1 and are based on RHINO or IGES files provided to Dr. Stern by the Navy, show negative (low) pressure under the stern rather than high pressure at all speeds. See DX 58 at 13, Figures 5, 6, 7; Tr. 1788:24 to 1789:18, 1827:8-22, 1851:2-12 (Test. of Dr. Frederick Stern). However, Dr. Stern's model is not a reliable representation of the behavior of LCS-1. First, the model of the LCS-1 hull provided to Dr. Stern did not include a hook or interceptors. See Tr. 1782:25 to 1783:15, 1846:19 to 1847:8 (Stern); Tr. 2292:19 to 2293:10 (Garwin). As explained infra, the hook is a key feature of the stern of LCS-1 that contributes to

Further, plaintiff's expert, Dr. Garwin,[23] determined that LCS-1's hook design specifically contributes high pressure lifting forces under the stern. See PX 413 at 1; Tr. 392:14-21 (Garwin). The hook, also called a "stern wedge," is a feature of the stern of LCS-1. Tr. 2148:6-25 (Waters); Tr. 385:9-24 (Garwin). Generally, the purpose of a hook is to change the trim of the ship by moving the stern upward. Tr. 1023:2-12 (Waters); see also Tr. 344:5-8 (Garwin) ("The hook . . . has the purpose of providing lift at the stern and forward trim and maintain[ing] a high pressure area then which intersects with the transom. . . ."); Tr. 1651:10-15 (Blount) ("[T]he hydrodynamic lift is influenced strongly by the buttock shape of the hull bottom as you approach the stern of the [semi-planing] vessel. And a hook, which is turning down the buttock shape, is like adding a wedge. It's similar to or analogous to adding a wedge to a stern of a planing boat. It increases the positive lift."). The '032 patent specification provided for inclusion of a hook at the aft portion of the hull. See '032 patent, col. 6, lines 1-2 (referring to "buttock lines with a slight downward hook terminating sharply at a transom stern"); '032 patent, col. 9, lines 44-45 (same). Using the data from the tank tests of Model 5623, Dr. Garwin assessed the difference in trim at 39.6 to 39.7 knots between the hull with a straight buttock and the hull with the hooked buttock ultimately used on LCS-1. PX 413 at 5 (citing PX 127 at 55); Tr. 347:21 to 348:4 (Garwin). He then calculated that the difference in trim, 0.38 meters, corresponded to an additional high-pressure lifting force at the stern of 30.4 metric tons. See PX

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hydrodynamic lift, and the engagement of the interceptors adds additional high pressure and lift under the stern. Additionally, Dr. Stern's "model of a model" calculations did not adequately account for the scaling of the effect of boundary layers and drag on the performance of the full-size LCS-1. See Tr. 2167:25 to 2168:15 (Waters) (explaining that Reynolds numbers, dimensionless calculations of frictional drag, do not scale, while Froude numbers can be scaled to represent wave-making drag). These flaws in Dr. Stern's model and methodology render his calculations unreliable, and the court affords them little weight.

[23]Dr. Garwin, an expert called to testify by FastShip, received his Ph.D. in physics from the University of Chicago in 1949 at the age of 21. PX 413 (Expert Report of Richard L. Garwin, Ph.D. (Mar. 4, 2016)) at 10. He formerly worked at IBM until his retirement in 1993, and serves as a consultant to the U.S. government and the White House Office of Science and Technology Policy through the JASON group. Tr. 276:25 to 278:10 (Garwin). He is a named inventor on about 50 United States patents, and has published dozens of articles in various fields related to physics. See PX 413 at 11-25; Tr. 279:12 to 280:11 (Garwin). He received the National Medal of Science in 2002, La Grande Médaille de l'Academie des Sciences from France, and was awarded a Presidential Medal of Freedom in 2016.

Relevant here, Dr. Garwin worked on a team with Mr. Giles in 1981 regarding the scaling of "short fat ships" to develop a new frigate for the Royal Navy. PX 413 at 10; Tr. 286:2 to 291:20, 306:17 to 311:5 (Garwin). Dr. Garwin was accepted by the court as an expert in fluid dynamics. Tr. 305:7-10. His expert reports were admitted into evidence. PX 413; PX 414 (Expert Report of Richard L. Garwin, Ph.D. (Mar. 31, 2016)); PX 415 (Expert Report of Richard L. Garwin, Ph.D. (Apr. 15, 2016)); PX 416 (Supplement to Expert Report of Richard L. Garwin, Ph.D. (May 4, 2016)).

413 at 5.[24] Because such a hook is part of the hull of LCS-1 as constructed, rather than a later-installed appendage, the high pressure and consequent hydrodynamic lift caused by the hook fall within the scope of the elements of Claim 1.

The government also contends that the interceptors on LCS-1, which it claims to be appendages to the hull and not part of the hull shape itself, are the only things that produce a high pressure area, if any, under the stern. Def.'s Post-Trial Br. at 19-22. Contrary to the government's assertion, the interceptors are part of the hull of LCS-1, and therefore their contribution to the high pressure under the stern is within the claims of the patent. See Tr. 382:3 to 385:7, 391:20 to 392:13 (Garwin) (explaining that he considers the interceptors to be part of the hull after observing them on multiple Freedom class ships under construction at the Marinette Marine Shipyard). Further, even if the interceptors were considered "appendages" rather than parts of the hull itself, the interceptors create high pressure that is additional to the pressure generated by the bare hull. Interceptors on ships are always designed to contribute a lifting force at the stern. See Tr. 315:21 to 316:3 (Garwin). However, the interceptors were included in the design of LCS-1 for ride stabilization purposes and are not necessary for lifting the stern. See PX 242 (Preliminary Technical Manual, Interceptor-Ride Control, ND-R-3247-01 (Nov. 1, 2014)) at G428276 (explaining that the Ride Control System on LCS-1, which includes the interceptors, "reduces roll, pitch and heave motions to increase passenger comfort"); PX 231 at G327994 (stating that the interceptors "provide motion stabilization for LCS"). Rather, as the Model 5640 tests for LCS-3 demonstrate, the stern lifts at a threshold speed without the interceptors deployed, and the deployment of the interceptors provides an additional lifting force at that speed. The following graph depicts trim and heave data at different speeds for models of LCS-1 and LCS-3:

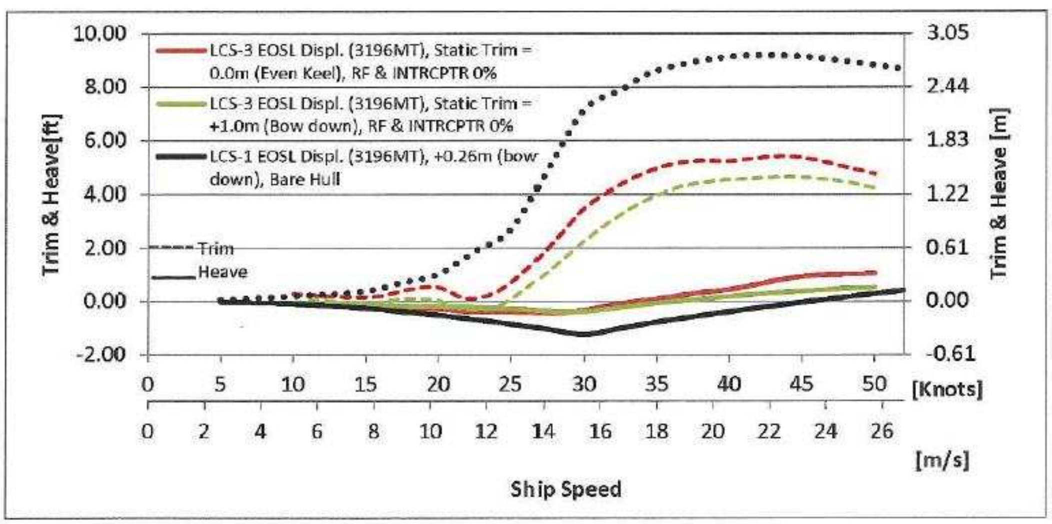

Figure A-14. LCS-3(Hull 2) and LCS-1(Hull 1) Trim and Heave at 3196MT

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[24]This calculation accounts for a correction to Dr. Garwin's expert report, which stated that 1 meter of trim corresponds to 70 metric tons of hydrodynamic lifting force. PX 413 at 5-6. The correct figure is 80 metric tons of lift to generate 1 meter of trim. Tr. 362:7-21 (Garwin).

PX 210 at G035128. For LCS-1, the inflection point where positive (bow-up) trim stops climbing and begins to level off is around 30 knots. Trim levels off around 35 knots and begins to move bow-down around 40 knots. See Tr. 378:4 to 379:2 (Garwin). As explained previously, the shift to bow-down trim is caused by hydrodynamic lifting of the stern, which in turn is caused by a high-pressure region under the stern. The deployment of the interceptors amplifies this bow-down effect:

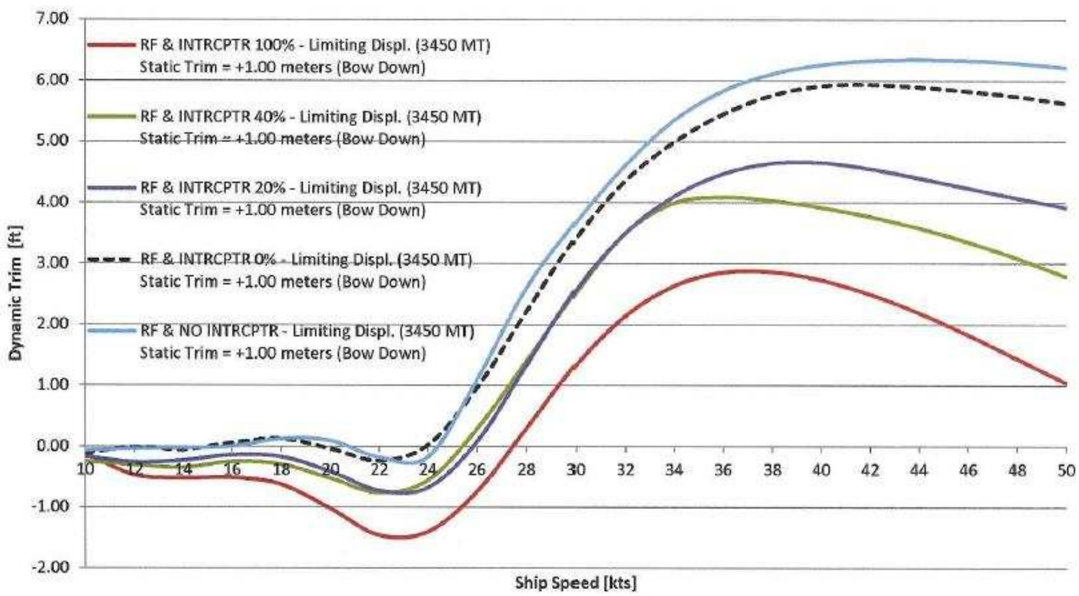


Figure B-5. Influence of Interceptor Immersion on Dynamic Hull Trim

PX 210 at G035142. As shown on this graph of the LCS-3 model data, bow-up trim begins to level off around 32 knots and begins to move bow-down around 35 knots when the interceptors are 100% deployed. The shift towards bow-down trim occurs at a lower speed when the interceptors are deployed than when the hull is bare, which indicates that the interceptors generate high pressure at the stern, and therefore generate upward lift, that is additional to the high pressure and upward lift generated at the stern of the bare hull. See Tr. 2279:18 to 2282:2 (Garwin).

In sum, FastShip has shown by a preponderance of the evidence that the hull of LCS-1 generates high pressure under the stern, which in turn causes hydrodynamic lifting of the stern at a threshold speed, within the scope of these elements of the subject claims.

2. *"[A]t least one inlet located within the high pressure area."*

The government argues that FastShip has not proven that the waterjet inlets on LCS-1 are in a "high pressure area." Def.'s Post-Trial Br. at 27-29. However, as explained previously, there is a "high pressure area" under the stern of LCS-1 that causes hydrodynamic lift. The waterjet inlets on LCS-1 are located within the stern section, and therefore are within the high pressure area. See Tr. 543:10-21, 547:23 to 548:2, 762:17 to 763:1 (McKesson); see also Tr.

398:11-20 (Garwin). During the LCS-3 model tests, consistent positive pressure was detected in the area just forward of the waterjet inlets. See PX 210 at G035071-72; Tr. 398:10-20 (Garwin); Tr. 545:16 to 547:6 (McKesson).[25] Pressure taps further back on the stern exhibited "variable" pressure. Tr. 399:19 to 400:13 (Garwin). The government's expert, Dr. Stern, agrees that there is high pressure at the "trailing edge" of the waterjet inlets. See Tr. 1844:5 to 1845:13 (Stern). Therefore, the inlet location on LCS-1 embodies this element of the subject claims.

B. Waterjets and Additional Hydrodynamic Lifting

1. "[A]cceleration of water into the at least one inlet and from the at least one waterjet produces hydrodynamic lift at the at least one inlet which is additional to the lifting produced by the bottom of the hull in the high pressure area."

The parties further dispute whether the waterjets on LCS-1 contribute an additional lifting force under the stern, in accord with the claims of the '032 and '946 patents. The court construed "additional" to mean "a greater upward force vector than that attributable to a single means," FastShip I, 114 Fed. Cl. at 509, and "acceleration of water into" to mean "an increase in the speed of the flow of water into," id. at 510. FastShip argues that the waterjets on LCS-1 were specifically designed to create additional lift, and a comparison of the model and full-scale tests shows that the use of waterjets causes bow-down trim in addition to the trim caused by the bare hull. Pl.'s Post-Trial Br. at 35-40. The government counters that Dr. Stern's calculations show that the hull is "sucked down" when the waterjets are employed, causing bow-up trim; therefore, the government argues that the waterjets counteract lift rather than cause additional lift. Def's Post-Trial Br. at 29-30.

As explained supra, the court accords little weight to Dr. Stern's analysis because it fails to take into account key characteristics of the performance of the model-scale and full-size LCS-1. See supra, at 22 n.22. In addition, Dr. Stern overestimated the force of the waterjets by a factor of four, which introduces errors into the calculation of their lifting or suctioning effect. See Tr. 2290:9 to 2293:10 (Garwin); Tr. 2321:9 to 2323:1 (McKesson). A failure to account for the scaling of the hydrodynamic boundary layer also introduces error into Dr. Stern's calculations because it overestimates the amount of water flowing into and expelled by the waterjets at full scale. See Tr. 2290:9 to 2293:10 (Garwin); Tr. 2317:15 to 2318:15 (McKesson). The court therefore discounts Dr. Stern's calculations with regard to the waterjet element of the representative claim.

The patents at issue teach that, as a general rule, waterjets generate lifting forces. See '032 patent, col. 10, lines 34-38 ("The flow of seawater is accelerated at or around the inlets by the pumps of the four waterjets, and this flow acceleration produces additional upward dynamic lift. . . ."). The evidence presented regarding the design and construction of LCS-1 shows that

[25] On LCS-3, the two outboard waterjets were moved aft from their positioning on LCS-1. See Tr. 545:22-25 (McKesson). The positioning of the two inboard waterjets remained the same, so the measure of pressure just forward of the inboard waterjets would be in approximately the same position for both vessels.

the waterjets and accompanying inlets on the ship were specifically designed in accord with this precept to create lift under the stern. Kamewa waterjets, which are both recommended by the patent, see '032 patent, col. 6, lines 3-9, and used on LCS-1, see PX 183 (Technical Manual, Propulsion Water Jets Model 153SII/153BII for use on the Littoral Contact Ship (LCS) (Mar. 1, 2009)) at G294357, are designed to and have been shown to create hydrodynamic lift, see PX 14 (Rolf Svensson, Experience with the Kamewa Water Jet Propulsion System) at G506909-10. LCS-1's Kamewa waterjets accelerate water in and thrust water out, creating pressure on the walls of the inlet in which the waterjet is mounted, which in turn exerts upward pressure on the hull. See Tr. 559:19 to 565:8 (McKesson); PX 183 at G294389 (graphing the distribution of positive pressure within the waterjet inlets on LCS-1). To ensure that the waterjets perform as specified, the inlet ducts on LCS-1 are carefully shaped to be "hydrodynamically optimized" to achieve the desired upward lift forces. Tr. 554:12 to 555:20 (McKesson) (discussing PX 138 (Littoral Combat Ship Waterjet Propulsor Specification) at GC0007274); see also Tr. 1647:18 to 1648:8 (Blount); Tr. 2297:9 to 2298:18 (Garwin) (explaining that a poorly-designed inlet will not create hydrodynamic lift).

The model tests of LCS-3 also reinforce that the waterjets cause additional lift.[26] Dr. Garwin compared the model test at 3,150 tons displacement without waterjets at 40 knots, which had a trim angle of 0.75 degrees, with the full-scale test in which the waterjets were employed at 3,135 tons displacement at 40 knots, which had a trim angle of 0.325 degrees. See PX 413 at 6-7 (citing PX 210 at G035045; PX 239 at G343539); Tr. 355:16-24 (Garwin). This change in trim, equivalent to 0.76 meters bow-down, stems from 61 metric tons of hydrodynamic lift at the stern contributed by the waterjets in addition to the hydrodynamic lift from the hull (including hook and interceptors) alone. PX 413 at 6-7; Tr. 358:5 to 359:1 (Garwin).

It is improper to compare the LCS-3 bare-hull model test with the LCS-3 sub-scale waterjet test, as the government seeks to do, because the sub-scale waterjet test was meant to isolate the effect of the inlets, not address the waterjets themselves. See Tr. 2198:7 to 2199:1, 2200:1-5 (Waters). The LCS-3 sub-scale waterjet tests did not use scale models of the Kamewa waterjets actually installed on the ship, but rather used other pumps and impellers that were on-hand at Carderock. See Tr. 2199:23 to 2200:1 (Waters).

FastShip has thus demonstrated that the acceleration of water into the waterjets on LCS-1 contributes an additional lifting force at the stern of the ship, fulfilling this element of the representative claim.

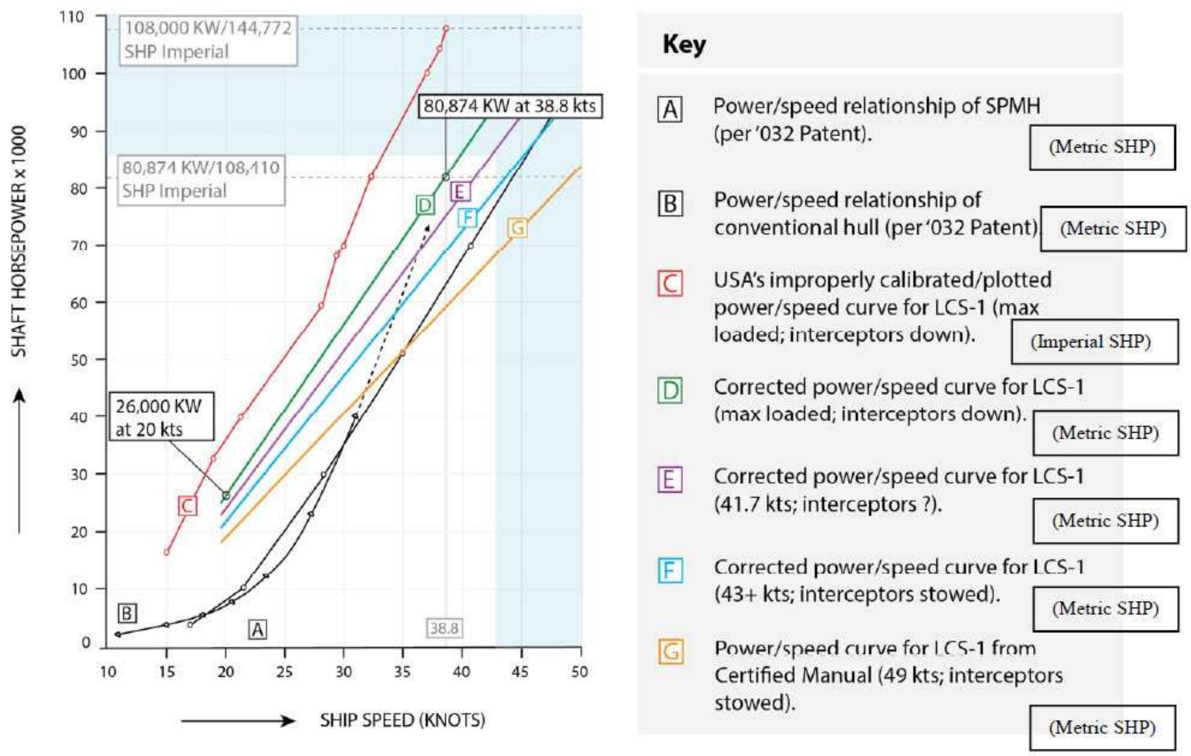
2. "[A]cceleration of water into the at least one inlet and from the at least one waterjet . . . increases efficiency of the hull and reduces drag."

Finally, the parties dispute whether the acceleration of water into the inlets and waterjets on LCS-1 "increases efficiency of the hull," which the court construed to mean that it "allows achievement of speed through application of less power than would be required for comparable or even lower speeds with a conventional displacement hull." FastShip I, 114 Fed. Cl. at 511.

[26] Comparable data for waterjet performance on the model or full-scale LCS-1 was not available to perform this analysis. See Tr. 355:8-12 (Garwin).

The government asserts that the evidence shows that LCS-1's waterjets do not allow LCS-1 to operate more efficiently than a "conventional" displacement hull because the ship requires more power than a conventional hull and only reaches speeds of [***] knots. Def.'s Post-Trial Br. at 31-33.

FastShip points out that the government's argument is misleading because the government compares speed vs. power graphs, as provided in the patents and for LCS-1, that use different units. Pl.'s Post-Trial Reply Br. at 18, ECF No. 167. FastShip is correct to convert the LCS-1 shaft power measurements to metric units (kilowatts) to conform to the metric units used on the power-speed graph in the '032 patent. See '032 patent, Figure 11 & col. 3, lines 42-61; Tr. 205:3-20 (Giles) (explaining that figure 11 in the '032 patent depicts shaft horsepower in metric units); PX 208 at G029442, G029466 (listing and graphing power data for LCS-1 in imperial units).[27] FastShip corrected the speed-power graph to metric units as follows:



Pl.'s Post-Trial Reply Br. at 19. As FastShip's graph shows, LCS-1 at max load (Curve D) requires less power than a traditional displacement hull (Curve B) at [***] knots, the maximum speed achieved by the ship in the calm water trials from which these data were collected. See PX 208 at G029461. LCS-1 continues to require less power than a traditional displacement hull at speeds between [***] knots and [***] knots, the highest speed achieved in the Builder's Trials. See PX 187 at 66. Further, at a light load (Curve E), the speed-power graph shows that LCS-1 is

[27]PX 208 describes the full-scale tests of LCS-1, in which the waterjets were employed. See PX 208 at G029434-35 (describing the propulsion plant states in which LCS-1 was tested, all of which include operation of at least 2 waterjets).

more efficient than the traditional displacement hull (Curve B) at speeds above approximately 35 knots. Therefore, in the states depicted on the graph at speeds known to be achievable, LCS-1 operates more efficiently than a traditional displacement hull within the scope of the patent claims.

In sum, the court finds that FastShip has proven by a preponderance of the evidence that LCS-1 literally infringes every element of the representative claim, and therefore literally infringes Claims 1 and 19 of the '032 patent and Claims 1, 3, 5, and 7 of the '946 patent.

II. VALIDITY

A. Obviousness

The government contends that a combination of prior art references, specifically regarding semi-planing monohulls and waterjet propulsion, renders the '032 and '946 patents obvious under 35 U.S.C. § 103. Def.'s Post-Trial Br. at 37-42. The government has the burden of proving obviousness by demonstrating "that a skilled artisan would have had reason to combine the teaching of the prior art references to achieve the claimed invention, and that the skilled artisan would have had a reasonable expectation of success from doing so." PAR Pharm., 773 F.3d at 1193. In making an obviousness determination, the court is required to "step backward in time and into the shoes worn by [the skilled artisan] when the invention was unknown and just before it was made . . . [and] then determine whether the patent challenger has convincingly established . . . that the claimed invention as a whole would have been obvious at that time to that person." Panduit Corp. v. Dennison Mfg. Co., 810 F.2d 1561, 1566 (Fed. Cir. 1987) (alteration in original) (citations omitted); see also Graham, 383 U.S. at 3. Additionally, before the court invalidates a patent due to obviousness, the court must consider secondary evidence of non-obviousness, such as "commercial success, long[-]felt but unsolved needs, [and] failure of others." Graham, 383 U.S. at 17-18.

The parties agree that the priority date of the '032 and '946 patents is October 11, 1989, the original filing date of Mr. Giles' related UK patent. Pl.'s Post-Trial Br. at 40; Def.'s Post-Trial Br. at 38; see also '032 patent, Foreign Application Priority Data; Tr. 132:5-7 (Giles).[28] The patent specification acknowledges that the semi-planing monohull design was already known at this time, and states that the new invention is the combination of the monohull design with gas turbines and waterjet propulsion. See '032 patent, col. 4, lines 60-68 ("The present invention utilizes a known monohull semi-planing design with inherent hydrodynamic lift and

[28]Prior to trial, the government filed a motion in limine seeking to prevent FastShip from asserting an earlier priority date, October 17, 1988, as the date of conception of the inventions contained in the '032 and '946 patents. See Def.'s Mot. in Limine to Exclude FastShip's Untimely Priority Date Assertions and Disclosures, ECF No. 103. In October 1988, Mr. Giles had presented a version of his vessel to the Navy, without success. See infra, at 32. The court denied the government's in limine motion. Order of Sept. 23, 2016, ECF No. 124. Nonetheless, at trial and in post-trial briefing, FastShip relied on its originally-asserted priority date, October 11, 1989, in its validity arguments. See Pl.'s Post-Trial Br. at 40. The court therefore orients its analysis around this later priority date accepted by both parties.

low length-to-beam (L/B) ratio but in a heretofore unknown combination with gas turbine power and waterjet propulsion which requires, for best efficiency, high pressure at the inlet of the waterjets which I have recognized corresponds to the stern area of the semi-planing hull where high pressure is generated to lift the hull."). The designs of the turbines and waterjets themselves were also known in the art. See id., col. 6, lines 4-9 ("[T]he ship according to the present invention will utilize eight conventional marine gas turbines of the type currently manufactured by General Electric under the designation LM 5000 and four waterjets of the general type currently manufactured by Riva Calzoni or KaMeWa.")

The government argues, however, that a feasibility analysis performed by Mr. Blount a few months before the priority date regarding the later-developed Destriero planing craft is evidence of a motivation to combine prior art references encompassing semi-planing monohull ship designs and waterjet propulsion, rendering the patented invention obvious. Def.'s Post-Trial Br. at 39-41. The government identifies as prior art eight references cited by Mr. Blount in his feasibility study that separately teach different elements of the '032 and '946 patents. See PX 14 (teaching that waterjet propulsion causes hydrodynamic lift); DX 9 (W.J. Marwood and D. Bailey, Design Data for High-Speed Displacement Hulls of Round-Bilge Form, Ship Report No. 99, National Physical Laboratory (Feb. 1969)) (describing tests of round-bilge hull models); DX 43 (Eugene P. Clement and Donald L. Blount, Resistance Tests of a Systematic Series of Planing Hull Forms, Transactions, SNAME (1963)) (describing model tests of planing hull forms at displacement speeds, semi-displacement speeds, semi-planing speeds, and planing speeds); DX 44 (John M. Almeter, Resistance Prediction and Optimization of Low Deadrise, Hard Chine, Stepless Planing Hulls, Star Symposium, SNAME (1989)) (explaining research regarding resistance testing and optimization of planing hulls); DX 45 (Hugh Y.H. Yeh, Series 64 Resistance Experiments on High-Speed Displacement Forms, Marine Technology (July 1965)) (describing resistance experiments on high-speed round-bilge hulls); DX 46 (Daniel Savitsky, Planing Craft, Naval Engineers Journal (Feb. 1985)) (describing features of planing hulls); DX 47 (Jorgen Strom-Tejsen, Hugh Y.H. Yeh, and David D. Moran, Added Resistance in Waves, Transactions, SNAME (1973)) (explaining performance of high-speed round-bilge hull forms in a seaway); DX 48 (Jan J. Blok and William Beukelman, The High-Speed Displacement Ship Systematic Series Hull Forms – Seakeeping Characteristics, Transactions, SNAME (1984)) (describing research regarding seakeeping of round-bilge hulls). None of these references alone teaches the combination of elements asserted by the '032 and '946 patents.

Mr. Blount's feasibility study, which was delivered to the "Bravo Romeo Project" for protected, proprietary use on April 30, 1989, proposes a double-chine hull ship (or yacht) that would "operate in a semi-planing condition when at full load and in a planing mode when lightly loaded." DX 42, Ex. C at 55.[29] The full-load displacement of the proposed ship would be 800

[29]The feasibility study for the "Bravo Romeo Project" was ultimately used to design and build the Destriero. See Tr. 1636:3 to 1639:14 (Blount). The name of the project comes from Bravo Romeo Limited, an Irish corporation that was going to fund the construction of the ship. See Tr. 1638:25 to 1639:2 (Blount). The study sought to determine the feasibility of a gas turbine-and-waterjet-propelled ship that could travel nonstop across the Atlantic Ocean at speeds of at least 50 knots. Tr. 1636:15-22 (Blount).

long tons (approximately 812 metric tons) and its light load displacement would be 200 long tons (approximately 203 metric tons). Id. at 52.[30] The proposed ship's length would be between 50 and 60 meters, and its beam would be between 10 and 14 meters. See id. at 65. The proposed ship also would use gas turbines and waterjets. See id. at 52-54. The study cites seven of the articles identified by the government as prior art. See id. at 56 (citing DX 9, DX 43, DX 44, DX 45, DX 46, DX 47, and DX 48). The government argues that Mr. Blount's combination of these prior art references in the feasibility study proves that the combination of a semi-planing monohull with waterjet propulsion would have been obvious to a person of ordinary skill in the art before the priority date of the '032 and '946 patents. See Def.'s Post-Trial Br. at 39-40.[31] Mr. Blount, however, was not a person of ordinary skill in the art at that time, but rather one of extraordinary skill. The parties agree that a person having ordinary skill in the art would have a "[b]achelor's degree in naval architecture, hydrodynamics, or marine engineering, or equivalent work experience in the same fields." Def.'s Post-Trial Br. at 41. In 1989, however, Mr. Blount had accumulated over three decades of experience as a naval architect, published numerous articles in the field, and served as the department head for the Combatant Craft Engineering Department within the Navy. DX 42, Ex. B. Therefore, his feasibility study is not evidence that a person of ordinary skill would find obvious the combination of elements in the '032 and '946 patents.

Further, FastShip has presented evidence of secondary considerations to demonstrate that the '032 and '946 patents were not obvious at the priority date. Secondary considerations "must always when present be considered en route to a determination of obviousness." In re Cyclobenzaprine, 676 F.3d at 1075 (quoting Stratoflex, 713 F.2d at 1538). These considerations can include commercial success, industry praise, copying by others, the presence of a long-felt but unsolved need for the invention, and unexpected results. See Apple Inc. v. Samsung Elecs. Co., 839 F.3d 1034, 1052 (Fed. Cir. 2016); In re Huai-Hung Kao, 639 F.3d 1057, 1067-68 (Fed. Cir. 2011). Although secondary considerations are not always dispositive, In re Huai-Hung Kao, 639 F.3d at 1067, they "may often be the most probative and cogent evidence in the record," In re Cyclobenzaprine, 676 F.3d at 1075 (quoting Stratoflex, 713 F.2d at 1538), and can guard against hindsight bias, Graham, 383 U.S. at 36.

[30]The material to be used for the hull to achieve these displacements was not specifically identified in the feasibility study. The Destriero, which was based upon this study, has an aluminum hull. DX 42 at 29. Given the weight specified for the ship in the feasibility study, aluminum would be the obvious leading candidate for the hull construction material.

[31]Even though it was written before the priority date, the feasibility study is not itself prior art against the '032 and '946 patents because it is confidential and was never publicly disseminated, see DX 42, Ex. C at 51 (marking report as "PROPRIETARY" and "PROTECTED MATERIAL"); Tr. 1698:21-23 (Blount), and is therefore not a "printed publication" within the definition of 35 U.S.C. § 102(b) (2006), see Cordis Corp. v. Boston Scientific Corp., 561 F.3d 1319, 1333-34 (Fed. Cir. 2009) (explaining that formal or informal confidentiality restrictions on distribution of a document weigh against a finding that the document is publicly accessible and therefore a "printed publication") (citing In re Klopfenstein, 380 F.3d 1345, 1351 (Fed. Cir. 2004)).

"For objective [evidence of secondary considerations] to be accorded substantial weight, its proponent must establish a nexus between the evidence and the merits of the claimed invention." Wyers v. Master Lock Co., 616 F.3d 1231, 1246 (Fed. Cir. 2010) (quoting In re GPAC Inc., 57 F.3d 1573, 1580 (Fed. Cir. 1995)); see also Demaco Corp. v. F. Von Langsdorff Licensing Ltd., 851 F.2d 1387, 1392 (Fed. Cir. 1988) ("The term 'nexus' is often used, in this context, to designate a legally and factually sufficient connection between the proven success and the patented invention. . . ."). The plaintiff has the burden of presenting sufficient evidence to establish a prima facie nexus. Demaco, 851 F.2d at 1392 (citations omitted). "Once the patentee demonstrates a prima facie nexus, the burden of coming forward with evidence in rebuttal shifts to the challenger." Crocs, Inc. v. International T*rade Comm'n*, 598 F.3d 1294, 1311 (Fed. Cir. 2010) (citing Demaco, 851 F.2d at 1393).

The court finds that FastShip has demonstrated a nexus between objective secondary considerations and the asserted claims in the '032 and '946 patents. First, the invention satisfies a long-felt but unsolved need in the community of naval architects. According to the patent specification, "[n]aval architects [had] long considered the problem of achieving significantly higher ship speeds without increasing length or decreasing beam as the equivalent of 'breaking the sound barrier' in aeronautical technology." '032 patent, col. 1, lines 45-49. FastShip's patented invention achieves that goal of a large, "fat" ship with a low length-to-beam ratio that can travel at high speeds.

Additionally, the naval architecture community was initially skeptical about the ship design presented by the '032 and '946 patents. Mr. Giles presented a version of the patented invention to both the U.S. Navy and the Royal Navy, and it was rejected. See PX 13 (Navy Review of TGC Monohull Fast Sealift Ship Unsolicited Proposal of 17 Oct. 1988); Tr. 96:8-15, 101:14-19, 120:6 to 123:11 (Giles). Among other reasons, the Navy rejected the proposal as unfeasible because "the size and performance characteristics of critical ship systems ha[d] been extrapolated to unprecedented levels," Tr. 122:9-13 (Giles), as well as for the proposal's use of waterjets, Tr. 122:15-22 (Giles). Dr. McKesson also characterized the development of relatively short, fat ships that achieve high speeds, such as the patented invention, as an "anomalous introduction" to the Navy's fleet of warships following decades of slender ships designed for high speed travel. See Tr. 451:10-22 (McKesson) (explaining PDX 6 (McKesson Slides) at 2). Upon the development of LCS-1, however, the semi-planing monohull design in combination with waterjet propulsion received acclaim from the Navy and naval architects. See, e.g., PX 456 (Statement of the Honorable Sean J. Stackley, Assistant Secretary of the Navy (Research, Development, and Acquisition) and VADM Richard Hunt, Director, Navy Staff, before the Subcommittee on Seapower & Projection Forces of the House Armed Services Committee on Department of the Navy Shipbuilding Programs (July 25, 2013)) at 1 (explaining the "critical importance" of the LCS program to the Navy, in part because of the ships' "great speed"). These objective indicia of initial skepticism and later acclaim are tied to the patented features of Mr. Giles' inventions that also appear in the design of LCS-1, and thus weigh in favor of a finding that the patents are not obvious.[32]

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[32]As additional objective evidence of non-obviousness, FastShip also claims that the Navy copied its patents in designing LCS-1, based on a comparison between Figure 11 of the '032 and '946 patents and a rendering of the semi-planing hull design from a presentation by

Thus, for the reasons stated, the asserted claims in the '032 and '946 patents are not invalid due to obviousness.

B. Enablement

The government further contends that the asserted claims in the '032 and '946 patents are invalid because they fail the enablement requirement under 35 U.S.C. § 112. Def.'s Post-Trial Br. at 42-43. A patent is invalid due to lack of enablement when the government proves that "a person of ordinary skill in the art would not be able to practice the claimed invention without 'undue experimentation.'" See Alcon Research, 745 F.3d at 1188 (citations omitted). In Wands, the Federal Circuit outlined a set of factors "that a court may consider when determining whether the amount of that experimentation is either 'undue' or sufficiently routine such that an ordinarily skilled artisan would reasonably be expected to carry it out." Id. (citing Wands, 858 F.2d at 737). The factors include:

> (1) the quantity of experimentation necessary,
> (2) the amount of direction or guidance presented,
> (3) the presence or absence of working examples,
> (4) the nature of the invention,
> (5) the state of the prior art,
> (6) the relative skill of those in the art,
> (7) the predictability or unpredictability of the art, and
> (8) the breadth of the claims.

Wands, 858 F.2d at 737.

The government first asserts that the specification of the '032 and '946 patents only discloses one mode of practicing the invention. Def.'s Post-Trial Br. at 43. However, describing a single mode of practicing the invention in the specification is permissible under the patent laws. See, e.g., Epistar Corp. v. Internatio*nal Trade Comm'n*, 566 F.3d 1321, 1336 (Fed. Cir. 2009) (explaining that "'[a]n applicant is not required to describe in the specification every conceivable and possible future embodiment of his invention'" as long as the specification enables a person of skill in the art to make the full scope of the claimed invention without undue experimentation) (quoting Cordis Corp. v. MedtronicAve Inc., 339 F.3d 1352, 1365 (Fed. Cir. 2003)).

The government further claims that the specification does not sufficiently describe how to determine whether the inlets under the stern are within the "high pressure area," as stated in the

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Gibbs & Cox during the FMHS procurement. Pl.'s Post-Trial Br. at 41 (citing '032 patent, Figure 11; PX 59 (Focused Mission High Speed (FMHS) Ship Concept Study, Final Review, Gibbs & Cox Team (Jan. 27, 2003)) at G011206). FastShip also claims that the flattened buttocks and hook, as well as the four waterjet inlets, on LCS-1 are evidence of copying. Pl.'s Post-Trial Br. at 41 (citing '032 patent, Figure 4; DX 141). The court need not determine whether these similarities are evidence of copying because other objective evidence shows that the patented inventions were not obvious at the priority date.

claims. Def.'s Post-Trial Br. at 43. However, the specification discloses that the high pressure area is below the stern. '032 patent, col. 4, lines 60-68 (explaining that the inlets should be located in a high pressure area "correspond[ing] to the stern area of the semi-planing hull where high pressure is generated to lift the hull"). This description is sufficiently enabling because persons of ordinary skill in the art would know how to configure inlets and waterjets within the high pressure area under the stern to maximize performance of the waterjets. See Tr. 1650:25 to 1651:9 (Blount) (explaining that naval architects measure hydrodynamic lift on bare hull models in the location of waterjet inlets "as a matter of routine"). Thus, undue experimentation to determine where to place the inlets is not required to practice the invention, and the government has failed to show by a preponderance of the evidence that the subject claims are not enabled by the specification of the '032 and '946 patents.

III. REASONABLE AND ENTIRE COMPENSATION

Because the government infringed the asserted claims of the '032 and '946 patents, and the patents are valid, FastShip is entitled to recover "reasonable and entire compensation" for the government's compulsory nonexclusive patent license. See 28 U.S.C. § 1498(a).

A. Reasonable Royalty

The proper measure of monetary compensation starts with determining a reasonable royalty, Standard Mfg., 42 Fed. Cl. at 758, that would have resulted from a hypothetical negotiation between the two parties at the time the infringement began, Rite-Hite, 56 F.3d at 1554. A reasonable royalty is "calculated by determining a reasonable royalty rate and multiplying it by a reasonable compensation base." Brunswick, 36 Fed. Cl. at 209 (citation omitted). Such a royalty must be based on "sound economic and factual predicates." Riles v. Shell Expl. & Prod. Co., 298 F.3d 1302, 1311 (Fed. Cir. 2002) (citations omitted).

1. Date of infringement.

The date of infringement, and therefore the date of the hypothetical negotiation, is deemed to be at "the time the United States takes a license from the plaintiff, that is, at the time the invention 'is used or manufactured by or for the United States.'" Boeing, 86 Fed. Cl. at 311 (quoting 28 U.S.C. § 1498(a)). FastShip asserts that the date of infringement is September 23, 2006, the launch date of LCS-1, see Pl.'s Post-Trial Br. at 45, whereas the government argues that the hypothetical negotiation would have taken place on December 15, 2004, when the Navy committed to building LCS-1, see Def.'s Post-Trial Br. at 52.

The court held in FastShip II that LCS-3 was not "used or manufactured" as of the expiration date of the patents on May 18, 2010 because that ship's hull and waterjets, which are covered by the patent claims, were then incomplete and inoperable. See FastShip II, 122 Fed. Cl. at 82-86. On December 15, 2004, the government's desired date for the hypothetical negotiation, LCS-1 was not yet in production; the Navy had merely agreed that it would be built in the future. See DX 56 (Expert Report of Kimberly J. Schenk (Apr. 1, 2016)) at 32. As none of the patented aspects of LCS-1 were in use or manufactured at that time, December 15, 2004 cannot be the date of infringement and consequently cannot be the date of the hypothetical negotiation. See Wright v. United States, 53 Fed. Cl. 466, 471 (2002) ("[I]nfringement occurs not at the time that an accused infringer contracts to 'use or manufacture' a product, but rather at the time that he or she actually uses or obtains the infringing goods.") (citing Tektronix v. United States, 575 F.2d 832, 836-37 (Ct. Cl. 1978)). By the launch date, however, the hull and waterjet propulsion systems of LCS-1 were substantially complete – otherwise the ship could not have been launched – and therefore were manufactured and in use by the Navy at that time. The court agrees with FastShip that the hypothetical negotiation would have taken place on September 23, 2006, and adopts this date as the basis for its reasonable royalty analysis.

2. Royalty rate.

To determine a reasonable royalty rate for the government's nonexclusive license to the '032 and '946 patents, both parties' experts framed their analysis around the Georgia-Pacific factors, but arrived at divergent results. When assessing established rates for the patents at issue and for comparable technology under Georgia-Pacific factors 1 and 2, the court finds that two licenses relied upon by FastShip's expert, Krista Holt,[33] that directly involve FastShip are the most relevant to determining a reasonable royalty. See PX 417 at 37-41; PDX 7 (Holt slides) at 47. The first is a term sheet and memorandum of understanding between FastShip and Lockheed Martin from 2001 in which FastShip granted Lockheed Martin an exclusive license to the "FastShip technology" for building vessels for the U.S. military in exchange for a $20 million payment and a 3% royalty of the "selling price or charter payments for each vessel [Lockheed Martin] sells or charters to the U.S. military." PX 43 (FastShip-Lockheed Martin Licensing Agreement, Term Sheet (Oct. 5, 2001)) at FS0163999. The FastShip technology included the patented semi-planing monohull design, as well as "a patented ship loading and unloading system and terminal handling technology." PX 45 at FS0116255. Lockheed Martin would also serve as a subcontractor on FastShip's project to institute a transatlantic cargo route. See id. at FS0116256-60. Although the memorandum of understanding was signed, it and the term sheet never resulted in a signed contract between FastShip and Lockheed Martin. See PX 417 at 41. Ms. Holt also relied on a 1994 licensing agreement between FastShip Atlantic and Thornycroft Giles, before the companies were both owned by FastShip, Inc., in which Thornycroft Giles exclusively licensed the technology embodied in the '032 and '946 patents to FastShip Atlantic to develop a transatlantic shipping fleet in exchange for a running royalty of 3% on the final construction cost of each vessel and 2% of the gross revenues from shipping operations. PX 30 at FS0000768-71. This agreement also included a license to an unrelated patent owned by Thornycroft Giles. See id. at FS0000781.[34]

[33]Ms. Holt has a bachelor's degree in psychology from Wake Forest University and a master's degree in business administration from the University of Louisville. PX 417 (Expert Report of Krista F. Holt (Mar. 4, 2016)), App. A at 3. She was accepted by the court as an expert in patent damages valuation. Tr. 1151:2-4. Her expert reports were admitted into evidence. PX 417; PX 418 (Surrebuttal of Krista F. Holt (Apr. 15, 2016)).

[34]In determining a reasonable royalty, Ms. Holt also relied upon a settlement agreement between the Navy and Stena Rederi ("Stena"), a Swedish shipbuilder, regarding the infringement of a hull design patent held by Stena. See PX 417 at 51-54. The Navy paid Stena $3.2 million to settle the patent infringement claim, which Ms. Holt determined was equal to 3.4% of the final

The licenses relied upon by the government's expert, Kimberly Schenk,[35] are less relevant to the hypothetical negotiation than the aforementioned agreements relied on by Ms. Holt. Ms. Schenk first relies on an agreement between the Navy and Intershipping Consultants Ltd. ("Intershipping") to license a patent relating to "ship hull design features." PX 15 (License Agreement (signed Jan. 12, 1989)) at G490804. The Navy agreed to pay Intershipping $1 up front and a per-ship royalty of $142,500 for the first ship in the class, $132,500 for the second ship, and $122,500 for the third ship and any subsequent ships. Id. at G490804-6; see also DX 56 at 36-37. No ships were constructed under this agreement. PX 417 at 55. Unlike the hypothetical negotiation in this case, the Navy had tested Intershipping's technology and decided not to use it in any ships before entering the license agreement with Intershipping. See Tr. 1259:1-14 (Holt). Thus, the terms of this agreement are not reflective of an agreement by the Navy for patented technology it wanted to use, as would be the case in the hypothetical negotiation here.

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price of the infringing ship. Id. at 53. The court accords meager weight to this agreement, as the Federal Circuit disfavors the use of settlement agreements to structure a reasonable royalty because settlements are made after infringement has begun and generally under the threat of litigation, and thus do not necessarily reflect the value of the patented technology. See Rude v. Wescott, 130 U.S. 152, 164 (1889) ("It is clear that a payment of any sum in settlement of a claim for an alleged infringement cannot . . . determin[e] the damages sustained by the owners of the patent in other cases of infringement."); Hanson v. Alpine Valley Ski Area, Inc., 718 F.2d 1075, 1078-79 (Fed. Cir. 1983) (explaining that settlement offers "made after the infringement had begun and litigation was threatened or probable" should not be relied upon to determine a royalty rate because they reflect considerations outside the value of the patents, such as the desire to avoid costly litigation) (citing Panduit Corp. v. Stahlin Bros. Fibre Works, Inc., 575 F.2d 1152, 1164 n.11 (6th Cir. 1978)); see also LaserDynamics, Inc. v. Quanta Computer, Inc., 694 F.3d 51, 77 (Fed. Cir. 2012) (noting that settlement agreements can be used to structure a reasonable royalty in limited circumstances, specifically when the agreement is the "most reliable license in [the] record") (quoting ResQNet.com, Inc. v. Lansa, Inc., 594 F.3d 860, 872 (Fed. Cir. 2010)).

The court also accords little weight to a 1987 agreement between Thornycroft, Giles & Associates ("TGA") and Aberdeen Shipbuilders for an exclusive license on TGA's Prelude ship design in exchange for a 5% royalty on the contract price of the ship and a 1% supervision fee. See PX 7 (Letter Regarding TGA-Aberdeen Agreement (Dec. 30, 1986)) at FS0167456-57; see also Tr. 2417:16 to 2418:21 (Test. of Krista Holt). This agreement predates the patents in suit, does not cover any patented technology, and grants an exclusive license. Therefore, it is of limited utility to determining a reasonable royalty for the Navy's nonexclusive use of the '032 and '946 patents in this case.

[35]Ms. Schenk has a bachelor's degree in finance and economics from Penn State University and a master's degree in forensic accounting from Florida Atlantic University. DX 56, Tab 1 at 1. She was accepted by the court as an expert in patent damages valuation. Tr. 1899:11-12. Her expert report and accompanying errata sheet were admitted into evidence. DX 56; DX 57 (Expert Report of Kimberly J. Schenk, Errata Sheet (May 24, 2016)).

Ms. Schenk also relied on a 2003 memorandum of understanding between FastShip and IZAR, a Spanish shipbuilder, in which FastShip granted an exclusive license to its technology, including the '032 and '946 patents, other U.S. patents and foreign patent applications, and research and development materials, in exchange for a $1 million "technology fee" and a 1.5% royalty "of the price to be paid by a third party to IZAR for each vessel constructed by IZAR using FastShip Technology . . . for third parties other than [FastShip]." PX 119 (Memorandum of Understanding Relating to Technology Development and Participation in Construction of Prototype Vessels (July 30, 2003)) at FS0000140-41, FS0000143-55. IZAR would construct vessels for FastShip's transatlantic fleet and would be permitted to construct ships for third parties as long as they paid the aforementioned royalty to FastShip. Id. at FS000123-24. This agreement is of limited relevance because the main purpose of the license was for IZAR to construct ships for FastShip, such that IZAR would serve as a subcontractor to FastShip and FastShip would profit from the completed ships as well as from the license agreement. The 1.5% royalty for ships manufactured for third parties is ancillary to this purpose, enabling FastShip to have multiple sources of income stemming from this one license. In contrast, under the hypothetical negotiation the Navy would not be a subcontractor to FastShip building vessels for FastShip's use; rather, the Navy would build LCS-1 for its own purposes, and FastShip's only source of payment for the use of its patented technologies would be the reasonable royalty. Thus, a higher royalty is merited for the hypothetical negotiation than the 1.5% in the IZAR agreement.

In light of the comparable licenses presented under Georgia-Pacific factors 1 and 2, the court finds that the parties would agree to a 3% royalty rate in a hypothetical negotiation. The 2001 agreement between FastShip and Lockheed Martin and the 1994 agreement between Thornycroft Giles and FastShip Atlantic both incorporate the patents at issue in this case and reflect a grant of patent rights to the licensee to build ships for the licensee's benefit, see PX 30; PX 43; PX 45, circumstances that would be present in the hypothetical negotiation. Both licenses, however, are for exclusive agreements and include other technologies in addition to the '032 and '946 patents. See PX 30 at FS0000768-71, FS0000781 (granting exclusive license for the '032 and '946 patents in addition to an unrelated patent); PX 43 at FS0163999 (granting exclusive license); PX 45 at FS0116255 (including rights for FastShip's semi-planing monohull as well as patented loading systems and terminal handling technology). To account for the additional rights granted by these licenses, the hypothetical negotiation would not include a lump-sum royalty payment in addition to the per-ship royalty rate.[36] The hypothetical

[36]FastShip asserts that it is entitled to a lump-sum payment beyond a per-ship royalty because of "the $48 million it invested from 1994-2004 for research, development, and testing to validate its designs" as well as the "revolutionary and innovative" nature of the patents in suit. Pl.'s Post-Trial Br. at 51, 56; Tr. 1337:24 to 1338:8, 2392:12-14 (Holt). Under 28 U.S.C. § 1498(a), the patentee is compensated for the government taking a naked, non-exclusive license to practice the patents in suit. Any investment by FastShip in research, development, and testing of the patented designs is not covered by this license, and therefore should not be included in the calculation of a reasonable royalty. Additionally, in light of the comparable licenses presented by the parties, the 3% per-ship royalty fully accounts for the level of innovation embodied by the '032 and '946 patents and no further lump-sum payment is warranted.

negotiation also would not incorporate the additional 2% royalty for gross revenues from shipping operations in the Thornycroft Giles-FastShip Atlantic license, see PX 30 at FS0000768-71, as there would be no such revenues from the Navy's operation of LCS-1. A 3% per-ship royalty rate, as embodied in both the FastShip-Lockheed Martin term sheet and the Thornycroft Giles-FastShip Atlantic license, reasonably reflects a hypothetical license between the parties for ship construction covering the '032 and '946 patents from September 23, 2006 until the expiration of the patents in 2010.

Georgia-Pacific factors 9 and 10,[37] referring to the utility and advantages of the patented invention over the prior art, and the nature, character, and benefits of the use of the patented invention, also indicate that this royalty is warranted. As explained supra, the semi-planing monohull design embodied in the patents, which generates hydrodynamic lift at the stern of the ship in combination with the waterjets, allows LCS-1 to efficiently achieve higher speeds for its size compared to the speeds obtained with previous Navy ship designs. The ship design in the '032 and '946 patents constitutes the key attributes and advantages of LCS-1; indeed, the ship would not function without its hull and waterjet propulsion system. Thus, the features and advantages of the patented technology as embodied in LCS-1 suggest that a 3% royalty would be agreed and adopted in a hypothetical negotiation.

3. Reasonable compensation base.

In this hypothetical negotiation, the 3% royalty rate is applied to a royalty base encompassing the features of LCS-1 that infringe the '032 and '946 patents. Damages are apportioned based on the "smallest salable patent-practicing unit" within the infringing article, meaning those features within the scope of the claimed invention. LaserDynamics, 694 F.3d at 67 ("Where small elements of multi-component products are accused of infringement, calculating a royalty on the entire product carries a considerable risk that the patentee will be improperly compensated for non-infringing components of that product. Thus, it is generally required that royalties be based not on the entire product, but instead on the 'smallest salable patent-practicing unit.'") (citation omitted). LCS-1 infringes the '032 and '946 patents via its hull design and waterjet propulsion system; therefore, only the costs applicable to these elements of LCS-1 will constitute the royalty base. Ms. Holt's approach to include the value of the entire ship as the royalty base, only excluding the cost of weapons, is inappropriate because LCS-1 incorporates a number of elements beyond those covered by the patent, e.g., the versatility of its mission modules, such that the patented features do not solely drive demand for the ship. See PX 456 at FS0165154 (praising the "interchangeable modules" and "focused-mission platform" of LCS-1); see also Virnetx, Inc. v. Cisco Systems, Inc., 767 F.3d 1308, 1326 (Fed. Cir. 2014) ("[W]hen claims are drawn to an individual component of a multi-component product, it is the exception, not the rule, that damages may be based upon the value of the multi-component product. . . . '[A] patentee may assess damages based on the entire market value of the accused product only where the patented feature creates the basis for customer demand or substantially

[37] "Factors 9 and 10 are frequently analyzed together due to their similarity and inherent overlap." PX 417 at 76.

creates the value of the component parts.'") (citing LaserDynamics, 694 F.3d at 67-68; Versata Software, Inc. v. SAP Am., Inc., 717 F.3d 1255, 1268 (Fed. Cir. 2013)).

The court looks to Lockheed Martin's cost performance reports as provided to the Navy to determine the smallest salable patent practicing unit through a component-based breakdown of costs. See DX 89 (Lockheed Martin, Cost Performance Reports, Contract No. N00024-03-C-2311). As explained by Ms. Schenk and adopted by the court, the cost categories that encompass the patented elements of LCS-1 are:

> Hull structure ([Work Breakdown Structure (WBS)] 1.2.1.1): Encompasses all superstructure and hull structure, including the shell plating, stiffeners and girders, internal and external decks, stanchions, inner bottom structure, tank boundaries, longitudinal and transverse structural bulkheads and stiffeners, deck house shell plating, decks, structural and stiffeners, foundations, and hull and deck house structural closures. It does not include non-structural bulkheads and non-structural closures. The hull structure is designed to withstand the hydrostatic and hydrodynamic loads imparted on the vessel at the vessel's full load displacement and at speeds up to its maximum sprint speed.
>
> Propulsion plant (WBS 1.2.1.2): Provides primary mobility for the platform under all ship speed and operational conditions. In addition to the mobility function, the waterjet propulsors provide primary maneuvering for the ship. The propulsion system consists of two propulsion plants, arranged port and starboard, each consisting of one propulsion diesel with a maximum continuous rating of approximately 7 MW and one gas turbine with a maximum continuous rating of approximately 26 MW in a Combination Diesel and Gas Turbine (CODAG) arrangement, driving two high speed waterjets via combining and reduction gearing.
>
> Electric plant (WBS 1.2.1.3): Includes all equipment for power-generation, conversion, inversion, transformation, transmission, and distribution of electrical energy and all associated auxiliary equipment needed to provide these functions. The electric power system also includes the consuming equipment such as lighting, power, interior communications, and auxiliaries such as heating, ventilation, and air conditioning.
>
> Seaframe design (WBS 1.2.1.10): Includes structural, distributive system, and construction drawings. In addition, schedules used in design and construction such as for fittings and coatings.

DX 56 at 33-34. In addition to the construction costs in the four cited categories, the royalty base must include the final system design cost for LCS-1, set forth in CLIN 0004 of the contract between the Navy and Lockheed Martin. Ms. Schenk apportions this cost across the 55 Freedom class ships that were proposed at the time Lockheed Martin entered the contract to build LCS-1. See DX 56 at 34; Tr. 1943:9 to 1945:6 (Schenk). This apportionment is inappropriate, however, because the full system design was necessary to build LCS-1 and therefore the full cost had to be incurred regardless of how many ships were to be subsequently built based on the same design. The full system design cost as of the date of the hypothetical negotiation, which was $86,658,094, DX 73 at G009752, shall therefore be included within the royalty base.

Further, the royalty base is assessed as the cost of the infringing components as of the date of the hypothetical negotiation, September 23, 2006. Ms. Schenk's approach of basing the royalty base on the contract price of the infringing components is inappropriate, see DX 56 at 34-35, because the Navy realized cost overruns by the date of the hypothetical negotiation. Ms. Holt's decision to base the royalty base on the final cost of LCS-1, including all cost overruns, see PX 417 at 34, is also improper because the parties would not have known the full extent of cost overruns on the date of the hypothetical negotiation. The cost of LCS-1 as apportioned for the royalty base must be assessed as of the date of the hypothetical negotiation, September 23, 2006, taking into account the expected costs and overruns that were known to the parties as of that date.

Accordingly, the court calculates the royalty base for the hypothetical negotiation based on the cumulative actual cost of work performed, as stated in Lockheed Martin's cost performance report for the reporting period from August 28, 2006 to September 24, 2006:

Cost Category	Total Cost
Hull Structure (WBS 1.2.1.1)	[***]
Propulsion Plant (WBS (1.2.1.2)	[***]
Electric Plant (WBS 1.2.1.3)	[***]
Seaframe Design (WBS 1.2.1.10)	[***]
Final Systems Design	[***]

DX 73 at G009752; DX 89 at G083086-87. In total, the royalty base is $214,986,194.

Thus, for the reasons stated, the court finds that a hypothetical licensing agreement between FastShip and the Navy on September 23, 2006 would have resulted in a payment of $6,449,585.82, reflecting a 3% royalty on the cost of the elements of LCS-1 covered by the '032 and '946 patents as of the date of the license.

B. Delay Damages

Reasonable and entire compensation includes interest for delayed compensation of the royalty, which ensures "that the patent owner is placed in as good a position as he would have been in had the infringer entered into a reasonable royalty agreement" and "serves to make the patent owner whole." General Motors Corp. v. Devex Corp., 461 U.S. 648, 655-56 (1983) (citations omitted). "Generally, the interest rate should be fixed as of the date of infringement, with interest then being awarded from that date to the date of judgment," or, more probably, the date of payment of the judgment. Boeing, 86 Fed. Cl. at 322 (citing Nickson Indus., Inc. v. Rol Mfg. Co., 847 F.2d 795, 800 (Fed. Cir. 1988)).

The parties and their experts agree that a 10-year Treasury note rate would be appropriate to determine delay compensation to FastShip. See Pl.'s Post-Trial Br. at 59; Def.'s Post-Trial Br.

at 59; PX 417 at 90; DX 56 at 55. The court concurs, and finds that a 10-year Treasury note rate sufficiently compensates FastShip because it reflects minimal risk and is consistent with the approximate length of time between the date of infringement and the date of judgment. Interest on a Treasury note is paid semi-annually, and it is therefore appropriate to compound the interest owed to FastShip semi-annually as well.

Accordingly, the court sets the interest rate for delay compensation at the 10-year Treasury note rate prevailing as of September 23, 2006, the launch date of LCS-1 and the date of the hypothetical negotiation, i.e., 4.58%. Interest on the $6,449,585.82 royalty to FastShip shall be calculated using the 10-year Treasury note rate for the period from September 23, 2006 until the date the judgment is actually paid, compounded semi-annually.

CONCLUSION

For the reasons stated, the court finds that Claims 1 and 19 of the '032 patent and Claims 1, 3, 5, and 7 of the '946 patent are valid and directly infringed by LCS-1. The court awards FastShip $6,449,585.82 in damages as of September 23, 2006, the launch date of LCS-1. FastShip is entitled to interest for delayed compensation at the 10-year Treasury note rate from September 23, 2006, 4.58%, compounded semi-annually, until the date the judgment is paid.

There being no just reason for delay, the court directs the clerk to enter final judgment pursuant to RCFC 54(b) respecting the reasonable and entire compensation for infringement. In due course, FastShip may apply for an award of reasonable costs and reasonable fees for expert witnesses and attorneys under 28 U.S.C. § 1498(a). Such a request for attorneys' fees and costs shall be filed within 30 days after any appellate process has been concluded or, alternatively, after the time for taking an appeal has expired.

It is so ORDERED.

s/ Charles F. Lettow
Charles F. Lettow
Judge